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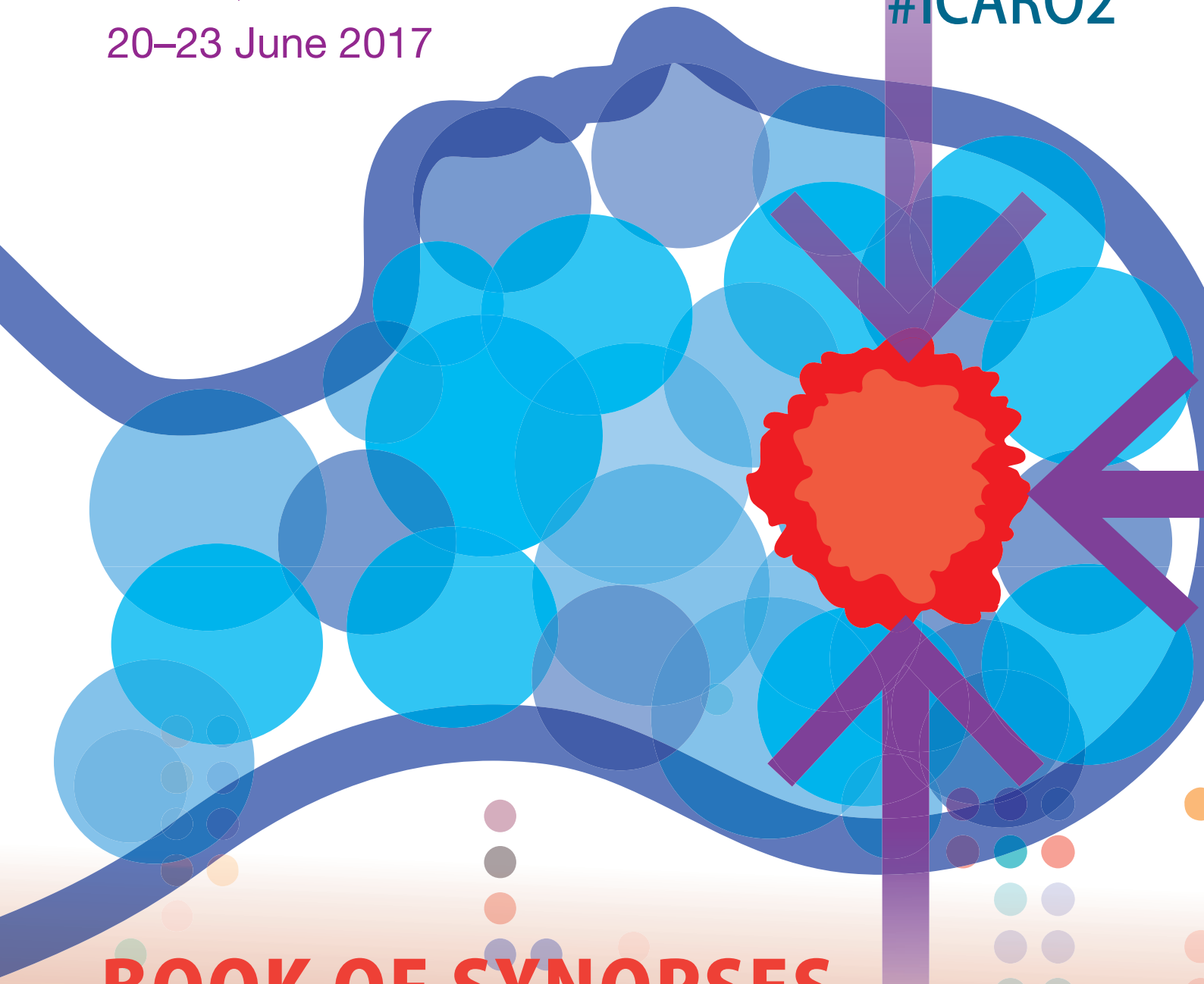

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Contents

Wednesday afternoon - Poster Presentations - Screen3 / 9

Dosimetric evaluation of newly developed well-type ionization chamber for use in the calibration of brachytherapy sources

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PURPOSE: To evaluate the dosimetric characteristics of newly developed well-type ionization chamber and to compare the results with the commercially available calibrated well-type ionization chambers that are being used for the calibration of brachytherapy sources.

METHOS AND MATERIALS: The newly developed well-type ionization chamber (BDS 1000) has been designed for convenient use in brachytherapy. The chamber has a volume of 240 cm3, weight of 2.5 Kg and the chamber is open to atmospheric conditions. The chamber characteristics such as leakage current, stability, scattering effect, ion collection efficiency, air-kerma strength and nominal response with energy were studied with the BDS 1000 well-type ionization chamber. The evaluated characteristics of BDS1000 well-type ionization chamber were compared with two other commercially available well-type ionization chambers.

RESULTS: The measured leakage current observed was negligible for the newly developed BDS 1000 well-type ionization chamber. The ion collection efficiency was close to 1 and the response of the chamber was found to be very stable. The determined sweet spot was 42 mm from bottom of the chamber insert. The overall dosimetric characteristics of BDS 1000 well-type ionization chamber were in good agreement with the dosimetric characteristics of other two well-type ionization chambers.

CONCLUSION: The study shows that the newly developed BDS 1000 well-type ionization chamber is high in sensitivity and reliable chamber for air-kerma strength calibration. The results obtained confirm that this chamber can be used for the calibrations of HDR and LDR brachytherapy sources.

Wednesday morning - Poster Presentations - Screen1 / 10

Novel aspects of application of cadmium telluride quantum dots nanostructures in radiation oncology

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Background of the study: In the last two decades, quantum dots nanomaterial have garnered a great deal of scientific interest because of their unique properties. Quantum dots (QDs) are inorganic fluorescent nanocrystals in the size range between 1 and 20 nm. Due to their structural properties, they possess distinctive properties and behave in different way than crystals in macro scale, in many branches of human life. It was already showed that the negatively charged CdTe QDs (–21.63 0.91 mV), with good dispersity and fluorescence stability, were rapidly internalized via endocytosis by HUVECs. Methodology: Cadmium telluride quantum dots (CdTe QDs) were labeled by 68Ga radio nuclide for fast in vivo targeting and Coincidence imaging of tumors. Using instant thin layer chromatography method, the physicochemical properties of the Cadmium telluride quantum dots labeled by 68Ga NPs (68Ga@ CdTe QDs) were found high enough stable in organic phases, e.g. a human serum, to be reliably used in bioapplications. In vivo biodistribution of the 68Ga@ CdTe QDs nanoconposite was investigated in rats bearing fibro sarcoma tumor after various post injection periods of time. Results: The 68Ga NPs nanocomposite exhibited a rapid as well as high tumor uptake in a very short period of time (less than 10 min), resulted in an efficient tumor targeting/imaging. Meantime, the low lipophilicity of the 68Ga NPs caused to its fast excretion throughout the body by kidneys (as also confirmed by the urinary tract). Conclusion: Because of the short half-life of 68Ga radionuclide, the 68Ga@ CdTe QDs with an excellent tumor targeting/imaging and fast washing out from the body can be suggested as one of the most effective and promising nanomaterials in nanotechnology-based cancer diagnosis and therapy.

Friday morning - Poster Presentations - Screen5 / 11

Specificity of fast neutron therapy. Is it necessary to restore projects in fast neutron irradiation

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Neutrons were first among elementary particles with high linear energy transfer coefficient, which were used to treat tumors. Neutrons high efficiency was based on high value linear energy transfer, independancy of irradiation effect from mitotic cycle, degree of cell saturation by oxygen, etc. After neutron irradiation even by small doses damaged cells actually cannot be restored, DNA breaks are not reconstructed. There was a belief that neutron action against cancer is similar to photons,but it is not. In incorrect approach complications after neutron irradiation were severe and doctors decided not to risk it and stay on solid grounds of radiotherapy and old standards in radiobiology. Fast neutron interaction with target have pecularities including the formation of recoil protons, which actually disappear in point of formation, resonance absorption of neutrons by nuclei of elements making up environment,emergence of new particles, for example alpha - particles, which in turn, moving through matter and its structural components not only create a cascade of ions in its path, but also breas in intermolecular bonds. Stage appearance of free radicals is the last factor in cells destroying. Free radicals only complete that was began by neutrons. For instance, after the passage of alpha particles through organic substance only “firewood” remains behind it - scraps of non-renewable structures. Penetration of neutron into matter launches sequence of interactions that lead to cell death. Each step is marked by specificity of interaction and own lifetime. First it is neutron absorption or excitation of nuclei, neutron energy changes, possible occurrence of alpha particle, disintegration, or the formation of gamma quanta absorbed by electrons, etc. Ionization associated with processes begins at last phase. Protons are formed permanently on the way of neutron trip. They are absorbed in the very place of origin. Therapeutic results of neutron irradiation were obtained in head and neck tumors, salivary gland recurrences, prostate adenocqarcinomas, sarcomas, slowly progressing tumors. Experiment showed that neutron irradiation effect has small dependance on number of fractions. Scientists tried to describe neutron action on organic matter in language of conventional radiobiology. But model cannot go beyond artificial boundaries even after attempt to modify parameters. In neutron irradiation familiar radiobiological models cannot be applied. Revived searches in these fields could be of help in understanding and improving existing models in radiobiology. Threshold dose in irradiation by neutrons exists, below which tumor response to radiation not changes and remains high at low doses without late complications dealing with irradiation. DNA brakes after neutron irradiation cannot be restored even after small doses.. Physicists should solve complex problems, without which exposure is not possible: stabilization of deuteron beam, measurements of angular distribution of neutron beam, creating of special multileaf collimator, diagnostic imaging transmission to planning system, dosimetry of components in flow - neutrons, protons, gamma photons etc. at different depths. Creating quality assurance system. For treatment beam typically deuteron beams are used with energy of about 14 MeV, bombarding Be target. Peak of neutron energy amounted 5.6 MeV. According data obtained in experiments highest radiobiological efficiency corresponds neutron energy 5.6 MeV. Why? It was shown in our calculations and experiment that basic destroying processes occuring during neutron irradiation are resonant processes in nuclei. Especially for nitrogen, for other elements resonance levels locte in other energy intervals. Times of these processes are small - about 10ˆ(-23) seconds. Time in which atomic nuclei lives, feel and breathe. Dose value appears in latest orders of time. Absorbed dose is a very common quantity; dose is made up of many previous events with different history and results and what is the most important – with different radiobiological effectiveness. In Kiev in 80’s Project was carried out studying effect of neutron beams on living tissue. Despite the basic findings, the project was not completed. Aim of report is to convince physicists to restore study of fast neutrons irradiation on living cells. It is necessary to reconsider the linear-quadratic model, restrict its application or create a new one in the case of irradiation by elementary particles. By variation of few parameters shaping accredited model, it is impossible to estimate effect of neutrons. Can occur that value of energy absorbed per unit volume (dose) will be not a crucial parameter leading to cell death or cell survival.

Tuesday morning - Poster Presentations - Screen3 / 13

Clinical outcomes and beam quality correlations on skin cancer radiotherapy management in Mexico: A national institute experience: 2000-2013

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Purpose: To evaluate the outcome of radiotherapy for nonmelanoma skin cancer of Mexican population in terms of the radiation therapy modality received and local relapse-free survival. To show the cost-effectiveness benefit of kV therapy compared to linac based electron ther- apy.

Introduction: Nowadays non-melanoma skin cancer (NMSC) is the most frequent malignant disease. Radiotherapy (RT) is a useful noninvasive alternative for some types of NMSC. It represents a valuable method for a minority histologically confirmed NMSC, in patients older than 60 years, where the patient's medical conditions contraindicate surgery procedures, or if the patient refuses surgery or if surgery would result in unacceptable morbidity. We summarize the Mexican population epidemiological data of NMSC patients of thirteen years from a main reference cancer center of Mexico, Instituto Nacional de Cancerología (INCan). RT modalities for NMSC are brachytherapy (BT), superficial x-ray (ST), electron beam (ET) and orthovoltage radiotherapy (OT). We studied the role of different RT modalities mainly kV therapy (ST/OT) vs ET or a combination of different beam qualities.The use of kV units for RT in Mexico has been decreasing in last decades. Nowadays only 6 kV units are installed, 3 in private hospitals and 3 in public hospitals as IMSS (recently in disuse), INCan (now in disuse) and INCMNSZ (recent acquisition and operation). On the other hand, linear accelerators with a wide range of high energy (MeV) electron beams (26 units) are the choice of most facilities for treating superficial tumors including NMSC. The main goal of this study was to compare the efficacy, considered as overall survival (OS), disease-free survival (DFS) and recurrence-free survival (RFS) in terms of the quality of radiation beam utilized. A simple cost-effectiveness study was carried on as well.

Material and Methods: We made a retrospective chart review of RT management on NMSC on a period of 13 years at the INCan. A total of 1224 patients treated with RT (palliative, radical or post-surgical intention) during 2000 to 2013 for NMSC were collected. Patient data included demographics (age at treatment date, gender, occupation, histology, surgical treatment, zone and lesion diameter). The median age was 72 years and 56% were female patients. Most patients (57%) were treated with kV therapy, the rest with ET (23%) and a combination of Co-60, electron and orthovoltage beams (20%). 24.1% of patients were treated with surgery, followed by RT and 67.2% were treated only with RT. We compared two groups of patients those who were treated with kV therapy and those treated with ET. All patients were treated with one single electron beam (4-6 MeV) in a Varian Linac or kV photon beams (50-200 kV) in a Gulmay kV unit. Radiotherapy data included the total absorbed dose (30-70 Gy) and fractionation scheme (10-35 fractions). The mean operational costs of 15 fractions in 2015 were $4*,* 448.00*MXN and*17,751.30MXN for kV and ET, respectively. We studied the success/fail according to local failure and survival rate. U-Mann Whitney and Chi2 tests were used in order to find independency and correlations between groups. Kaplan-Meier curves were obtained for estimation of overall, disease-free and recurrence survival. Multi variate analysis was made also in order to analyze other factors contributing the outcome such as surgery. The statistical analyses were performed using v.23 of IBM SPSS Statistics software.

Results and conclusions: The mean follow-up was 48 months. Population balance in terms on histological subtype were 75% basal and 30% epidermoid. There are few reports illustrating the outcomes of RT for NMSC. Our review includes a heterogeneous sample of beam quality management and it could be the first one in our country. We found a significant correlation (chi2 test, $p<0.03$) when we compare kV vs. ET in terms of clinical outcomes. The test of equality on free-recurrence survival distributions for different levels of RT modality had a significant result (Log-Rank Mantel-Cox $p=0.019$) with a best median of 15 months for kV therapy (12 months for ET and 9 for ET+kV). This finding suggests that the kV therapy should be the best decision for RT in NMSC. Moreover, our simple analysis comparing the costs and benefits of each modality enhance this conclusion, being the cost

of ET triple expensive than kV therapy. Our finding suggests that keeping and increasing kV units in our country is necessary for a not cure rates reduction alternative. It is important to recognize that this simple technology is allocated to treat superficial lesions and discharge a linac machine for more complex and costly treatments.

Session 24b - Brachytherapy **/** 15

High doses regimes of HDR brachytherapy at squamous cell carcinoma of the lip

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Introduction. Despite the large number of recommendations the applicator insertion during HDR brachytherapy, a lot of questions regarding the choice and placement of the applicators, normalization and dose selection are still under discussion. Randomized trial comparing standard fractionation modes with other modes are not available. There are recommendations for the applicator types: they can be flexible or rigid, placed parallel to (French school) or “hand free”. Data taking into account are the follows: the volume of the tumor, histology and data from diagnostic tests. If the absence of invasion to regional lymph node are confirmed by different diagnostic tests we deliver monobrachytherapy. The aim of the study was to evaluate the efficacy of high local doses using HDR brachytherapy for lip squamous cell cancer. **Materials and methods**. 27 patients with histologically confirmed squamous cell carcinoma of the lower lip were treated in the department of radiation therapy from 2012 to 2016. According to US or CT data, regional lymph nodes were not invaded by the tumor. All patients underwent interstitial HDR brachytherapy wuth MicroSelectron (source 192Ir). Metal needles were inserted “hand free” under local anesthesia and were removed after each fraction. The geometry of needle spacing and the direction was dictated by the necessity to deliver maximal dose to the tumor. The number of needles varied from 2 to 7 depending on the tumor volume. The mandible was considered as a critical organ. A single dose was 8 Gy. Irradiation was carried out 2 times per week, total of 4 fractions. Irradiated volume ranged between 10 to 28 ccm. Treatment planning was carried out based on the 3D CT and with Oncentra treatment planning system. Graphical optimization was used. An example of a dose distribution is shown in Figure 1.

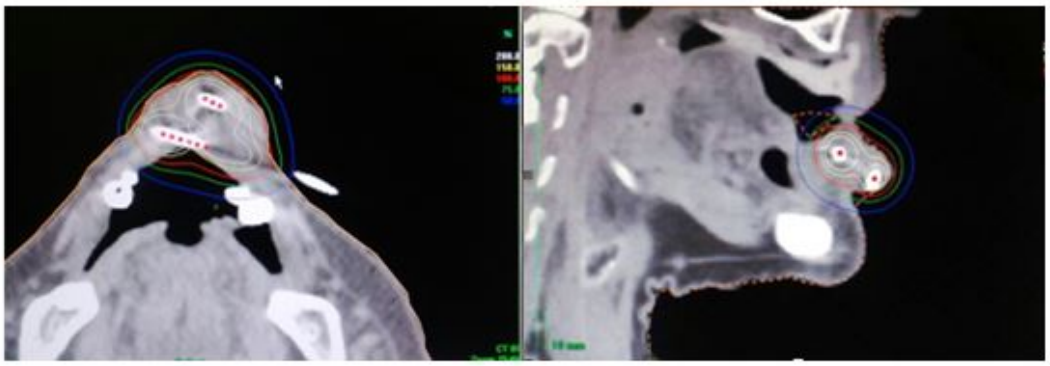

Figure 1.Dose distribution example

Patients were examined every month during the first half off a year and every 3 month later. If necessary, the frequency of examination was increased.

Results. Treated patients felt comfortable between the factions since the needles were extracted after each irradiation session. This reduces the risk of infection, which is often observed after insertion of flexible applicators. Short bleeding could happen just after the needles extraction but in few minutes it stopped. Swelling after the insertion of the needles usually disappeared in the evening of the same day of treatment. Radiation reactions lasted one month on average. New young tissue was formed under the crusts. No recurrence during period of observation was noted in all patients. Severe complications were also not noticed. **Conclusion**. 8 Gy per fraction, 4 fractions total, 2 times per week irradiation scheme for squamous cell carcinoma of the lower lip seems to be tolerant method of HDR brachytherapy allowing good local tumor control with reduced chance of infection. It significantly improves the patient’s well-being between the fractions. Radiation complications were not observed in this fractionation regime.

Patient-specific quality assurance evaluation for stereotactic volumetric modulated arc delivery using 6FFF beams

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The patient-specific QA have been performed to verify accuracy of MLC movement of IMRT/VMAT technique prior to first day of treatment delivery. Nowadays, the SBRT in lung region is normally performed with VMAT plans especially with flattening filter free option to reduce beam-on time. The purpose of this study was to compare the dosimetric evaluation of lung SBRT plans in patient-specific QA using various detector types. The 15 lung SBRT plans with PTV volume ranging from 7.5 to 318.4 cm3 were optimized and calculated for VMAT technique by Eclipse TPS version 11.0.31. The dose calculation was obtained with Acuros algorithm by 6 MV FFF beams. The maximum dose rate at 1400 MU/min was selected before inverse planning optimization. The dose prescription was in the range of 4-30 Gy/F and the several fraction schemes were used depending on indication. After these plans were approved by radiation oncologist according to RTOG dose limitation protocol, the plans were transferred and recalculated in ArcCHECK and Lucy phantoms. The ArcCHECK phantom contains 1,386 diode array in helical grid geometry around the phantom with 1 cm. detector spacing and it is possible to measure the dose in solid center plug using CC13 ionization chamber, while the Lucy 3D QA phantom for sterotactic QA was designed to place the Gafchromic EBT3 film and to insert the IBA CC01 and CC13 ion chambers for patient-specific QA. The plans were exported to TrueBeam linear accelerator for dose measurement. The irradiated films were scanned with Epson Perfection V700. The percentage of point dose differences between measurement and calculation were analyzed using absolute dose from ion chamber position, while the fluence map differences can be analyzed by gamma passing rate from film and ArcCHECK diode array. The gamma pass criteria was set at 3% global dose difference and 3 mm. distance to agreement with 10% dose threshold. The measurement was selected as a reference, so the percentage of point dose differences were calculated from the following equation. %Dose difference=(Calculated dose-Measured dose)/(Measured dose) 100 The PTV from these 15 cases can be catagorized into 6 small (7.5 to 22.4 cm3), 4 medium (65.5 to 86.1 cm3), and 5 large (145.3 to 318.4 cm3) volumes. The ArcCHECK presented very good agreement between dose measurement and calculation in both chamber detectors and diode array. The average point dose difference from CC13 chamber was -1.24 2.55% (-7.61 to 1.72%), while gamma passing rate from ArcCHECK diode array was 94.89 1.88% (91.7 to 98.4%). There was a case that presented high dose difference between CC13 point dose chamber in ArcCHECK and dose calculation of -7.61% due to the high dose gradient position in very small PTV volume. If this case was excluded, the error was only -0.79 1.46% (-3.41 to 1.58%). In Lucy phantom, the average dose differences from CC01 and CC13 chambers were -1.37 1.74% (-3.73% to 1.95%) and -0.67 2.27% (-4.41% to 4.62%), respectively. The error from CC13 chamber was wider variation than from CC01 because CC13 is larger volume that may present the volume averaing effect in the case of chamber located in high dose gradient area. The EBT3 film showed the average of gamma passing rate of 92.18 6.99% (80.7 to 99.1%) which the lower passing rates were detected in large PTV size with complicated plans. For all point dose evaluation, the percent dose difference was dose per fraction and PTV volume independence but position of chamber is an important factor. For the film and diode array comparison, although EBT film is the excellent spatial resoluion detector, it showed the lower passing rate and larger variation than diode array from ArcCHECK because the accuracy of film dosimetry is according to various factors, especially in film calibration. In conclusion, the Lucy phantom is special designed for sterotactic patient-specific QA with possible option to select detectors for point dose measurement, that both CC01 and CC13 chamers are the option to use in this purpose with the average accuracy within 1.5% and average gamma passing rate from EBT3 film is higher than 90%. The ArcCHECK that is more convenient to perform is originally designed for conventional VMAT plan QA but it is possible to apply for dose verification in SBRT case for various dose per

fraction and different PTV size with the average absolute deviation for a single point chamber measurement around 1% and gamma passing rate of 95%. ACKNOWLEDGEMENT This present work was financially supported by the IAEA's Coordinated Research Project on "Testing of Code of Practice on Small Field Dosimetry" (E2.40.21).

Radiobiological effects of cisplatin in carbon-irradiated cancer and bystander normal cells: the involvement of gap junction communication and NRF2 antioxidant system

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Introduction Glioblastoma multiforme (GBM) is the most common and most aggressive human brain tumor. Because most of GBM patients die of their disease and the median overall survival is approximately 1 year. In addition, GBM is difficult to treat since the tumors contain many different types of cell. To this end, the treatment plans for GBM may combine several approaches. Generally, GBM patients are treated with surgical resection together with a combination of radiotherapy and chemotherapy. Even though the plan is implemented, it does not effectively enough to prevent the recurrence and resistance of the tumor during the course follow-up. To date, the mechanisms for recurrence and resistance of GBM to radiochemotherapy that occurs within the irradiated field are not fully examined. To overcome this problem, carbon ions radiotherapy is a promising treatment modality of GBM because it is able to provide a high dose of radiation given to the tumor without the excess damage to normal tissue. Therefore, it would significantly improve survival rates in patients. However, its mechanism of action with chemotherapy in the non-irradiated bystander normal cells surrounding carbon-irradiated cancer cells has not been investigated. To address this question, we perform the in-depth investigation of the effect of combined radiochemotherapy with cisplatin in co-cultured with carbon-irradiated human GBM (T98G) cells and non-irradiated bystander human skin fibroblasts (NB1RGB) with particular emphasis on the role of gap-junction intercellular communication (GJIC) and Nuclear factor (erythroid-derived 2)-like 2 (Nrf2).

Materials and Methods The layered tissue culture strategy that allows isolation of pure non- irradiated bystander normal cells and carbon-irradiated cancer cells was used (Fig. 1). Briefly, confluent T98G cells were treated with cisplatin, followed by carbon ions (Dose 6 Gy, LET 76 keV/um) at the biology experiment port of the Heavy Ion Medical Accelerator in Chiba (HIMAC) at the National Institute of Radiological Sciences (NIRS) in Japan. Within 15-20 min following exposure, carbon-irradiated T98G cells were trypsinzied and seeded on the top of insert with normal human NB1RGB cells in the presence and absence of gap-junction inhibitor (AGA) at the bottom of it. Following co-culture for 5 h, T98G and NB1RGB cells were then harvest and assayed for colony formation, micronucleus formation and western blot.

Results Using this co-culture system our results clearly indicate that GJIC enhances cisplatin toxicity in carbon-irradiated T98G cells and bystander NB1RGB cells. However, the cytotoxicity in the bystander NB1RGB cells can be partially suppressed by inhibiting of GJIC with AGA. The protective mechanism of AGA against the toxic effect of radiochemotherapy was assessed based on the restoration of the antioxidant defenses via activation of Nrf2. With the result obtained, it can be inferred that the activation of Nrf2 might facilitate accumulation of antioxidant enzymes within cells and can affect cell survival by increasing the repair capacity in a community of cells. Therefore, GJIC and Nrf2 significantly influence in the propagation of damaging effects of high-LET carbon ions combined with cisplatin from irradiated cancer cells to non-irradiated bystander normal cells.

Conclusion The finding provides further insight into the radiobiological aspect of high-LET carbon ions for GBM patients that entails potential implications for clinical radiation oncology. Additional research is needed to focus on new drug with the inclusion of cisplatin that could potentially further improve the overall prognosis of GBM patients.

Acknowledgments The author would like to thank Drs. Masao Suzuki, Teruaki Konishi, Cuihua Liu, Takeshi Murakami and the staffs in HIMAC at NIRS for their excellent support. These studies were supported by a grant from The JSPS Kakenhi, NIRS-HIMAC, The Higher Education Research Promotion, Northern Thai Research Group of Therapeutic Radiology and Oncology (NTRG-TRO), National Research University Project of Thailand (Chiang Mai University-Gynecologic Cancer Research Cluster), Office of The Higher Education Commission and Chiang Mai University.

Tuesday morning - Poster Presentations - Screen1 / 20

A centralized model of effective radiation oncology service development:the Azerbaijan Republic experience

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The history of radiotherapy in Azerbaijan starts in 1940with the establishment of the Scientific Research Institute of Roentgenology and Radiology (SRIRR). At that time Azerbaijan was part of the former USSR. In the beginning,the Institute was equipped with X-ray orthovoltage machines and one teletherapy machine with cesium source.Radium sources were used for brachytherapy.. In 1956 the first cobalt unit was installed. Thereafter and up to the collapse of the USSR, four more cobalt machines and several X-ray machines of soviet manufacture were provided which yielded to western analogs. In 1985 the first and only afterloading brachytherapy unit was installed, which got out of order in a few months and has never since been repaired. The crisis of the Soviet system led to the deterioration of economic and social spheres including healthcare in general, and radiotherapy in particular in all republics of the former Soviet Union. Isolation from the rest of the world and absence of cooperation of our oncologists with specialists outside the USSR did not allow gettingaccess to updated information on the latest radiotherapy developments. As a result, in early 2003 there were only three othovoltage X-ray machines and two cobalt machines which sources had not been changed for 18 years. For this reason the treatment of one patient lasted up to 40 minutes. After Azerbaijan's independence we could only avoid a complete collapse of radiotherapy services due to awareness of the importance of radiation oncology by the management of the National Center of Oncology (the former SRIRR) who raised the problem before high level Government authorities. Since then, the situation has dramatically changed. This was followed by the Azerbaijan Republic presidential decree "On the cancer care", which served as an additional boost for the development of radiation therapy. In 2003 the Azerbaijan Government signed a cooperation agreement with the International Atomic Energy Agency (IAEA) one of the tasks of which was improvement of radiotherapy services quality in the country. As a result, the National Cancer Care Program was established covering prevention, early detection, effective treatment and palliation of oncological patients. It also includeda radiation therapy development program. A very important factor in our case is the existence of a close interaction between state legislative, financial structures and healthcare authorities. This was the basis for making appropriate and goal oriented decisions taking into account radiotherapy service demands defined by specialists in radiation oncology with a public health perspective. The Radiation therapy development program incorporates a policy of carefully planned, stepwise implementation of modern methods of radiation therapy in practice. Especially the technological developments in radiotherapy we have witnessed in the past 10 years. It has become clear that the only right way to achieve a goal in this area, is the combination of factorssuch as: governmental support (both legislative and financial support taking into consideration the heavy expenses for equipment and facilities),investment in staff education and training and the guidance and recommendations of experienced international organizations like the IAEA, WHO, and ESTRO.Taking into account the relative complexity and costliness of radiotherapy service in general, relatively small population (about 10 million) and short travel distances in our countryand after thorough discussions with health care administration of the Republic we have decided to adopta so called centralized system of radiotherapy service in Azerbaijan. Following the Radiation therapy development program,for 2003 to 2013,a high level dedicated radiation oncology center was established on the basis of the existing radiotherapy department of the National Center of Oncology (NCO) of the Ministry of Health of the Azerbaijan Republic. The most conformal and precise treatment modalities such as 3D conformal radiotherapy, IMRT, VMAT, SBRT, IGRT, SRS, 3D image guided interstitial brachytherapy are now implemented at NCO with a flow of 2000-2500 patients per year. Two additional radiotherapy centers were established in other regions equipped with orthovoltage machines and cobalt units. These units are significantly less expensive and easier in their operation and service. The vast majority of palliative treatments in the country are carried out in these two satellite centers. Conclusion. The centralized radiotherapy service is feasible from both organizational and effective treatment points of view in relatively small countries like Azerbaijan.Long-term strategic planning and purposeful progressive implementation according to objective demands in radiotherapy techniques, governmental support, close interaction between state legislative and financial structures, country's medical society and authorized international organizations are keyfactors for the successful development of an effective radiotherapy service in a country.

Use of volumetric arc therapy for nodal boosting in cervical cancer radiotherapy

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Background.Cervical cancer is the second most common malignancy affecting females in Azerbaijan and one of the main mortality causesin the female population in developing countries. In addition to its high morbidity rate in the developing world, cervical cancer is usually diagnosed at late, locally advanced stages: 74% of new cases are IIB – IVA stage and this determines a higher risk of pelvic and para-aortic lymph node metastasis. Radiotherapy remains an integralcomponent of the standard treatment for locally advanced cervical cancer and a combination of megavoltage external beam radiotherapy (EBRT) and intracavitary brachytherapy (ICBT) with concurrent cisplatin-based chemotherapy is the accepted definitive modality of treatment. Brachytherapy allows increasing the dose delivered to the primary tumor while for metastatic lymph nodesit is possible only by external beam boostingup to a total dose of 60 Gy (by 2Gy fractionation equivalent dose, EQD2). But the main limitation for EBRT nodal boost is the proximity of surrounding normal tissues and organs like rectum, femoral heads, small and large intestine„ bladder and pelvic bones. Recent advances in radiotherapy techniques like volumetric modulated arc therapy (VMAT) make it possible to deliver higher radiation doses to targets while sparing organs at risk. On the other hand it is well known that prolongation of the overall treatment time could adversely affect radiation therapy results. Taking into account the above, we decided to use a VMAT-based integrated boost method for the treatment of node positive cervical cancer patients. Objective.The aim of this research was to document the treatment results of metastatic lymph node cervical cancer patients treated by VMAT-based integrated EBRT boost.
Material and methods. We analyzed radiotherapy results of 52 patients treated in the Department of Radiotherapy of the National Center of Oncology, Baku, Azerbaijan from 2014 to 2016. Planning was done in automatic regimen and the dose distribution was improved (more conformal) if two dynamic arcs with 6 MV photon beams were used. The total number of fractions was 25. The fraction dose prescribed to the pelvis (primary tumor and regional zone up to the aortic bifurcation or L1-L2 interspace) was 2.0 Gy while the fraction dose prescribed to the metastatic lymph nodes was 2.3 Gy during the same treatment, thus reachinga total dose of 50 Gy and 59 Gy respectively (EQD2 by a/b = 10). From the first day of treatment patients received concurrent weekly cisplatin at the dose of 40 mg/m2 (max. 70 mg), 5 infusions. After 46 Gy of EBRT we started high dose rate (HDR)3D image guided brachytherapy which consisted of four weekly 7.0 Gy fractions to the high risk clinical target volume (HR-CTV).
Results.Implementation of a VMAT-based integrated boost technique allowed reducing the total treatment time by one week in comparison with the sequential boost approach.Also, arc therapy having shorter irradiation time in comparison with traditional static field 3D conformal radiotherapy and IMRT procured an improved patient set up. We analyzed close results of the treatment which were assessed one month after the course was completed. Complete regression, partial regression and stabilization of the tumor occurred in 88.5% (n=46), 9.6% (n=5), and 1.9% (n=1) cases respectively.
Conclusion: VMAT EBRT with integrated boost, HDR brachytherapy and concurrent cisplatin appears to be a safe and effective treatment modality for pelvic lymph node metastatic uterine cervical carcinoma providing high rate local tumor control and acceptable toxicity. It also could provide improved radiobiological conditions such asa shorter overall treatment time and higher fraction sizes. These may be especially important for radiotherapy of relatively hypoxic tumor cells in metastatic lymph nodes. But to reach final conclusions we need a longer follow up

Leakage radiation of ARTISTE LINAC machine

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INTRODUCTION Leakage radiation evaluation, as a part of acceptance tests during linac commissioning, is of paramount importance regarding patient and staff radiation protection. In this study, leakage tests were performed for a newly installed linac according to IEC 6061.

METHODS I) Photon beam a) Photons leakage from head and beam transport system: In order to measure the potential leakage from the linac waveguide and the source,EDR-2 films were used to wrap around the linac head, covering all the sides of linac head except the collimator.The films should be marked to permit the determination of theirposition on the machine after they are exposed and processed. Next, a long enough exposure of 1000 MU was delivered using the 15MV photon beams in a situation that the jaws and MLC leaves were fully closed, Gantry=0, Collimator=0.In the next step, after developing the films, the leakage was measured inany area with density greater than the background or fog using an ionization chamber-style survey meter.

b) Photon leakage from beam limiting system and reaching outside the useful beam: First, a 0.6 cc Farmer ion chamber(withappropriate buildup caps) was placed at SSD=100 in a 10×10 cm^2 field size to be exposed 1000 Monitor Unit for three times using the highest available energy. The ion chamber should be positioned along an arc of 1 meter radius circle to repeat delivering the same exposure. Finally, the results compared with the reading collected at the reference condition.

II) Electron beam Cone leakage: In order to evaluate the leakage from electron cone, a ROOS ion chamber was positioned in center of radiation field at SSD=100 cm. The gantry, couch and collimator angles were set zero. The position of the ion chamber should be changed in a line 2 cm and 4 cm outside the periphery of the geometrical radiation field. 100 MU was delivered using 18 MeV exposure in each position for each measurement point. This procedure should be performed for all available applicators.

RESULTS According to the head leakage test, there were no hot spots on films.Dose due to photons leakage outside the useful beam, ranged from 0.01 percent to 0.03 percentof maximum absorbed dose measured at isocentre plane in a 10 10 radiation field. As far as electron beam tests are concerned, the maximum ratio of dose at 2 cm and 4 cm from useful beam edge to dose at isocenterwere5.01% for applicator 20 20 and 2.16% for 15 15 applicator, respectively.

DISCUSSION From this study, it has been found that: 1- Leakage radiation at 1 meter along the path of the electrons between gun and target not exceed 0.1 percent of the maximum dose measured at isocentre of a reference radiation field. 2- Leakage radiation at any point outside the maximum useful beam and in a circular plane of radius 1 m from isocenter also not exceed 0.2% of the isocenter. 3- Absorbed dose at 2cm outside the 18 MeV useful beam area for all applicators not exceed 10% max absorbed dose on the reference axis at SSD=100.

CONCLUSION The newly installedARTISTE linac was allowed to be used for clinical applications asall the radiation leakageparameters were within the tolerance limit specified by theIEC60-61 requirements. It is suggested that measurement of radiation leakage should be necessary during acceptancetesting of a linac machine, especially for new type machines such as the ARTISRE, toensure patient and staff safety.

Measurement of fast neutron contamination caused by presence of wedge and block by CR-39 detector

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Introduction: In some radiation therapy protocols, beam modifiers are used to modify the radiation spectrum. Among the most common modifiers are block, wedge filter, flattening filter, multi-leaf collimator and asymmetric jaws. Medical linear accelerators which produce photons with energies higher than 8 MV, impose an unwanted dose to patients due to neutron production. Neutron is primarily produced due to collision of high energy photons with high Z materials which exist in the components of the head of accelerator. Nowadays, secondary cancer resulted from radiation therapy is a growing concern, and exposing patients to unwanted neutrons is considered as one of the most important causes of secondary cancers in patients who are irradiated with high-energy photon beams. Therefore our knowledge of the relevant patients dose incurred from radiotherapy is of utmost importance. Various instruments can be used to measure neutrons including thermoluminescent dosimeters, bubble detectors, and solid state dosimeters. One of the most common and most widely used solid-state nuclear track detectors is CR-39. There are many advantages for CR-39 film dosimetry approach such as insensitivity to ultraviolet and X-ray, archiving of recorded tracks, and similar composition to human tissues. Furthermore, this type of detector tends to be more sensitive to fast neutrons, and make up a suitable choice for fast neutron dosimetry purposes.

Material and method: CR-39 detectors were used for measurement of fast neutron equivalent dose. Neutron contamination arising from presence of 30˚, 45˚ and 60˚ angles wedges and a cerrobend block were measured. Films were calibrated by an Am-Be source. Three detectors were not exposed, but kept exactly under the same condition as sample films for estimation of background neutron dose. The studied linear accelerator was a Siemens Primus with 15 MV photon energy at the Reza Radiation Oncology Center (Mashhad, Iran), and the neutron contamination was measured for an open field and three wedges (30˚, 45˚ and 60˚ angles). In order to estimate neutron contamination in the presence of a block, a piece of cerrobend block (1.5 1.5 7.0 cm3) was made and measurements were carried out in the presence of the block on the central axis of the photon beam. All measurements were carried out at source to surface distance (SSD) of 100 cm in a 10 10 cm2 photon field. Fast neutron equivalent doses were obtained in a 30 cm 30 cm 30 cm Perspex phantom at 0.5, 2, 3, and 4 centimeter depths. Measured values were based on irradiation of 1 Gy photon dose at the depth of maximum dose. CR-39 detectors chemical etching was carried out in sodium hydroxide (NaOH) solution of 6.25 M concentration at 85˚C for 3 hours.

Results: As presented in the Table, the fast neutron equivalent dose (mSv/Gy) for 45-degree wedge at 0.5 cm phantom depth has caused the highest value and the lowest value (zero) is obtained at the depth of 4 cm of an open field. The main reason for higher fast neutron equivalent dose in the 45-degree wedge is because the 45-degree wedge has a smaller wedge factor than the other wedges (the wedge factor for 30, 45 and 60-degree wedge are: 0.6, 0.4, and 0.43, respectively). Since MU value is divided by a smaller value for this wedge relative to the other wedge factors, the maximum MU value belong to 45-degree wedge (250 MU). Therefore, higher neutron contamination is produced when a higher monitor unit is applied. With increase in phantom depth, the fast neutron equivalent dose is reduced in all field types, but this reduction trend is not the same for the blocked field. The reason for the lack of similar reduction trend in the cerrobend blocked field may be because only a small portion of the 10 10 cm2 field is blocked, therefore, the contribution of block material in producing neutron contamination is smaller. As it is showed in the Table fast neutron dose equivalent values, in the 0.5 cm depth of phantom, are higher for all fields. So, superficial tissue receive higher fast neutron equivalent dose than the steeper depths.

Conclusion: The presence of wedge in the path of primary high energy photon beam increases to some extent the neutron contamination dose of the patients. Furthermore, the 45-degree wedge contributed a higher neutron contamination than the other wedges. The results of this study also showed that superficial tissues receive higher fast neutron equivalent dose than the steeper depths. It recommended taking into account the additional neutron dose in radiotherapy resulted from high energy photon beam in presence of wedge filter, or if possible, alternative methods such as field in field method can be used in radiotherapy to spare organs at risk.

Comparison of various radiation therapy techniques in breast cancer with inclusion of internal mammary nodes by use of a RANDO phantom and thermoluminescent dosimeter

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Introduction: Breast cancer treatment techniques include mainly surgery, radiation therapy, chemotherapy, hormone therapy, targeted therapy. Breast cancer patients may experience local-regional recurrence in the chest wall or regional nodes. A combination of surgery followed by radiation therapy significantly reduces the risk of local recurrence. One of the controversial issues of the radiotherapy treatment of breast cancer is irradiation of the internal mammary nodes (IMNs). Indeed, the existence of the IMNs in the target volume may increase the heart or lungs toxicity. The aim of this study was to compare breast cancer radiotherapy techniques including wide tangent (WT), oblique parasternal photon (OPP), and oblique parasternal electron (OPE) techniques in terms of the coverage of left IMNs, left axillary lymph nodes, left supraclavicular nodes, and the chest wall; and the dose received by the heart and left lung. **Method:** An adult Rando phantom was used as a hypothetical patient. TLD-100 and TLD-700 chips were used for photon and electron dosimetry, respectively. Prior to irradiation TLD chips of both types were annealed and calibrated. First, the organs were contoured, then TP was performed by Prowess Panther version 5.2. Field arrangements in all 3 TPs included a 15MV anterior supraclavicular field and a 15MV posterior axillary field. Furthermore, two opposed tangential 6MV photon beams were planned in the WT technique and the internal tangent included parasternal lymph nodes. The multileaf collimator was used in this technique. In OPP and OPE techniques, tangential 6MV photon beams were covered the tumor bed only. An anterior oblique 6MV photon field and an anterior oblique 15MeV electron field abutted to the internal tangent in OPP and OPE techniques, respectively to cover IMNs. In OPE technique for anterior oblique electron field, a 7.5 mm thick leaded shield was also used. For WT and OPP techniques, 28 TLD-100 were placed in pre-selected points of the phantom within the slices No. 10-16 and then the phantom was irradiated. This procedure was repeated 4 times for all techniques and the average of 4 measurements was calculated. The OPE technique was performed in two steps. In the first step, 28 TLD-100 chips were used, similar to the two previous techniques. Then the phantom was irradiated according to the relevant TP only by photons. In the second step, 16 TLD-700 were placed in the region of the parasternal field and its surrounding area, within the slices No.12-16. Also, TLD-700 chips were placed exactly in the same places as TLD-100s in the latter step. Then phantom was irradiated with the anterior oblique electron field. Finally, the dose values obtained from the two steps were added point to point. This procedure was repeated 4 times. For dose values obtained for lymph nodes and chest wall, Tuckey's test and for corresponding results for the heart and left lung, the non-parametric Mann-Whitney U test were used. **Results:** a) Left supraclavicular nodes: In the WT and OPP techniques, the left supraclavicular nodes were enveloped by the adequate equivalent dose and no statistically significant differences were observed. But the mean absorbed dose received by this nodes in the OPE technique was significantly higher than the other two techniques. b) Left axillary lymph nodes: In all techniques, the left axillary nodes received defined equivalent dose and no statistically significant differences were observed. c) Left IMNs: In WT and OPP techniques, the left IMNs received an adequate equivalent dose, but the OPE technique didn't provide sufficient coverage for the IMNs. Nevertheless, because of the large standard deviation in OPE technique, no statistically significant differences were observed among all 3 techniques. d) Chest wall: In all techniques, left chest wall received an adequate equivalent dose. So from this viewpoint, the 3 techniques were statistically similar. e) Left lung: The mean dose by the left lung for WT was lower compared with the OPP technique; nevertheless, it was not significant because of the large standard deviation among the WT data. The left lung dose from OPE technique was not significantly lower than WT technique, while it was significantly lower than absorbed dose from OPP technique. The mean dose of the left lung in the OPP technique was more than the lung tolerance dose (20 Gy). f) Heart: The doses received by heart from three different techniques were statistically different. The lowest heart dose was obtained from the WT technique, and the highest from the OPP technique. The results of

measurements are shown in the table. **Conclusion:** Based on the results of this study, WT technique is a better technique compared to OPE and OPP techniques. Because WT technique provides a good coverage for lymphatic nodes, especially for the IMNs and spares critical structures properly.

Clinical implementation of intracranial stereotactic radio-therapy with non dedicated linear accelerator in a develop- ing country: the cuban experience

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Purpose: To introduce stereotactic treatment performed with a general purpose LINAC for brain lesions management.

Methods and Materials: Between April 2008 and august 2016, 35 patients underwent SRS (26) and SRT (9). The patients' average age was 51 years old. The indications were: primary treatment in 21 cases (10-meningiomas; 8-schwanomas; 1-ependymoma; 1-pineal germinoma; 1-glomus) and 14 cases as post- whole brain radiotherapy (5-breast, 7-lung, 1-nasopharingeal and 1-colon brain metastases). Stereotactic treatment was delivered with 6MV general purpose LINAC. The techniques used were dynamic non-coplanar arcs with micro-multileaf collimator for 27 patients and non coplanar arcs using cones for other 4 patients. The treatment planning systems used were Elekta Ergo ++ and Elekta Monaco version 5.0. In the case of benign tumors, the average dose prescribed was 16 Gy (range, 13-17 Gy) for single fraction SRS and 8 Gy for 2 sessions of SRT. In the case of metastatic lesions, the average dose was 18 Gy (range, 16-19 Gy) for single fraction SRS and 7Gy for 3 sessions of SRT. In all cases the prescription selected curve was the 90% of the dose distribution. Plans were evaluated using: target coverage, conformity index (CI), homogeneity index (HI) doses in critical structures, in planning target volume (PTV).

Results and Conclusions: Both treatments (SRS / SRT) were well tolerated. The assessed parameters were in agreement with the international reported levels, taking into account our technology and expertise. The multidisciplinary team, showed their capability of successfully handling these treatments.

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Development of a BNCT facility based on axial Deuterium–Deuterium (D–D) neutron generator using MCNP code

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The Boron Neutron Capture Therapy (BNCT) is a promising method to treat malignant brain tumors. The basic principle of this technique is to irradiate the boron-containing tumor with epithermal neutrons. Optimization of the Beam Shaping Assembly (BSA) assembly for BNCT has been performed using the Monte Carlo N-Particle Transport Code (MCNP6) to shape the 2.45 MeV neutrons that are produced in the axial Deuterium-Deuterium (D-D) neutron generator developed at Adelphi Technology, Inc with a radio frequency (RF) driven ion source and nominal yield of about 1010 fast neutrons per second. Different materials and Beam Shaping Assemblies (BSA) are investigated and an optimized configuration is proposed. The feasibility of using low enrichment uranium as a neutron multiplier is investigated to increase the number of neutrons emitted from D-D neutron generators, TiF3 and Al2O3 as moderators, Pb as reflector, Ni as shield and Li-Poly as collimator to guide neutrons toward the patient position. Also a simulated Snyder head phantom was used to evaluate dose profiles due to the irradiation of designed beam. The neutron beam quality is defined by the standard free beam parameters, calculated averaging over the collimator aperture. The results are discussed and compared with the performances of other facilities.

Dosimetric measurements for small circular cones of a Stereotactic linear accelerator

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Introduction: Stereotactic radiosurgery (SRS) is a technique for non-invasive destruction of intracranial tissues or lesion that may be inaccessible or unsuitable for open surgery using ionizing radiation. Initially stereotactic radiosurgery was started with gamma knife unit with Cobalt-60 sources and had circular apertures of 4, 8, 14 and 18 mm[. Subsequently linear accelerator (Linac) based radiosurgery was introduced, in which circular collimator inserts of size 12.5mm to 30mm were used. Though most Linac based SRS programs use MLCs with miniature leafs of sizes 2.5mm and 3mm at the isocenter, use of circular collimators are still applicable for small lesions. The Cyber Knife, a robotic radiosurgery unit uses circular collimators of size 5, 7.5, 10, 12.5, 15, 20, 25, 30, 35, 40, 50 and 60 mm diameter (FWHM) at 80cm source to axis distance (SAD). The recent model of the Gamma Knife, the Perfexion (GK PFN) has circular collimators of size 4, 8 and 14mm in diameter at the focal point. In addition to the mini and micro MLCs, both BrainLab and Varian provide circular cones of sizes 4mm to 30mm for Linac based SRS.
The dosimetry of such small photon fields is a difficult and challenging task due to issues such as lack of lateral electronic equilibrium, steep dose gradients, volume averaging effect and source occlusion. The objective of this work is to perform measurements for the small circular beams required for commissioning of 'cone planning' module of Eclipse planning system, with different detectors. Though a number of publications have been made available for small circular beams, this is an early measurement on the new EDGE stereotactic linear accelerator for commissioning eclipse 'cone planning' module.

Methodology: The linac used was the Edge^{TM} Truebeam STX Linac (Varian Medical Systems, Palo Alto, CA) designed mainly for Stereotactic Radiosurgery with 6MV, 6FFF and 10FFF beams, 120 leaf HD MLC and provision for fixing small circular cones. The dosimetric data required for commissioning 'cone planning' were, the Tissue Maximum Ratio (TMR), output factors and off-axis factors at 5 cm depth for three different SADs. The data were measured for circular collimators of 4mm, 5mm, 7.5 mm, 10 mm, 12.5mm, 15 mm and 17.5mm diameters for 6MV, 6FFF and 10 FFF beams. TMRs for these collimators were measured using EDGE diode in water equivalent solid phantom and with EDGE diode and pin point chamber in Sun Nuclear 3D SCANNER water phantom (Figure 1). The beam profiles were measured with the 3D SCANNER using EDGE diode and pinpoint ion-chamber. The output factors were measured with EDGE diode, pinpoint chamber and for specific collimators with radio-chromic films.

Results:TMR data measured with EDGE detector using water equivalent slab phantom matched well with the TMR data obtained with the 'TPR measurement option' of the 3D Scanner water phantom except in the pre build-up regions. The maximum deviation was 2% for 4mm collimator and was less than 1% for 10mm and 15mm cones for all the three beam energies beyond the depth of dose maximum. This showed that the TPR measurement option of the 3D Scanner provides accurate measurement of TMR data. The TMR values measured with EDGE diode detector and the pinpoint chamber agreed well but for a slight higher estimation at greater depth with EDGE diode for 4mm and 10 mm cones. This increased response of the EDGE diode was within 1-2% for all the beam energies. Beam profiles measured with pinpoint chamber showed larger penumbra compared to the profiles obtained with EDGE diode and this is in expected lines due to the higher detector volume of the ion chamber compared to the EDGE diode and use of pinpoint chamber for profile measurement would provide inaccurate data. The output factors measured with EDGE diode matched within 1-1.5% with the published data. The output factors obtained with the pinpoint detector for cones of less than 10mm deviated by more than 10-20% and hence the pinpoint detector may be used only for cones of sizes larger than 10mm. The output factor measured with radio-chromic films were close to that of EDGE diode except for the pixel heterogeneity observed and one would need to do more sampling to get accurate results.

Conclusion:The TMR values measured with 3D SCANNER and the solid phantoms agreed well. The output factor measurements performed with EDGE diode were closer to published values and were suitable for commissioning the 'cone planning' module of the Eclipse planning system.

Audit of the radiotherapy waiting times for patients in Malta

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Introduction: The Radiotherapy Patient Pathway (RPP) outlining the major stages involved from date of patient consultation to treatment was established for Sir Anthony Mamo Oncology Centre (SAMOC) for all patients receiving radiotherapy. Figure 1 below is an illustration of the main stages, as a subset of the RPP, which were included in this audit. An audit of the established RPP was performed to determine the waiting times at specific stages and the overall waiting time. Waiting times were also sub-divided per treatment site.

Method: A sample of 290 patients, based on a 95% confidence interval and 5% margin of error, was randomly generated as a representation of the patient population of 1 year. Records were selected both retrospectively and prospectively over a 7 month period. A proportional sampling method was used to subdivide patients into 6 treatment sites: Palliative; Breast; Prostate; Pelvis; Abdomen/Thorax; Head&Neck. Each patient journey was mapped on the RPP and the date of arrival at each stage was recorded. Statistical analysis was performed to determine the weighted mean, median and mode waiting times for all records analysed.

Results: Results indicate an overall total weighted mean waiting time of 36 days with a maximum of 62 days for Prostate and a minimum of 19 days for Palliative. Analysis of the waiting time between specific stages of the RPP showed a total weighted mean of 8 days from Consultation to date of CT scan; 13 days from date of CT scan to arrival at the Medical Physics department; 15 days in the Medical Physics department, and 8 days from the Pre-Treatment stage to the Treatment Date.

Conclusions: Methods of decreasing patient waiting times across the RPP should be explored in order to provide a more timely radiotherapy service at SAMOC. Recommendations for a more efficient workflow include the further development of an existing oncology information system MosaiqTM, and developing and re-engineering the organisation structure within the context of a multidisciplinary team.

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Mathematical modeling and optimization of radiation ther- apy dose-time treatment scheme

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Optimization of radiation therapy treatment scheme using mathematical modeling is one of the topical problems in modern radiation oncology. For these purposes formalized description of dynamic processes in clinical radiobiology is used.

Task of justification of radiotherapy dose fractionation schedules can be formulated in terms of the optimal control theory. For example, we fix a total radiation dose value D Gy and duration of radiation therapy treatment T. Then the optimization task can be formalized as follows: it is possible to reduce the number of survived cancer cells using radiotherapy dose fractionation schedule, provided that the total radiotherapy dose does not exceed D Gy and radiotherapy duration is days.

Let consider the main biological assumptions used in mathematical models: 1. Cancer tumor consists both oxygenated and hypoxic cells. The volume of oxygenated fraction consisting of X cancer cells is oxygen/=exp(-b), b=const. 2. The fraction of oxygenated cancer cells consists of cells in different phases of the cell cycle - G1, S, G2, M phases. Hypoxic cells are in G0 phase. 3. Conventional survival equations are used for description of radiation effects on tumor cells at different stages of the cell cycle G1, S, G2, M, G0. Cells in G0 phase are more resistant to radiation therapy. 4. Radiotherapy induces arrest of proliferative activity of tumor cells, which is proportionate to the radiation dose delivered.

With account of the above assumptions of mathematical models various scenarios of dose fraction- ation were examined. On figure 1 survival of cancer cells following delivery of equal-dose fractions (2 Gy/day) and nonuniform dose fractions (increasing fraction size up to 5 Gy/day) is presented. In both cases the total dose D is 50 Gy, the treatment period T is 5 weeks. It is seen that due to the use of dynamic fractionation of total radiation therapy dose the number of survived tumor cells can be reduced by a factor of 10 as compared to the original number (1010 cancer cells).

So, modern methods of mathematical and computer modeling in clinical radiobiology are effective tools for optimization of radiation therapy dose-time. treatment scheme.

Dose Evaluation of the AAA for small, Large and Asymmet- ric fields with a 6MV Photon Energy

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Purpose: Before a new calculation algorithm can be utilized clinically, a comprehensive evaluation is necessary. The accuracy of the dose calculated is very important for the quality and reliability of radiotherapy planning and delivery. The aim of the this study was to achieve an accurate calculation of dose for small fields(2x2,3x3) large field(7x7,10x10,20x20,25x25,30x30) and three asymmetric field dimensions Asymmetric 1 field (X1=-2,X2=5,Y1=-2,Y2=5) Asymmetric 2 field (X1=-2,X2=5,Y1=1.5,Y2=1.5) Asymmetric 3 field (X1=1.5,X2=1.5,Y1=-2,Y2=5) by evaluating the accuracy of AAA calculations in the Eclipse Treatment Planning System with measurement.

Material and Method: All the tested fields were calculated in the Eclipse treatment planning system(version 8.9.08) with AAA algorithms. A Varian Clinac 2100C/D accelerator delivering 6MV photons was used for all measurements in a blue Phantom 2 water tank. The CC13 detector was used for large field measurement whiles the A14SL detector was used for small and asymmetric field measurement. Determination of the physical factors required for dose estimation measured by the two ionization chambers and calculated by treatment planning system (TPS) were based on the latest technical report series (IAEATRS-398).The acceptability criteria used for the comparison of the calculated and measured data acquired were based on the report of the AAPM Task Group 53.

Results: Good agreement between the measured and calculated dose were found, with the maximum difference not exceeding 1% for all fields. The highest difference between the calculated and measured data was seen in the large fields. The deviation in small fields, asymmetric fields and large fields were in the range of 0.0%-0.1%, 0.0%-0.3% and 0.1%-0.5% respectively.

Conclusion: Since the accuracy desired in radiotherapy chain should mostly be less than 5% in dose delivery, the results from this study are well within tolerance and that the accuracy of AAA of Eclipse is adequate for clinical applications

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High dose rate surface Brachytherapy for skin with Flap applicator. Technique and discussion of a case

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Introduction of the study: The Freiburg Flap from ELEKTA is a flexible mesh still surface mould for skin or intraoperative surface treatment. The mould can be easily adapted to any shape. It ensures a constant distance of the treatment catheter to the skin of 5mm for reproducible dosimetry, treatment channels are set 10 mm a part from each others. Cutter, flexible implant tubes are introduced in the Flap. The mould provides an excellent alternative for orthovoltage or electron beams treatment in case of superficial macroscopic tumor irradiation depth 1 cm or in case of microscopic disease with marginal limits. ≤

Methodology: We describe the technique of irradiation in one case treated in the department of Radiotherapy at the National Institute of Oncology in Rabat. This is a patient aged 66 years, operated for a T3 well-differentiated squamous cell carcinoma of the scalp. The resection was marginal at 1mm from the deep plan; hence the indication of adjuvant therapy with brachytherapy is retained. The tumor bed was delineated with ink on the surface with 0.5cm margin and radio-opaque wire is applied. The Flap applicator is fixed over an aquaplast base frame and shielding is used to make better contact. The target volume is delineated on the CT images and intended dose is prescribed to an approximate depth of 3mm from the skin surface. Treatment planning (reconstruction of catheters, prescription of the dose, activation of dwell positions and optimization to create conformal plan) is done on CT images with Treatment Planning System of ONCENTRA BRACHY .The plan is validated on 3D views and DVH tables. We used for treatment nine Cutter flexible implant tubes. A procedure of Quality Control has been followed for each tube before clinical use. It consists on checking the first dwell position with the source position simulator set, this value is the indexer that should be introduced on the TPS and this first dwell position must be checked with gafchromic films. The patient is treated with 6 fractions of 5Gy each, twice a week over two weeks.

Results Low acute dermal reactions were noted, the patient will be followed 15 days after brachytherapy, 1 month and then every 3 months during 2 years.

Conclusion Our initial experience with 3 dimensional topographic applicator skin brachytherapy is especially encouraging with an easier and safety use, an adaptative application for each fraction, feasibility for all sites and excellent dosimetric conformity.

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Trend of availability and use of Intensity-Modulated Radiotherapy(IMRT) in Thailand, statistical report from 2008 to 2015.

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Introduction of the study Since the introduction of IMRT in late 1990, it gradually becomes a standard or recommended radiotherapy techniques for many kinds of cancer. However, its implementation needs a lot of resources which preventing its availability in developing country like Thailand. This study is aimed to report the growth of availabilty and use of Intensity-Modulated Radiotherapy (IMRT) in Thailand and tried to find the resource factors which are associated with the use of IMRT.

Methodology Annual statistical reports published by Thai Association of Radiation Oncology(THASTRO) were used for analyses. Availability of IMRT-capable machines were drawn from machine statistics and the use of IMRT was analysed by number of patients, number of patients per available machines and as a percentage of IMRT patients. Analyses were performed in overall data and grouped by geographic location and type of radiotherapy center. Manpower and other resource factors were also analyses.

Results The first implementation of IMRT in Thailand was in 2003 but the annual statistical reports were available only from 2008 to 2015. Overall from 2008 to 2015, Availability of IMRT- capable machines was increasing from 9 machines to 42 machines and the use of IMRT was increasing from 615 patients (2.5%) to 4083 patients(12.52%). When considered with geographic distribution, the growth of IMRT availability and use were mostly observed in Bangkok (Capital of Thailand). IMRT-capable machines in Bangkok was increasing from 7 machines to 28 machines compared to 2 machines to 14 machines in the rest of country. Growth of IMRT use was also different, it was increasing from 559 patients(5.22%) to 3296 patients(19.81%) in Bangkok compared with 56 patients(0.41%) to 787 patients(4.92%) in the rest of country. Interestingly, the effiency of IMRT use per IMRT-capable machines were better in Bangkok, the average number of IMRT patients per machine in 2015 were 106.61 and 51.65 in Bangkok and the rest of country, respectively(p=0.05). This difference might be explained by the significant higher workload for radiation oncologist and medical physicist, the average number of patients per one radiation oncologist and medical physicist were 158.3 and 223.22 for centers in Bangkok compared to 316.09 and 552.82 for centers in the rest of country (p=0.0024 and 0.0058, respectively)

Conclusion Availability and use of IMRT in Thailand was gradually increased but mostly concentrated in Bangkok. This should urge the attention of policy makers to improve the assessibility and distribution of IMRT in Thailand.

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A novel technique for postal intercomparison of beam Qual- ity Assurance criterion of Proton Therapy facilities using radiochromic film EBT3

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Introduction: Validation of therapeutic proton field bases on daily quality assurance (QA) procedure is imperative to routine proton therapy. The ratio of delivered and measured proton dose at the reference point under "standard condition" is defined as primary QA criterion. The standard condition (R20M10) is characterized as follows: (a) proton beam energy corresponding to a range (R) of 20 cm in water, (b) beam modulation (M) depth, known as spread out Bragg Peak (SOBP) of 10 cm, (c) Field size of 10 cm x 10 cm, (d) Air-gap of 20 cm, (e) dosimetry point (reference) located at the center of the SOBP and (f) proton dose of 2 Gy delivered in a single fraction using uniform scanning (US) mode. The proton dose under standard condition in a water or polystyrene pate phantom are commonly evaluated using various active devices, including Flat plate ionization chamber (FPIC), Multi layer ionisation chamber (MLIC) or a compact QA dosimetry device (Model: QA3; Manufacturer: Sun Nuclear Corp., Florida, USA). At WPE/IBA Group in Essen, Germany we have developed a passive method of proton dosimetry under standard condition using radiochromic film (Model: EBT3; Manufacturer: International Speciality Product, Wayne, USA). A handheld optical densitometer (Model: Unilight D; Manufacturer: IBA Dosimetry, Schwrzenbrück, Germany) was used for film readout purpose. The technique does not require and active electrical power hence, ideally suited for inter-facility proton beam QA inter-comparison studies.

Methods: We cut out six sections (8cm x 8cm) from a standard sheet (25cm x 10cm) of Gafchromic EBT3 film using a pair of sharp scissors. The sensitivity of EBT3 films depends on their orientations i.e. Landscape (LSC) or Portrait (POR) mode. In order to compensate this effect we stacked two film sections with LSC and POR orientations at right angles (90o) to each other. We have prepared six batches EBT3 dosimeter each incorporating three stacks. Five dosimeter batches were mailed to five proton therapy centres in Europe and USA operating PROTEUS Plus and PROTEUS One Medical Cyclotrons of IBA. The 6th batch was exposed under standard conditions at WPE as benchmark. The beam Quality Assurance Criterion (QAC) is defined as the ratio of net (background subtracted) optical density (NOD) of the 1st film stack exposed to a proton dose of 2Gy at the Proton Therapy Centre of interest (NODx) and the NOD of the 2nd film stack of the same batch exposed to a proton dose of 2Gy at WPE (NODwpe**strong text**) under standard condition. The optical density (OD) of the 3rd film stack (control) was used for background subtraction:

QAC = (NODx/NODwpe)2Gy (1)

Results: We have duly received the samples exposed to protons under standard conditions from ProCure Proton Therapy Center (PCPTC), Oklahoma City, USA operating a PROTEUS Plus cyclotron like ours at WPE. The delivery of exposed film samples from four PT centres are still pending. The NOD was evaluated at three spots in the central zone of the films using IBA Unilight D densitometer. The QAC was calculated using equation 1. Results are depicted in Figure 1.

Conclusion: We have developed a robust and simple method for postal intercomparison of quality assurance criterion of proton therapy facilities. The method is based on radiochromic films widely used by medical physics fraternity. The inherent shortcomings of radiochromic films namely, orientation dependence of sensitivity and batch inhomogeneity were resolved. The usage of TLD has the pitfalls like fading, complex evaluation routine and requirements of expensive TLD reader and annealing oven. Our method outperforms the postal dose intercomparison studies using TLD. A worldwide implementation of this novel technique in commercial basis is envisaged.

Intensity modulated radiotherapy benefits comparing to conventional radiotherapy for locally recurrent nasopharyngeal carcinoma

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Purpose : Locally recurrent nasopharyngeal carcinoma (NPC) can be salvaged by reirradiation with a substantial degree of radiation related complications. The aim of this study was to evaluate the dosimetric advantage of intensity modulated radiotherapy (IMRT) in treating locally recurrent NPC.

Methods : Between January 2015 and September 2016, six patients with no metastatic locally recurrent NPC were re-irradiated with concomitant chemotherapy. The median prescrepted dose was 60 Gy with 2 Gy per fraction. Treatment planning of each patient was performed for tow techniques : Three dimensional Conformal radiotherapy (3D CRT) and Intensity modulated radiotherapy (IMRT). The minimum dose (Dmin), the maximuim dose (Dmax) and the volume that received 95% of the dose prescrepted (D95%) of the planning target volume (PTV) and doses to the organs at risk (Spinal cord and brainstem) were calculated and compared for the tow techniques.

Results : All two techniques delivered adequate doses to the PTV. The average Dmin was 48Gy for the two techniques, the average Dmax was 67,5 Gy vs 64,2 Gy respectively for IMRT and 3D CRT (p=0,41) and D95% was 96%. Concerning the organs at risk, the Dmax for the brainstem was significantly higher for 3D CRT (22 Gy vs 14 Gy, p= 0,003). This finding were similar for the spinal cord (20Gy vs 7,8 Gy). But, the difference was not statically significant (p=0,12).

Conclusion: Based on the dosimetric comparaison, IMRT was optimal by delivering a conformal and homogenous dose to the PTV with significant better sparing of critical organs than 3D CRT. In this regard, re-irradiation using IMRT may be a very attractive technique for locally recurrent NPC.

Hypofractionated radiation for pediatric diffuse intrinsic pontine glioma (DIPG) is non-inferior to conventional fractionation: a prospective randomized trial including 222 children

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Background: Pediatric diffuse intrinsic pontine glioma (DIPG) remains for the last decades as a dismal disease though of the rigorous attempts to improve results through adding chemotherapy, immunotherapy or target therapy in different combination, scheduling and intensity to the already established conventional radiation therapy. We previously reported that hypofractionated radiotherapy, in a dose of 39 Gy in 2.6 weeks, had similar clinical end-results to conventional 54 Gy in 6 weeks. Aim of the work: to confirm the non-inferiority of hypofractionated to conventional fractionation in treating pediatric DIPG and to explore the optimum dose level for such treatment to achieve better overall (OS), progression-free survival (PFS) and toxicity profile.

Methodology: Tow hundred twenty-two children fulfilling the typical clinical and MR imaging features of DIPG were randomized into 3 groups: 1. Hypofractionated 39 Gy in 13 fractions (300 cGy/fraction), 2. Hypofractionated 45 Gy in 15 fractions (300 cGy/fraction) and 3. Conventional 54 Gy in 30 fractions (180 cGy/ fraction).

Results: The distribution of patients' characteristics in the 3 groups were even and did not show any statistically significant differences. The median overall survival (OS) of all patients was 8.5 months (95% CI: 7.6 – 9.4) while the progression-free survival (PFS) was 6.8 months (5.9 -7.6). The median OS of the 3 groups (39, 45 and 54 Gy) were 9.6 (7.6 -11.6), 7.7 (6.2 -9.3) and 8.6 (7.3 – 9.9) months respectively. The 18-months OS for the 3 groups were 14.0 4.7%, 14.5 4.4% and 9.7 4.3% respectively revealing non-inferiority of either hypofractionated group to the conventional group. Furthermore, the median PFS in the 2 hypofractionated (39 and 45 Gy groups) were 8.0 months (6.4 - 9.6) and 5.8 months (4.8 – 6.9) respectively compared to 6.9 months (5.9 – 8.0) for the conventional group. These PFS results of either hypofractionated group proved to be non-inferior to that of conventional fractionated group. The toxicity profile was similar in the 3 treatment groups. Both median OS, PFS and the 18-months OS and PFS were not affected by the patient gender nor age. However, it was noticed that young patients (below 5 years old) had better treatment outcome (OS and PFS) though not statistically significant.

Conclusion: Hypofractionated radiotherapy clinical outcome is non-inferior to conventional fractionation for the treatment of pediatric DIPG. It seems that no optimal dose level for hypofractionated radiotherapy of DIPG. These results may establish hypofractionated radiotherapy as the standard of care for such aggressive disease to minimize the burden on the child, the family and treating institution without jeopardizing the results of treatment including OS, PFS and toxicity.

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Radiotherapy in cancer treatment in Ghana: from the past to present

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Cancer is a complex disease and should be a concern for all since we are all at risk of any type of cancer at a point in our lives. Early detection coupled with effective treatment is almost impossible without the existence of the requisite equipment and trained personnel. The world has made a huge progress in cancer treatments, research and advocacy and Ghana is no different. Radiotherapy is a form of treatment for cancer that uses carefully measured and controlled high energy X-rays to kill cancer cells. Radiotherapy forms a greater percentage of cancer treatment, which is one of the most cost-effective. Although the number of radiotherapy facilities in the country are inadequate, Ghana has made some strides in the development of its radiotherapy facilities. According to the World Health Organisation, over 50% of all cancer patients require Radiotherapy at one stage or the other in the course of the disease for treatment and 40% of all the cancer cures result directly from the use of Radiotherapy. In Ghana, cancer of cervix is currently the most common cancer among women, and Radiotherapy plays a major role in its management. Radiotherapy is a specialised treatment and is not available in every hospital. In Ghana, Radiotherapy Services can be assessed at Korle-bu Teaching Hospital in Accra, Komfo Anokye teaching Hospital in Kumasi, both public facilities and the Sweden Ghana Medical Centre in Accra which is a private centre. Radiotherapy was introduced to Ghana in 1992 when the first radium brachytherapy was performed with the aid of the German Government. Before this, there had been unsuccessful attempts to establish a radiotherapy centre in Ghana since 1960. During that period a cobalt machine was donated by the Canadian Government to be used for medical purposes. However, because of lack of funds to house it, the machine was donated to the Lagos University Hospital in Nigeria. Korle-bu Teaching Hospital radiotherapy centre became operational in 1997 and the Komfo Anokye Teaching Hospital radiotherapy centre started treatment in June 2005 both with a strong support from the International Atomic Energy Agency through the Ghana Atomic Energy Commission. Presently, external and internal radiotherapy are available at both hospitals with low dose rate (Cesium-37) in Kumasi and high dose rate (cobalt-60) in Accra. The Korle-Bu and Komfo Anokye Teaching Hospitals' Radiotherapy Centres now provide a comprehensive service, treating over 1000 patients a year. A lot of patients have been treated so far with radiotherapy in Ghana, over a quarter of whom are women with cervical cancer. Many of them are farmers especially at the Komfo Anokye Teaching Hospital.The high number of patients is further exacerbated by the fact that the neighbouring countries of Côte d'Ivoire, Burkina Faso, Togo, Benin and Sierra Leone have no Radiotherapy treatment facilities of their own. Hence most of their cancer patients who require radiotherapy are referred to Ghana for treatment. The establishment of these centres have also reduce the number of patients who travel abroad for radiotherapy services. Ghanaians can therefore have the luxury of being treated in the country by fellow Ghanaians. Due to the high cancer cases coupled with lack of accessibility and modernisation in Radiotherapy practice there is the need for further development in this specialty. The Population of Ghana has since increased from the time this centres were established. The population of Ghana is currently estimated to be approximately 25million, with a male to female ratio of 49:51. Where a 70% of this population is living in the south of the country with the majority of these, living in the Ashanti and Coastal regions. The two major radiotherapy centres are 250km apart making accessibility a challenge. In response to this challenge the Government of Ghana recently acquired a $13.5 million from the OPEC Fund and the Arab Bank for Economic Development in Africa for the upgrading and expansion of the two radiotherapy centres in Accra and Kumasi. Under this expansion project, the old cobalt units are being replaced with 2 Linacs and a new cobalt unit. A 6 MV Linac along with the new cobalt unit are being installed in Accra, while a dual energy 6/10 MV Linac is being installed in Kumasi. Due to the advancement in radiotherapy, linacs are mostly the standardised machines used in all modern Radiotherapy Centres in the World. Moreover, other obsolete equipment will be replaced and the human resource will be strengthened. In all these the IAEA has been very instrumental with alot of projects in the country. Currently two staffs of Komfo Anokye Teaching Hospital are currently on International Atomic Energy Agency fellowship on advance radiotherapy training in partnership with the International Centre for theoretical physics(I.C.T.P) in Italy.

Dosimetric comparison of dose to contralateral breast in postmestectomy patients treated using different treatment techniques

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Purpose Postoperative radiotherapy significantly reduces the risk of loco-regional failure and improves disease-free survival. However, peripheral dose to the contralatral breast is cause of concern due to its higher radiosensitivity towards radiation induced second malignancy. The present study aimed to measure the contralatral breast dose from the post mastectomy radiotherapy (PMRT) using conventional asymmetric jaw and 3D conformal radiation therapy (3DCRT) treatment techniques separately. A comprehensive analysis of data of contralatral breast dose was made to determine methods if radiation could be delivered safely and effectively with a reduced contralatral breast doses. Materials and methods: Fifty breast cancer patients with post mastectomy were included in the study, which underwent external beam therapy on cobalt-60 teletherapy machine and linear accelerator machine. Patients were planned to treat to the chest wall (CW) to a dose of 50 Gy/ 25# with opposed tangents, Supra Clavicular Field. Of these, twenty five patients treated with PMRT on Bhabhatron-II TAW telecobalt machine using asymmetric jaws with conventional medial and lateral tangential fields were treated on alternate days. Rest twenty five treated on Siemens Oncor Expression linear accelerator using 3DCRT technique with medial and lateral tangential fields daily. The contralatral breast doses in assessed using optically stimulated luminescence dosimeter (OSLD) which was placed at the level of contralatral breast nipple prior to start of the treatment. The dose contribution was measured only for tangential fields; SCF doses were not included in the study. Results and discussions: The dose measured at the contralateral breast nipple for patients treated on telecobalt machine was observed between 114.25 to 193.12 cGy for total primary breast dose of 5000 cGy in 25 equal fractions which accounted to be 2.28-3.86% of total dose to ipsilateral breast while for the patients treated on linear accelerator the dose measured at the contralateral breast nipple was observed between 73.75-171.00 cGy for total primary breast dose of 5000 cGy in 25 equal fractions which accounted to be 1.47-3.42% of total dose to ipsilateral breast. The cause of higher doses observed in patients treated on telecobalt machine is due to fact that the beam modification was achieved with asymmetric jaw in the cobalt-60 teletherapy machine while in linear accelerator the beam modification was achieved with the help of multileaf collimator (MLC), which resulting in a reduced scatter dose to contralateral breast dose. Further, it was observed that the maximum contribution of contralateral breast dose was due to medial tangential (MT) fields, which was about two times higher than dose contribution due to the lateral tangential (LT) field. Conclusions: Though the use of MLC in 3DCRT treatment showed acceptable coverage of PTV provides excellent normal tissue sparing with a reduced dose to contralatral breast. However, MLC does not seem to be suitable for PBRT with unacceptably tight margins of PTV. The use of telecobalt machine with asymmetric jaws is a good choice for PMRT considering socioeconomically factors, at a cost of slightly higher dose to contralatral breast.

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Role of radiotherapy in multiple myeloma; a multicentric experience

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Background: Multiple myeloma (MM) is hematologic malignancy characterized by the accumu- lation of malignant plasma cells in the bone marrow. Recently, MM remains uniformly fatal with a median survival of approximately 50 months after diagnosis. MM is extremely susceptible to radiation treatment and targeted radiotherapy including bone-seeking radiopharmaceuticals, monoclonal antibodies conjugated to radionuclides (radioimmunotherapy), and radiotargeted gene therapy using recombinant oncolytic viruses (radiovirotherapy) now offers a new paradigm to target this systemic malignancy. Palliative irradiation of osteolytic lesions is a considerable component in the treatment for patients with multiple myeloma. The aim of this study was to assess indications for RT as well as its effectiveness in MM patients. Patients and methods: 67 patients were retrospectively analyzed with MMs who was admitted to multi-centric Institutes of Cancer during 5 years period. According to the staging system of Durie & Salmon 50 patients were classified as stage III. Nearly seventy present of patients (47/67) were treated with radiotherapy of at least one and up to 6 bony lesions at different times. Evaluation for the effect of local radiotherapy on pain relief and bone re-calcification was performed. Complete information on dose, fractionation and volume of radiotherapy was available from 35 patients treated in 56 target volumes for pain relief, and from 32 patients treated in 48 target volumes for recalcification. Total radiation doses varied between 8 Gy to 50 Gy (median dose 25 Gy in 2.5 Gy fractions, 5 times a week). Results: Radiotherapy resulted in complete local pain relief in 20(29.9%) and partial local pain relief in 36(53.7%) of the patients. The higher total radiation doses and higher age at the time of radiotherapy were significantly associated with a higher likelihood of pain relief, whereas no significant association was detected for concurrent systemic treatment, type and stage of myeloma and location of bone lesions. Re-calcification was observed in 47.9% of irradiated bone lesions. The higher radiation doses were significantly associated with an increased likelihood of re-calcification. Side effects of radiotherapy were generally mild. Conclusions: Despite the introduction of novel effective agents in the treatment of MM, RT remains a major therapeutic component for the management in 70% of patients. It continues to play a prominent role in the palliative treatment and it effectively provides pain control. However, the therapeutic measures appear to develop a better analgesic effect in elderly. Higher total biological radiation doses were associated with better pain relief and re-calcification in MM patients. Keywords: Multiple myeloma, Radiation therapy, Analgesic effect, Re-calcification, Side effects.

Expertise mobilization: addressing the medical physics gap

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The growing disparity in Medical Physics needs between high income countries (HICs) and low-to-middle income countries (LMICs) is especially evident with the growing incidence of cancer in LMICs. Recent Lancet Oncology Commission projections indicate that an additional 22,000 Medical Physicists (MPs) will be required by 2035 to provide uniform access to radiation therapy globally. The following highlight important factors in closing this Medical Physics gap:
Local desire in LMICs for Medical Physics mobilization
Basic infrastructure allowing Medical Physics mobilization
Resources available for Medical Physics mobilization
Local individuals seeking Medical Physics expertise advancement
Collaboration and partnering with enriching organizations
Clear understanding by mentors and collaborating organizations of local circumstances

Regarding formal education, the general consensus is that at minimum a Master's degree along with a 2-year "on-the-job" residency is required to become a clinically qualified MP. While in many LMIC jurisdictions such education and training may be difficult to obtain locally, it should be obtained as close to home as possible. With 55 countries having no radiation therapy and, by implication, no capacity to train MPs, outside partnering support will be required. Partnering can range from local on-site visits by international experts for lecturing to "hands-on" guidance for practical clinical applications. It could also consist of sending local LMIC MPs abroad; however, this has the risk of contributing to the "brain drain". Information and communication technologies (ICTs) are very useful tools for global interactions for the collaborating individuals.
Multiple (>35) Medical Physics and Oncology related organizations are involved in providing support to enhance cancer therapy in LMICs, especially as related to education, training and human resource development. To avoid redundancy and to ensure efficiency, the enriching organizations need to develop communication approaches that allow clear indications of activities planned or in progress in LMIC contexts. The collation and communication of these activities remains an on-going challenge.
MPs at all levels of their careers might be able to offer some partnering support. This may be especially relevant for retirees who have more free time available to share their well-honed skills. For those in regular employ, they could use (mini-)sabbaticals or even parts of their vacations for international activities. ICTs are an excellent resource for providing continued interactivity. For those in training or early in their careers, especially if they have global health interests, international collaborations could provide experiential opportunities. In all situations, except for the retirees, there would be a tremendous added incentive and benefit if their employers, i.e., upper level management, were to encourage this type of altruistic outreach. The benefits to involved individuals and institutions are substantial. However, this does require philosophical support from the employer for this type of outreach activity. Encouragement of employers by the Medical Physics community will increase employer support for outreach activity. While there are already examples of partnering institutions with LMIC environments, these represent a very small minority.
In summary, the mobilization of Medical Physics expertise in LMICs requires multiple approaches, which can be supported by HIC environments. Coordination of the multiple organizations and individuals supporting LMIC activities remains an on-going challenge, which could be aided by the resolve of one of the major international organizations. Additional support would be greatly aided if many of the cancer therapy institutions in HIC contexts would include a component of international outreach as a truly supported activity. Overt attention with structured and altruistic actions by HIC contexts will help make inroads into the LMIC needs. Clear options throughout career structures in support of global health considerations combined with strong partnerships between interested parties in HICs and LMICs will enhance the development of safe and resource-appropriate strategies for advancing Medical Physics capabilities.

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Metachronous cancers in patients with survival greater than 5 years

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Introduction: As a result of an increase in diagnosis and therapy efficiency, as well as supportive therapies, the number of survivors and the overall surviving period for cancer patients has increased. A subgroup of these patients are diagnosed with a second cancer, this being one reason for readmission to an Oncology Department, others being the relapse of the first tumor, or periodic controls in absence of any signs of disease. The goal of this study was to evaluate the causes of readmission of patients to the Radiation Oncology Department of Oncology Institute Cluj- Napoca, Romania who were first registered at the Institute more than 5 years ago. An additional goal was to describe the characteristics of the metachronous subgroup patients. Methodology: From the patients admitted to the Radiation Oncology Department of Oncology Insitute Cluj- Napoca,Romania in 2014-2015, we selected only those patients who were first admitted to the same institute at least 5 years prior to 2014-2015. For these patients we evaluated the reasons of the first presentation, as well as those for the 2014-2015 readmission. Furthermore, we analyzed every case with metachronous tumor by considering the location of the first and second primary tumour. Results: Between 2014 and 2015 a total of 5080 cancer patients were admitted tothe Oncology Institute Cluj-Napoca, Romania. 110 (2.17%) of these patients were first admitted more than 5 years ago. 25 (22.7%) of these 110 patients had no signs of oncologic disease, 21 (19.1%) had a continuous disease progression, 20 (18.2%) had a relapse after a free disease period, and 44 (40%) had a second primary tumor. Median age in this group was 65, with a median survival of 12 years after the diagnosis of the first cancer. The female to male ratio F:M was 1.3:1. In women's metachronous cancer subgroup, the first primary tumors were: breast 12 (48%), followed by cervical 4 (16%), endometrial 3 (12%), colon 2 (8%), and ovary, thyroid and skin 1 (4%) each. In the same subgroup, the second primary cancers were: lung 5 (20%), cervix and central nervous system 4 (16% each), rectum 3 (12%), endometrial 2(8%), and breast, head and neck, soft tissue, lymphoma, myeloma, kidney, parotids 1 (4%) each. In men's metachronous cancer subgroup, the first tumors were: head and neck 5 (26.3%), followed by gastric, colon, lung, and prostate 2 (10.5%) each, and urinary bladder, rectum, melanoma, and skin 1 (5.3%) each. In the same subgroup, the second primary cancers were: lung 8 (42.1%), head and neck 3 (15.8%), gastric, rectum and soft tissue 2 (10.5%) each, prostate and esophagus 1 (5.3%) each. Metachronous cancer at central nervous system level was found only in women (16 vs 0%), and lung cancer was more frequent in men (42.1% vs 20%), but not statistically significant. Among all male and female patients whose first primary cancer diagnosis was head and neck cancer and who subsequently developed a second primary cancer, it was found that the incidence of second primary cancer was more frequent in men (26.3% vs 3.8%, p=0.02). Conclusion: Metachronous tumors are a frequent cause of readmission for cancer patients who survived for more than 5 years. In the women's subgroup, breast cancer was found to be the most frequent first cancer. In the men's subgroup, the most frequent first cancer was head and neck. The second primary cancer that occurred most frequently was lung cancer, in both men and women. For patients who were diagnosed with head and neck cancers as first cancer and who survived long (>5 years) and who also developed a second primary cancer, it was found that the second primary cancer occurs more frequently in men than in women. The ratio of central nervous system cancer as second primary tumor for female to male was found to be F:M=4:0. However, this observation did not reach statistical significance and is currently the subject of further investigation. In patients with risk factors for smoking-related malignancies, follow-up and survivorship programs must continue to focus on the development of second primaries.

The risk for developing a second primary tumor in long surviving cancer patients

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Introduction: Survival rate in cancer patients has increased in recent years and it is still growing. In these patients, there is a significant risk for developing a second primary tumor because of risk factors like genetic background, unhealthy behaviors or side effects from the therapy of first cancer. The goal of this study was to evaluate the frequency of incidence of different cancer types diagnosed in readmitted long-term survivors. An additional goal was to assess the risk for developing a metachronous cancer in patients with long-term survival. Methodology: From the patients admitted tothe Oncology Insitute, Cluj-Napoca,Romania, in 2014-2015,we selected only those patients who were first admitted to the same inistitute at least 5 years prior to 2014-2015. For these patients we evaluated the reasons of the first presentation, as well as those for the 2014-2015 readmission. Furthermore, we analyzed every case with metachronous tumor by considering the location of the first and second primary tumour. Results: Between2014 and 2015 a total of 5080 cancer patients were admitted to the Oncology Institute Cluj-Napoca, Romania. 110 (2.17%) of these patients were first admitted more than 5 years ago. 25 (22.7%) of these 110 patients had no signs of oncologic disease, 21 (19.1 %) had a continuous disease progression, 20 (18.2%) had a relapse after a free disease period, and 44 (40%) had a second primary tumor. Median age in this group was 65, with a median survival of 12 years after the diagnosis of the first malignancy. The female to male ratio F : M was 1.3:1. In the men's subgroup, head and neck cancers were found in 11 patients (23% of the cases), lung cancer in 7 (14.6%), central nervous system cancer in 5 (10.4%), and each of colon and urinary bladder cancer in 3 (6.3%) patients. In the women's subgroup, breast cancer was diagnosed in 14 patients (23.3% of the cases), cervical cancer in 8 (13.3%), endometrial cancer in 7 (11,7%), ovarian cancer in 6 (10%), and each of head and neck and soft tissue cancer in 4 (6,7%) cases. In men with long-term survival (more than 5 years), 45% of those who were previously diagnosed with head and neck cancer developed in time a second primary cancer (5 of 11). Similar results for lung and prostate cancer patients were 28.5% (2 of 7) and 25% (2 of 8) respectively. None of the 5 cases of long term survivors of brain tumors developed second cancer. In the women's subgroup, 12 of 14 (85%) of the patients who had breast cancer were diagnosed with a second malignancy. The corresponding data for cervical cancer was 4 of 8 (50%), for endometrial cancer 3 of 7 (42.8%), and for ovarian cancer 1 of 6 (16.66%).When common primary cancer sites are compared for both sexes, head and neck cancer was found to be significantly more frequent in men (23% vs 6.7%, p=0.01); for lung cancer it was (14.6% vs 3.3%, p=0.03) and for urinary bladder cancer it was 6.3% vs 0%, with a p value of p=0.05. Conclusion: 4 of 10 of the long-term survivors readmitted in the Oncology Institute were diagnosed with a second malignancy. In men, the most frequent first cancer was head and neck, and breast cancer was women's most frequent malignancy. A comparison of common cancer sites for both sexes show the following: head and neck, lung and urinary bladder cancers were more common in men. Almost half of the men surviving for more than 5 years after being diagnosed with a tumor on the head and neck were diagnosed with a second cancer. The same situation was found for almost a third of the men who were previously diagnosed with lung cancer and a quarter of those who were previously diagnosed with prostate cancer. In women, the reason for readmission for 85% of the patients with breast cancer diagnosis more than 5 years ago was the occurrence of a second primary tumor. Cervical cancer and endometrial cancer also represented an increased risk (around 50%) of developing a new primary cancer.

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Measurement of testicular dose during the treatment of Ewing Sarcoma patient underwent External Beam Radiotherapy

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Purpose The present investigation aimed to measure testicular dose during the treatment of Ewing Sarcoma patient underwent external beam radiotherapy.

Materials and methods A right sided pelvis Ewing Sarcoma patient aged 17 years with pubertal status was chosen for the study. The patient was planned to treat with external beam radiotherapy with radiation dose prescription of a total of 60 Gy/30#. The treatment plan of patient was planned on TiGRT treatment planning system (LinaTech). The patient was treated with 3DCRT on Siemens Oncor Expression machine. The thermoluminesense dosimeter system used in the study is a commercial TL reader system with CaSO4: Dy discs, manufactured by Nucleonix, India. Thermoluminesence dosimeters were used to measure the testicular dose during the external beam radiotherapy treatment.

Results The TPS calculated testicular volume of right and left testicle was found to be 20.01 and 12.20 cc respectively. The TPS calculated doses for right and left testicle were found to be 1.40 cGy and 0.80 cGy respectively. The measurements were made for right and left testicle dose and observed doses were found to be 1.31 cGy and 1.03 cGy respectively. The cumulative dose to testes in whole treatment was estimated to 35.03 cGy. The percentage deviation between TPS calculated dose and TLD measured dose were observed 7% and 20% for right and left testes respectively.

Conclusion TLD has been proven to be a promising dosimeter for in vivo dosimetry. The cumulative dose to testes in whole EBRT treatment was found lesser than the ICRP recommended threshold absorbed dose for occurrence of deterministic effect of radiation. Our results of dose to right gonad showed that the measurement of dose at the surface of testicular is sufficient to evaluate the dose to testicle during radiotherapy. However, TLD calculated dose for left gonad indicating the non reliability of TPS calculated dose for distant OARs from the radiation field.

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Saturation correction for ionisation chambers at different DPP

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Introduction: For the exact measurement of dose with an ionisation cahmber in radiotherapy it is essential to have knowledge of the dose per pulse (DPP) of the radiation beam and the saturation correction factor kS of the chamber with respect to the DPP. There are several methods for the determination of kS (i.e. Jaffé diagrams, 2 voltage methods with different formulas and a theoretical calculation model).

Methodology: kS was determined for several ionisation chambers (Semiflex, PinPoint, Roos, advanced Markus) at increasing DPP in photon and electron beams at a conventional linac (Varian NovalisTx) and at a mobile intraoperative electron linac (LIAC). Measurements were performed in a water phantom or in a solid water phantom at different depths corresponding to a PDD-shaped DPP gradient. The focus was on the one hand on the visualisation of the difference in kS in different depths and the influence on dose calibration according to TRS-398 at a depth different than the dose maximum. On the other hand the focus was on the correct measurement of dose and DPP-independent measurement of PDDs with a suitable detector in high-DPP beams.

Results: As expected, the values for kS for the different chambers are increasing with the DPP. For evaluation of the factor at very high DPP in the electron beams, a modified 2 voltage method has to be used because the standard methods are inconsistent in these dose regions. In the low DPP regions at the conventional Linac, all methods yield approximately the same chamberspecific values at the different DPPs. At the IOeRT linac, the use of the standard methods can result in very large deviations in kS and consequently in dose, the only suitable method is one including a model that accounts for a free-electron component. To reduce the relative deviation by applying kS, the highest applicable chamber polarisation voltage should be used to keep the correction factor as low as possible.

Conclusion: When measuring absolute dose or percentage depth doses in a high energy radiation beam, one must be aware of the dose per pulse and how to determine the correspondent correction factor kS. The choice of a suitable detector is imperative to avoid possible devations between real and measured or calculated dose.

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Issues & challenges of medical physicists in Nepal

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Nepal, one of the least developed countries with population of 26.6 million people is one of the biggest populated countries among countries without a regulatory body. In Nepal, use of radiation is almost confined to medical field for diagnostic and therapeutic purposes. In the absence of regulatory body and regulation for radiation used in medical field, hospitals as well as medical physicist have been facing problems in quality assurance, purchase, transportation, safety and security of radioactive material and its management. A medical physicist is an important member of the team in department of radiology, nuclear medicine and radiotherapy. These entire departments must have a qualified medical physicist. In radiation therapy, it is the responsibility of the physicists to use maximum physics data and instruments to improve the accuracy of the treatment. In order to achieve this goal, physicists must have sophisticated costly instruments and also strict regulatory system in place. In a developing country like Nepal, we still do not have regulatory body and radiation regulations. The availability of modern equipment is very much limited. With fewer instruments, it is the challenge and responsibility of the physicist to use his intelligence to reach a better quality of treatment of a patient. It is also the duty of medical physicists to do regular quality assurance to maintain a machine in good working condition to meet international standards. Medical physicists are also required to act as a Radiation Safety Officer due to lack of manpower. Though the history of radiation practice is long, we still don't have any radiation act, nor any legal standards for radiation. There are no official records on radiological facilities in operation. The number and types of units, radiation workers and their qualifications, safety measures and conditions of workplace remain virtually unknown. No governmental or private organization has the authentic statistics. Nepal is a member country of International Atomic Energy Agency (IAEA) since 8th July, 2008, and this will certainly support and speed up the creation of appropriate conditions. And the Ministry of Science & Technology (MOST) is the line agency responsible for official contact with the IAEA. Now is the time for the establishment of a radiation regulatory body for developing and monitoring of essential nuclear safety and radiation control infrastructure in the country. The most essential introduction of radiation Safety and radiation control act is long overdue, not to mention its subsequent enforcement for providing licenses, establishment of other concomitant radiation rules and regulations, code of radiological practice, supervision of quality assurance and radiation protection program, training of manpower and conducting required research to sustain and maintain quality assurance and radiation protection, establishment of personnel radiation monitoring system along with proper management and disposal of radioactive waste. In view of the above mentioned issues and challenges, we remain optimistic on the eventual promulgation of the Nuclear Law and formation of the Regulatory Board. From 2012 onwards, we have also been involved in various projects associated with the IAEA including the establishment of radiation regulatory framework, medical physicist's education and training etc.

Early results and toxicity profile of Glioblastoma multiforme patients treated with hypofractionated Radiotherapy along with concurrent Temozolomide.

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Introduction:
Glioblastoma multiforme (GBM) is one of the most aggressive and most common glial tumors. Maximal safe surgical resection followed by 6 weeks of adjuvant partial brain radiation (RT) with concurrent and adjuvant temozolomide (TMZ) is the standard of care. The present study assessed the acute toxicity and tolerance of a hypofractionated schedule of concurrent RT with Temozolomide in patients with GBM.

Materials and Methods:
From September 2012 to August 2016, 20 GBM patients were treated using various hypofractionation schedules, along with concurrent oral Temozolomide at a dose of 75mg/m2. Clinical information regarding patient demographics, tumor characteristics and treatment outcomes was assembled. Acute toxicity during radiation, reflected by unplanned discontinuation of RT, reduction in RT dose or treatment breaks due to haematological toxicity were assessed.

Results:
The median age of 20 evaluated patients was 48 years (range 22-68 years). The median Karnofsky Performance Status (KPS) was 80. The schedules used were 55Gy in 25 fractions (n=10), 50Gy in 20 fractions (n=5), 56.25Gy in 25 fractions (n=3), 51.75Gy in 23 fractions(n=1) and 52.8Gy in 24 fractions(n=1). Seventeen patients (85%) were treated with Volumetric Modulated Arc Therapy (VMAT), while three (15%) were treated using Intensity Modulated Arc Therapy (IMRT). Mean PTV volume (cc) was 270cc (range 77.7cc- 438.8cc). All patients completed the planned treatment course without any treatment interruption. Total treatment duration for 6 patients (30%) was 28 days and 29-36 days for the remaining 14 patients (70%). Fourteen patients (70%) were seen to have grade I CNS toxicity, while 3 patients (15%) experienced grade II CNS toxicity. Grade II alopecia was seen in 11 patients (55%) and all patients (100%) had Grade I skin toxicity at RT conclusion. No event of Grade II or higher haematological toxicity was seen in any patient.

Conclusion: This retrospective study suggests that hypofractionated RT along with concurrent Temozolomide is safe and well tolerated. Such schedules can be used to decrease overall treatment times, logistically benefitting the patient and healthcare resources.

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Conversion of measured percentage depth dose to Tissue maximum ratio values in the small fields: Is it worth?

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The goal is to find if there were clear differences between the direct measurement of TMR and that calculated from PDD. The dedicated 6-MV and 10-MV treatments were delivered on Siemens (Siemens Medical Solutions, Malvern, PA) ONCOR Expression linear accelerator with an 82 multi-leaf collimator (MLC)-based Stereotactic radiosurgery and radiotherapy (SRS/SRT) is used in Children's Cancer Hospital. The dosimetric data were taken using PTW water phantom. The cone sizes vary from 12.5 to 40.0 mm diameter. Mean error 1.5% was observed between the measured and calculated TMR values for all clinically relevant field sizes and depths. The data Present of no significant differences between TMR values with a p-value < 0.05. The differences between measured and calculated TMR values averaged over depth shows a strong positive correlation with the field size ranging from 1 cm x1cm to 10 cm x10cm. Keywords: TMR, PDD, Dosimetry

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Treatment of Head and Neck cancers with modulated radiation at an Indian Centre

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Introduction: Head and neck cancers (HNC) constitute one of the most common cancers in the developing world. In India, approximately 556,400 cancer deaths in the year 2010, the most fatal cancers were HNC, including malignancies of the oral cavity, lip ,oro- pharynx,nasopharynx and hypopharynx. Over 60% patients present with locally advanced disease. RT planning and treatment delivery for HNC has come a long way from being two-dimensional to three dimensional. Use of highly conformal techniques such as intensity-modulated radiotherapy (IMRT) and image guided radiotherapy (IGRT) have allowed radiation oncologists to deliver curative radiation doses to the tumour with higher accuracy, thereby restricting the dose to organs at risk and consequently reducing treatment-related morbidity. In developing countries there are limited centres with such advanced facilities.The present study evaluated the survival outcome of radical and post-operative radiotherapy(RT) among patients with head and neck cancer (HNC) treated either with IMRT or volumetric modulated radiotherapy(VMAT)at our Institute.

Materials and methods: 1030 head and neck (HNC) cancer patients were treated between Feb 2010 to Sept 2016 patients, with at least 1 years of follow up post treatment were taken up for this study. A cohort of 696/1030 patients treated till Dec,2014 were taken up for this study. 608/696 HNC patients were available for follow -up and analysis .The subsites included were oral cavity, oropharynx, hypopharynx, larynx and nasopharynx. Eligible patients included those treated with radical or post-operative RT between 2010 to Dec 2014. More than 90% patients received modulated radiotherapy (IMRT or VMAT) with/without concurrent chemotherapy as per indications. All patient data was extracted from electronic hospital information system and Mosaic-intranet. All patients underwent dental prophylaxis and nutritional counselling pretreatment. After informed consent, patients underwent mould room procedure (immobilization in thermoplastic mask) and simulation with contrast-enhanced CT scan with 3-mm slice thickness. IMRT or volumetric modulated arc therapy without simultaneous integrated boost plans were generated on CMS MONACO v. 3.0 (Elekta, Stockholm, Sweden). Target volume and normal structures were delineated as per departmental protocol(RTOG and Gregoire guidelines). The treatment plans were verified and authorized after cross-sectional and dose–volume histogram analysis of the PTV and organs at risk dose assessment. RT was delivered with 6-MV photon beams on a linear accelerator. Patient alignment was checked online before treatment by using cone-beam CT. Online corrections were applied if there was deviation beyond the threshold limit 3-5 mm.In 10% cases a re-planning scan was done at 4 weeks to account for shrinkage of the tumour volume and an adaptive approach to treatment was applied. Demographic parameters and disease related factors were analysed.Disease free survival (DFS) was calculated from end date of radiotherapy till last follow up or last date of disease control. Overall survival (OS) was calculated from date of registration to last follow up date if alive. The primary end point was survival The statistical analysis were performed using SPSS version 20.0 and Kaplan Meir method was used for calculation survival. Toxicity was recorded as per CTC version 3.0 criteria.For the ease of analysis, we divided the entire cohort into 3 broad groups viz. Oral Cavity, Oropharynx-Nasopharynx and Hypopharynx-Larynx.

Results: Among the evaluable patients, the median age was 60 years (range: 11-90 years) with a male preponderance (Male 513/608). Majority cases had a squamous cell carcinoma (568/608). The subsites treated were oral cavity 32%(224), oropharynx 23%(161), larynx 20%(139), hypopharynx 8.9%(62) , nasopharynx 5.9%(41) and 69 miscellaneous . RT intent was radical (386) and post-operative (222) with 60% receiving concurrent chemotherapy. There were 77% patients with advanced stage disease.With a median follow up of 2.5 years, median OS was 19 months and median DFS was 1 year among evaluable patients. The 2 year,3 year and 5 year OS was 78%, 70% and 55% respectively for all stages combined. The early stage OS at 2 and 5 years was 90% and 65% respectively (p=0.001).As per sub site early stage larynx had best OS at 2 years; more than 90% and hypopharynx had worst 2 years OS (65%).Among the evaluable patients, 110 patients developed disease recurrence with 70% recurrences being loco-regional. They received surgical salvage, chemoradiation of hypofractionated RT depending upon the recommendation of multidisciplinary tumour

board decision.

Conclusion:-Although >75% patients presenting at a late stage of disease definitive well planned and executed radiotherapy resulted in overall survival of 78% at 2 years;70% at 3 years and 55% at 5 years.The next phase is to identify the bio-markers and smoking/non-smoking cohorts in head and neck cancers and their outcomes post treatment.

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Optimisation of protection in breast mamamography

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Xray mammography is the most reliable method of detecting breast cancer being the method of choice for b treast screening program in many countries ,high mammogram s have to be obtained at a reduced breast dose in combination of correct equipment used

Methodology linear attenuation coefficients for different types of breast tissue are similar in magnitude and the soft tissue contrast can be quite low tha is to say the main variable of mammographic imaging system that were consideerd in this study included contrast ,sharpness ,dose and noise

Results contrast was made as high as possible by imaging with a low photon energy hence increased breast dose wasseen . contrast decreased by a factor of 6 between 15 and 20kev . the glandular tissue contrast fall below 0.1 for enegies above 28kev unsharpness in the image contributor included receptor blur eas made as small as 0.1 -0.15mm full width at half maximum of a point of response function

Dose decreased rapidily with depth in tissue due to low energy Xray spectrum used at 20kev theere was dose increase by afactor 17 between thickness 2cm and 8cm of 30 between photon energies 19 and 30kev for 8cm thick breast there was a dose increase of afactor of 30 between photon energies 19 and 30kev image noise was a contributed from film grain and electronic noise **Conclusion**

In practice breast dose was acomprise made between the requirement s of low dose and high contrast. these factors are the important physical parameters for optimisation of protection in mammography.

Tunable compact monochromatic X-ray synchrotron radi- ation source based on inverse compton scattering for ad- vanced radiological applications

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Radiation protection of patients and physicians are the main concern of radiation protection program adopted in any radiological facility. The usage of conventional X-ray sources in radiological facilities is usually associated with exposure to wide spectrum of X-ray energies although only a narrow band of the X-ray spectrum is used in diagnostic/treatment process, while the remained spectrum is considered to be parasitic and non avoidable. In some radiological applications this parasitic portion contributes significantly to the total dose delivered to the patients as well as the physicians. Accordingly, developing and implementing new advanced diagnostic/therapeutic technology that use tunable mono-energetic (monochromatic) X-ray source without generating such parasitic portion of conventional X-ray sources will lead to significant decrease in the dose delivered to both patient and physician; this in turn will enhance the radiation protection program significantly. In that context, there were a plenty of research papers already proved the fascinating use of monochromatic X-ray synchrotron radiation in many radiological applications. Figure 1 represents an example of such outstanding applications of monochromatic X-ray radiation in early diagnostics of breast cancer; more details will be introduced in the full paper of this synopsis. However, high brightness monochromatic X-ray synchrotron radiation is traditionally obtainable exclusively in giant facilities like 3rd generation light source when ultra relativistic electron beam (GeV) passes through a periodic magnetic structure (undulator). This unluckily limits the dissemination of the radiological applications of X-ray synchrotron radiation within the synchrotron facilities only. In order to disseminate this technology worldwide, a novel and compact system should be developed in order to be hosted in ordinary hospitals. Many research efforts have been conducted during last decade to develop a compact system that offers the opportunity to produce high-brilliance X-ray synchrotron radiation with a laboratory-scale when a relativistic electron beam from linear accelerator (LINAC) collide with high power laser via Inverse Compton Scattering (ICS) interaction. Unfortunately, so far, no system has been produced in commercial scale due to some technological difficulties related mainly to the linear accelerator (LINAC) which is the main core of that system. In this contribution we propose a certain compact (1 m) traveling wave X-band (12 GHz) LINAC that can produces up to 50 MeV electrons suitable for T̃CS source. This X-band LINAC has been proposed in specific since a similar structure has been already designed and fabricated in cooperation with CERN, Paul Sherrer Institute (PSI) and Italian synchrotron facility ELETTRA; one of the authors has been involved in developing such LINAC. The CERN-PSI-ELETTRA structure is based on cutting edge technologies such as mode launcher and alignment monitors that overcomes the most known shortcomings associated with other versions of X-band LINACs; many unites are already fully functioning at the premises of aforementioned facilities without any significant technological problems; this nominates such X-band LINAC as a best solution for ICS source. Usually, the output electron beam parameters will be significantly affected by the operating conditions of LINACs such as the field gradient, initial & final beam energy, length of LINAC & its type, operating mode, shunt impedance, etc. Accordingly the output electron beam parameters will be significantly different form purpose to another. To prove the suitability of the proposed X-band LINAC to be used for ICS source, the LINAC resonance cavities have been simulated using SUPERFISH code and the output electromagnetic field mappings have been used to investigate the electron beam dynamics along the LINAC using ASTRA code. Finally, the monochromatic X-ray that is produced by collision between the electron beam with Table Top Terra Watt (T3W) laser has been simulated using CAIN code. The simulation results show that the resultant monochromatic X-ray is very convenient for many advanced radiological applications such as Dynamic Intra Venous Coronary Arterio Graphy, early diagnosis of breast cancers and Auger Cascade Radiotherapy. We conclude that, the CERN-PSI-ELETTRA X-band LINAC and similar LINACS proposed in this study is the best candidate for ISC source and eventually a quantum leap in achieving a stable and compact ISC source is at the reach of hands in very near future.

Electrometers intercomparison using ionization chamber and radioactive check source

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Introduction Radiophysics department of the Institute of Oncology Ljubljana, use different electrometers for absolute dosimetry. They are from two different vendors PTW Freiburg GmbH and IBA Dosimetry GmbH. Intercomparison study was carried out in which a total of nine electrometers were compared by using a radioactive check source. An electrometer used by the Institute of Occupational Safety was used as a reference as the institute is approved by national authority to perform external dosimetry audits in the field of radiotherapy.

Materials and methods In the study we used five electrometers from PTW (2 PTW Unidos and 3 PTW UnidosWebline) and four from IBA Dosimetry (3 IBA Dose1 and 1 IBA Dose2) (figure 1). The 0.6 cm3 Farmer type chamber (PTW 30013) was inserted in a Sr-90 radioactive check device (PTW T48012-0444) with an activity of 33 MBq from 15/2/2010. The chamber was connected with a triaxial extension cable to the electrometer. Collected charge at bias voltage +400V for the time of 180 s was measured. The ambient temperature and air pressure were monitored during the measurements to be able to correct the results. With each electrometer we carried out 3 measurements to ensure the stability as well as to minimize the statistic error.

Results From the results in the table 1 we can see that the PTW electrometers collected charge is positive while for IBA electrometers charge is negative, even though the voltage was set to +400V. The reasons for these discrepancies are the differences in conventions expressing the polarity of the voltage of the two manufactures. In IBA electrometers a central electrode of the chamber is positive when you apply +400V while for the PTW electrometers central electrode is charged to -400V. Discovering this difference the measurements were repeated in a physically correct way. The repeated results as well as the difference regarding to the electrometer of the Institute of Occupational Safety are shown in the table 1. During the measurements the temperature and the pressure were stable therefore no correction was necessary.

Conclusion This study showed an excellent agreement between the electrometers for the same vendor and series. As we could expect, there is a minor difference between the manufactures which is very low and can be neglected. We have to emphasize in the results we did not consider the uncertainty of the measurements. However we discovered that the oldest electrometers (PTW Unidos) used in our test had the largest difference to a reference and a manufacture recalibration should be considered. Unfortunately the manufactures do not use the same convention for the definition of the polarity of central electrode which can lead to larger discrepancies when measuring the absolute dose.

Empirical model for phantom scatter for small beam dosime- try in different density media

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Purpose: phantom scatter, Sp, is an important factor needed to calculate dose in media. It is affected by small beam dosimetry, in a similar way as collimator scatter, Sc, with the added layer of media (density) effect. Our work is geared towards finding a simple model for calculating Sp for small beams in various media. The results were verified by comparing calculated Sp vs measured Sp in an anthropomorphic phantom.

Materials/method: Various size chambers were used to measure the total scatter factor, Scp, and the collimator scatter, Sc, for MLC-shaped square fields with sides (r) 0.49 to 10 cm using Elekta's Apex collimator. Three different cube phantoms were constructed from solid water, wood and plastic. An anthropomorphic phantom representing the thoracic region was CT-scanned. Fourpoints in three regions, mediastinum, lung (central and peripheral points) and spinal cord, were irradiated with various beam geometries, AP, PA and Lat. From the measured dose, Sp for each point was calculated and then compared with our predicted value.

Results: A term called the output factor ratio (OFR) defined as (S_(p_medium) (r))[U+2044](S_(p_water) (r)) was created. OFR was plotted against chamber size and a linear curve was obtained, Fig1. The extrapolation gives the OFR value independent of detector size for every r. Another relation was constructed by plotting OFR vs field size and normalizing each value to that of water, Fig2. This is used to relate Sp for small r with that of large r. Fig 2 shows that OFR values are straight and matching that of water within +5% until very small beams where it slightly curves upward for low density medium or downward for high density medium. An exponential function was used to fit this behavior in the form [U+3016]OFR[U+3017]_wˆm=Q+Peˆ(-Kr), where Q, P and K are fitting parameters. Sp can then be calculated for any beam size using values measured for broad beam geometries. Table 1 compares measured vs calculated Sp values in various tissue composition for various beam entry. Sp for the phantom was measured by dividing the dose in air (with buildup) to the dose in the phantom at that point for the same SSD, MU and beam. Various entries of radiation was used to change the composition and layers of tissue that the beam goes through before it reaches the point. The measured Sp has, as expected, different values for each location/beam entry, whereas our model only predicts one value per tissue composition, the calculated Sp was within 3% of Sp measured in 8/12 cases, within 5% in 2/12 cases, and within 8% in 2/12 cases, Table 1.

Conclusion: Our model calculating Sp for small beams and in various media successfully predicted Sp values to within 5% from measured values in (10/12) combinations of beam-entry and location inside the anthropomorphic phantom. Improvement on the model requires taking into account the layers of heterogeneities surrounding the point to increase accuracy of Sp values that are sensitive to surrounding tissue.

Comparison of two techniques for irradiation of the breast and the regional lymphatics - helical tomotherapy and 3D conformal radiotherapy

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Purpose: The breast cancer is the most common malignancy among women in our country. In the National Hospital of Oncology we have been treated about 600 patients per year. The purpose of the study is to present treatment planning protocols for left and right site breast irradiation, when the planning target volume include the involved breast (PTV), and supraclavicular lymph nodes (PTV_SCLN) using helical tomotherapy and to compare with “one isocenter” 3D conformal radiotherapy.

Methods and Materials: The irradiation was planned for 10 real patients with left and 10 with right breast cancer using “one isocenter” technique, which is our protocol for irradiation with an isocenter situated at the lower edge of the supraclavicular part of the target volume, and asymmetrically irregularly MLC collimated beams. Tomo Helical plan was developed for the same patients using field with – 5.048 cm, pitch 0.22 cm and Modulation Factor 3. The fall-off of the dose was controlled by help contours at a distance of 1,5cm form PTV and PTV_SCLN. Directional blocking was applied to the heart and contralateral breast and lung. The planned total treatment dose was 50 Gy for both PTV and PTV_SCLN. The critical organs were: contralateral breast, ipsilateral and contralateral lung, heart and liver. For evaluation dose volume histograms were used.

Results: The average results with standard deviation (SD) for Tomo helical and 3D CRT plans are presented in Table1. The averaged minimum dose for PTV in 2 ccm (Dmin2ccm) increased from 25.9 ± 6 Gy for 3D plans to 39.7 ± 1 Gy for tomo helical and for PTV_SCLN from 37.8 ± 1.6 Gy to 45.4 ± 0.6 Gy. The maximum dose in 2ccm (Dmax2ccm) decreased for PTV from 54.51 ± 0.6 Gy for CRT plans to 52.7 ± 0.4 Gy for tomo, and from 55.2 ± 0.6 Gy to 51.8 ± 0.2 Gy for PTV_SCLN. The homogeneity index (HI=(D_(2%)-D_(98%))/D_mean)was HIPTV_tomo = 0.09 ± 0.01; HIPTV_SCLN_tomo = 0.06 ± 0.01, respectively HIPTV_3DCRT = 0.29 ± 0.04 and HIPTV_SCLN_3DCRT = 0.23 ± 0.05. The conformity index for PTV+PTV_SCLN (CI=V_(98%)/V_PTV) was CITomo = 1.03 0.1; CI3DCRT = 0.94 0.1. For both techniques, ipsilateral lung received the same middle dose - 13 Gy (+0.3Gy; -0.7 Gy), the volume obtained 30 Gy was 8.5% higher in the CRT plans but the dose received in 65% of the lung volume was 3 Gy more for Tommo helical. The middle dose for contralateral lung was 3.5 Gy lower for 3D CRT (1.2 Gy vs 4.8 Gy). Heart’s average dose for left breast cases was 5 Gy greater for helical plans, but in 3D CRT plans Dmax was10 Gy more and V30Gy was 3.6% vs 0.6%. The average dose in contralateral breast was 2.5 Gy more in tomo helical plans. The liver in right breast cases with 3D CRT plans got 5 Gy less average dose but 7 Gy more for Dmax. The average irradiation time for 3D CRT with gantry rotation was 5.2 minutes, for tomo helical - 6.5.

Conclusion: The conformity and homogeneity of PTVs were better for helical tomotherapy plans than the 3D CRT for both left and right breast tumor with regional lymph node involvement. The organs at risk: ipsilateral lung, contralateral lung, contralateral breast, heart and liver received a higher average dose in tomo helical plans, but lower maximum dose and a low dose in adjacent to PTVs part of their volume. There was no significant difference in irradiation time. Key words: Treatment planning, Breast cancer, 3D conformal radiotherapy, Helical tomotherapy

Abscopal effects with non-ionizing radiation

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Introduction Radiation therapy in oncology is in most of the cases local. The malignancy (counting the circulation cancer cells and the micro- and macro-metastases) is systemic, causing controversy with the local actions in curative basis. The abscopal effect of low intensity ionizing radiation is well-known. Our objective is to show the abscopal effect with local non-ionizing radiation, action on blocking the invasion of cells to the blood-stream and together with immune-stimuli extends the local method to systemic therapy.

Method Non-ionizing modulated RF radiation (mEHT, trade name: oncothermia) is used. This technology is impedance controlled capacitive coupling with amplitude modulation by the time-fractal pattern. mEHT selectively targets the rafts of transmembrane proteins on the cell membrane of malignant cells. The nano-selection is based on the certain deviations of metabolic-processes which enriches the ionic species in the extracellular electrolyte increasing the local conductivity and guiding the RF-flow. The missing or rearranged cellular organizing pattern of malignant cells also makes the selection of the irregular cells possible. Finally the cell-killing energy absorption is connected to the beta and delta absorption in the cell-membranes. There were various in-vitro and in-vivo immune-histochemical studies proving this selection and its effects.

Results Significant tumor-cell death shown by TUNEL caused by mEHT. Mitochondrial Bax and release of Cytochrome C and nuclear translocation of apoptosis inducing factor AIF are measured [3]. Immunohistochemistry and apoptosis protein array proved elevated hsp70 and hsp90 expression and released them from the cell. Earlier cytoplasmic to cell membrane exposure of calreticulin and later release of HMGB1 protein from cell nuclei were observed. The set of molecules in the measured apoptotic processes form damage associated molecular pattern (DAMP) concluding to immunogenic cell-death (ICD) [4]. The abscopal effect is proven by the in-vivo experiment using an intratumoral dendritic cell (DC) injection together with the mEHT for C3H/He mice inoculated with tumor in femoral region. The non-treated tumor in the abdomen was measured. The whole body antitumor effects are proven, [5]. Furthermore, mEHT plus DC administration significantly inhibits the CT26 tumor growth in BALB/c mice, while even the re-challenging of the tumor inoculation became impossible, [6]. In this case the abscopal effect works like vaccination. The combined mEHT-DC treatment increases the leucocytes and macrophages with increased eosinophils, organizing specific T-cell response. Together with the experimental research level multiple clinical results show the efficacy of the method and feasibility of the new abscopal approach. The method is combined with most of the major oncotherapies. The main observable indicators of the results are the elongation of the survival time and at the same time improvement the quality of life. There are case-reports, Phase I and Phase II trials that approve the promising technique, including lesions: Bone (metastatic); Breast; Colorectal; Gliomas; Head & neck; Brain (metastatic), Kidney; Liver (metastatic and primary); Lung (NSCLC, and SCLC); Pancreas; Cervix; Ovary; Prostate; Soft-tissue sarcoma; Stomach; Urinary-bladder; Uterus.

Conclusion Method of mEHT induces tumor cell apoptosis and enhances the release of Hsp70, unlike conventional hyperthermia. The consequence of the selective heating of the membrane rafts induces DAMP and ICD. mEHT can create a favorable tumor microenvironment for an immunological chain reaction that improves the success rate of intratumoral DC immunotherapy inducing abscopal effect by tumor specific immune reaction. The main medical advantages of the method are its personalized targeting together with the effective selection and distortion of the malignant cells. The new direction of application focuses on the blocking of their dissemination, as well as promoting the bystander (abscopal) effect acting on far distant metastases by local treatment. The method is successfully developed in the direction of the immune-support, pointing an exciting area: cancer-vaccination. These effects are well indicated in clinical practice but due to the proper funding the Phase III clinical trial is missing yet. For further development of the method the Phase III clinical trial is warranted.

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Evaluation of metallic implant artefact on photon beam calculation algorithms: a study using CIRS thorax phantom

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The aim of this study was to evaluate the effect of metallic artifact on dose calculations for patients with metallic implants and to find ways in reducing the errors associated with actual dose delivered. The error magnitude in dose calculations using two different treatment planning system (TPS) algorithms and dose measurements in a CIRS (Model 002LFC) IMRT thorax phantom with a metal insert in the spine was assessed for two different CT window settings. As described in figure 1, the CIRS phantom was CT scanned using an adult thorax routine for two sets of images (i.e. Mediastinum and Osteo window settings). A 3D anterior-posterior (APPA) conformal treatment plans (using 6MV and then 15MV photon beams) was done using a typical 2 Gy to a target volume (point 5 on the CIRS phantom) with a Collapsed Cone (CC) and Pencil Beam (PB) calculation algorithms for both CT image sets. Maintaining the same parameters, the plans were recalculated using a corrected image set (overriding the metal density in the artifact region with that of water). Doses to the selected point of interest in the phantom were measured using a calibrated PTW Farmer ionization chamber TM 30010 and a PTW UNIDOS webline electrometer based on the techniques as described in IAEA TRS 398 and compared with the TPS calculations. Average discrepancies of 2.4% and 5.2% for 6MV and 4.6% and 4.5% for 15MV between calculated and measured doses were observed for collapsed cone and pencil beam algorithms respectively using the mediastinum CT window setting. For the Osteo window setting, discrepancies of 2.7% and 3.1% for 6MV and 5.0% and 2.7% for 15MV between calculated and measured doses were observed for collapsed cone and pencil beam algorithms respectively. Correcting for the metal artifact by overriding its densities in CT sets during planning gave higher average dose discrepancies of 16% for both energies. This suggests that caution should be exercised when using only corrected metal artifact CT scans for dose calculations in TPS as it only gives superior isodose coverage but not the actual dose to selected point of interest. The results as captured in table 1 of this study indicated the shortcomings of the PB algorithm and higher photon energy for the test case performed and, therefore the use of the CC algorithm and low photon energy is highly desirable. There was no statistically significant difference according to the kinds of CT window settings used. In addition, it will be necessary in the future to consider the use commercial metal artifact reduction tool for clinical routine to help avoid misinterpretation of dose distributions during planning.

Table 1 Comparison of TPS calculated doses and ion chamber measured doses at measurement points obtained for the anterior-posterior technique (APPA) for both algorithms

Collapsed Cone (CC)				
	AP(Gy)		**PA (Gy)**	
	TPS	**Meas**	**TPS**	**Meas**
6MV	1.20	1.23	0.80	0.82
15MV	1.17	1.23	0.83	0.86
Pencil Beam (PB)				
	AP(Gy)		**PA (Gy)**	
	TPS	**Meas**	**TPS**	**Meas**
6MV	1.15	1.19	0.85	0.79
15MV	1.13	1.18	0.87	0.83

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15MV	1.13	1.18	0.87	0.83

Evaluation and quantification of long-term results of the Technical Cooperation Project - BRA/6/023 – IAEA

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Introduction. Advances in radiotherapy technologies have led to many benefits including better quality of treatments with potential less morbidity and survival improvement. These technologies, however, require not only more advanced equipment with higher costs, but also well trained human resources. In places where this technology is being implemented, qualified personnel is desired in order to properly start the treatment by itself. There is a lack of qualified personnel in our country regarding this subject. A Technical Cooperation Project (TCP) - "BRA/6/023- Supporting the Qualification of Human Resources in Advanced Radiotherapy Techniques" was, thus, developed with the IAEA including three reference centers in Brazil. The objective of the project was to provide personnel training in advanced technologies in radiotherapy such as Volumetric Modulated Arc Therapy (VMAT), 4D technology and Stereotactic Body Radiation Therapy (SBRT), and Image-Guided Radiation Therapy (IGRT). Overall, 17 professionals participated in specific trainings in international institutions during the period of the project, in 2012 and 2013. The objectives of this study were to evaluate and quantify the long-term results of this training.

Methodology. A questionnaire with 22 queries was sent to all the 17 participants of the TCP - BRA/6/023. Training was performed through fellowships or scientific visits. The questions included demographic data, years of experience in the field, information about the specific training and the outcomes after the training program. Personal comments were allowed at the end of the questionnaire.

Results. Seven radiation oncologists and 10 medical physicists were trained, seven male and 10 female. The mean age was 37, and the years of experience in the field ranged from 2 to 35 years, being the majority 3 years. The home institutions of the participants were Hospital das Clínicas of University of São Paulo, São Paulo, 48.9% (41.2% from the Cancer Institute – ICESP, and 17.7% from the Radiology Institute – INRAD); 35.3% from Hospital Sírio-Libanês, São Paulo, and 17.6% from Centro Infantil Boldrini, Campinas, respectively Training was performed in North American and European countries being 41.2% in the USA, 23.5%, Canada; 17.6% Germany; 5.9%, Netherlands; and 11.8%, others. The training activities started in July 2012 and finished in Nov 2013 being the great majority, 85.7%, a fellowship of one month period followed by 7.1%, for 2 months and 7.1% for 2 weeks (scientific visit) training, respectively. The topics of interest for training were VMAT: 52.9%, 4D technology: 47.1%, SBRT: 82.4%, and IGRT: 70.6%. Interestingly, besides the subjects directly related to the project, cranial radiosurgery (41.2%), brachytherapy (17.6%) and others (41.2%) were also referred as areas of having some training. Regarding the outcomes and contribution in the daily practice, 100% answered that they are using the training in their routine; and 82.4% helped in the training of other professionals in their institution, from 3 to more than 20 people. The knowledge was reported to increase in 100%. Development of a project in the host institution was possible for 41.2%, and 100% considered the training "Good" (35.3%) or "Excellent" (64.7%) and recommend the host institution to others. An increase in the use of the technology that was trained was reported by 88.2%. In their respective departments there was an increase of at least 50% in the use of more advanced technology with improvement of the processes in 76.5%. Among the general comments, besides the improvement of the professional skills, comments about the opportunity to interact with experienced professionals and "keeping in touch" with them, to have an overview of the Radiotherapy Departments' routine, and to interact with another culture in a different language were the highlights. "The training was for me one of the best experiences that I had in my professional life".

Conclusions. The TCP BRA/6/023 has enabled the upgrade of a good number of physicists and radiation oncologists from the centers. The implementation of new technologies was better supported with the training program, and, at the same time, the knowledge was shared and transmitted to other professionals. Overall, the training program was considered an excellent type of training by all the participants, and after almost three years, the use of the technology in the participating centers was increased in at least 50%.

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Low dose-rate prostate brachytherapy: do different seeds manufacturers matters?

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Introduction: Prostate cancer is the most common cancer in males, excluding non-melanoma skin cancers. Clinical presentation is variable and the disease is classified as having low, intermediate or high-risk. The main modalities of treatment are radical prostatectomy (RP), brachytherapy (BT), and external beam radiation therapy (EBRT), with or without androgen deprivation. Brachytherapy is a treatment option with the same efficacy as EBRT or RP alone in patients with newly diagnosed low- or intermediate-risk prostate. In Brazil, there are few centers (23) performing low dose rate (LDR) BT, using about 25,000 seeds/year. We started our program at the Hospital Sírio-Libanês (HSL) in 1998 and currently we have already treated 1043 patients with LDR BT. The source description in the planning system has an important role for the treatment, because the source geometries, including encapsulation and internal structure leads us to use different parameters of dose rate constants, radial dose and anisotropy functions. AAPM Recommendations Regarding Clinical calibration of seeds, ask for calibration of at least 10% of the seeds prior to the implant, for every implant. Clinical calibration agreement with manufacturer should be within 3% of batch mean and 5% maximum deviation from mean. For the past 18 years, this was the procedure at HSL using the OncoSeedOR 6711, produced by Amersham using Well Chamber (Standard Imaging HDr Plus) with calibration factor for 6711 seeds model. In March 2016, after a government motion, all the centers performing LDR BT started to use Best R seeds model 2301, for the first time in the country. When performing the clinical calibration of this new seed, a difference of 17%, between the certificated one and our measurement was observed. At this time we were using the same dosimetry system. In Brazil there is no Accredited Laboratory and no possibility to obtain the calibration factor for Iodine-125 seeds Best model 2301. In addition, the dose calculations for treatment were generated by the VariseedOR treatment planning system (TPS) using the parameters of the two sources and the dose distribution was different between them. The objectives of this study were to determine the correct calibration factor of our well chamber for the Best 2301 seeds and to determine the clinical source calibration of these seeds; to evaluate the interchangeability of the two commercially available 125I sources by assessing the dosimetric effect in the implant dose distribution and how this affects our daily practice.

Methodology: Three sources with different activities: 0.502 mCi , 1.001 mCi . and 1.194 mCi were sent to Instituto de Pesquisas Energéticas e Nucleares (IPEN) by Best Company. The seeds were calibrated by National Institute of Standards and Technology (NIST). With the known sources activities, we performed cross-calibration measurements and the new calibration factor was set for our well chamber. Calculations using the available sources geometries, radial dose functions and anisotropy distributions were performed with both manufacturers' seeds and the results were compared. The Variseed TPS was used for calculations. Results: The dose-volume histogram generated for each manufacturer showed marked differences mainly in the high-dose regions. The measured difference in the calibration for the two sources was 17%. Using this new factor, a difference of only 1 to 3% between the certified value and our calibration was observed. When comparing the dose distribution in the volume receiving 100% of the prescribed dose, differences of up to 10% mainly in the high dose region within the implant were observed.The reason of this can be explained by source geometries differences, including encapsulation and internal structure leads to different parameters of dose rate constants, radial dose and anisotropy functions.

Conclusions: Chamber calibration factor for the specific manufacturer is necessary for the clinical source calibration and In the absence of an Accredited Laboratory , like in Brazil, the cross-calibration measurements is a reasonable solution. The dose distribution for two source designs presented important differences mainly in the volume within the internal high-dose regions and may affect the dose received by non-target internal sites. A simple interchangeabilitof sources from different manufacturers is not recommended without the appropriate clinical calibration and dosimetric evaluation.

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Audit of VMAT delivery techniques in the Baltic States

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Purpose: To evaluate VMAT planning and dosimetric delivery accuracy in the Baltic States through on site visits with the PTW Octavius 4D 1500 system.
Methods: The data (CT images with contours in DICOM RT format) for three patients (prostate, pelvic nodes, head & neck) was send to participants to be planned on local Treatment Planning System (TPS). The target dose objectives and critical organ dose constrains were specified in the planning instructions. The verification plans for 3 cases were created for PTW Octavius 4D phantom. During on site visit the prepared treatment plans were reviewed and measured with PTW Octavius 4D 1500 system which was brought in to each site and results were analyzed using PTW Verisoft 6.1 software using 3D gamma method with 3% (local and global dose) and 3 mm criteria. 6MV beam from Varian linacs was used in all centers and Varian Eclipse TPS was used in 3 centers and Elekta Monaco TPS was used in one center.
Results: The audit was carried out in 4 hospitals that performed VMAT during 2015. The audit measurements took approximately 4-5 hours in each hospital and were performed after clinical work. The gamma pass-rates are shown at Figure 1.
Conclusion: The audit showed acceptable dose distribution results for the implementation of VMAT delivery in the visited centers. It has also showed the feasibility of using commercial 2D array with the phantom for on-site visit types of audit.

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Application of output correction factors for three small beam radiation detectors: comparison of results for a TrueBeam Stx linac

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Purpose
To compare and analyze the corrected out factors resulting from three different radiation detectors for small fields of a TrueBeam STx linac. Materials and MethodsDetector signal ratios ($M^{f_{clin}}/M^{f_{msr}}$) were measured for a 6 MV WFF (with flatting filter)Q_{clin} Q_{msr} photon beam of a TrueBeam STx linac. The following nominal square field sizes were used: 0.5, 1.0, 2.0, 3.0, 4.0, 6.0, and 10 cm^2. The small fields were set by the jaw collimators and their actual size was verified and recorded. The radiation measurements were performed in liquid water at 10 cm depth with a source to surface distance of 100 cm. The detectors used were a synthetic diamond (model PTW-60019, manufactured by PTW-Freiburg, Germany), a mini-ionization chamber (model PTW-31016, manufactured by PTW-Freiburg, Germany) and a silicon diode detector (model SFD, manufactured by IBA-Dosimetry, Germany). The operation and characteristics of each detector can be found elsewhere on the literature. Each detector is referenced in this work by its commercial name: microDiamond (PTW-60019), SFD (SFD silicon diode) and PinPoint 3D (PTW-31016). A UNIDOS electrometer (PTW-Freiburg, Ger- many) was used to measure the detector signal. In the case of the ionization chamber, all the measured signals were corrected by the influence quantities. The signal ratios were corrected by ap- plying the specific correction factors for each detector and field size. The output correction factors ($k^{fclin,fmsr}{Qclin,Qmsr}$)*weretakenf romT ABLE*26*of T* RS483draf *tfromalinearinterpolationasaf unctionof* field sizes. ResultsThe actual field sizes show a variation up to 10% for field sizes greater than 1 cm^2. For the smaller field size (0.5 cm^2), it was impossible to perform the measurement. This field size was redefined with different jaw settings to allow the measurement. The Figure 1a shows $M^{f_{clin}}/M^{f_{msr}}$ as a
Q_{clin} Q_{msr}
function of the actual field size expressed as the equivalent square field size. It can be observed the typical behavior of the signal ratios for each detector. The differences between the measurements are greater for the smaller field sizes (< 1.0 cm2), up to 5.6% for 0.5 cm2 field size. The Figure 1b shows the corrected out factors ($\Omega^{fclin,fmsr}{Qclin,Qmsr}$).*Itcanbeobservedanagreementbetweenthe**Ome*

Conclusions
The application of the output correction factors to the signal ratio for each detector to obtain the corrected output factors, shows an overall excellent agreement (<1%) between the radiation detec- tors and field sizes used in this work. The 1.0 cm^2 field size showed the highest dispersion, 0.8%. The mutual difference analysis showed that the output factors measured with the microDiamond detector differ from the other detectors up to 2.3% for the 1.0 cm2 field size. The comparison of the daisy chain $k^{f_{clin},f_{msr}}$ with those from TRS 483 showed a good agreement better than 0.7%. In the near future more detectors will be added to this work.

Measurement of the percentage dose at surface with radiochromic films

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Introduction The measurement of the dose on the surface of a patient in radiotherapy treatments is a useful parameter for a quality assurance protocol. The surface dose can be associated to the skin dose, or entrance dose depending on the depth at which the measurement is done. The very high gradient of the percentage depth dose makes difficult to define the point of measurement for any detector. The radiochromic films (RF) are an alternative instrument to measure the dose at the surface. They are 2D detectors commonly used for quality assurance of intensity modulated radiotherapy treatments (IMRT). They are near tissue equivalent and they do not need post irradiation chemical process. Particularly, Gafchromic EBT3 has shown radiation particle independence as limited energy and dose rate independence. In this work the percentage of the dose at the surface was measured of the beam of a linear accelerator (LINAC) Novalis (BrainLab, Germany) with nominal energy of 6MV. Three different field sizes were used, two conventional (10cm 10cm, 5cm 5cm) and one considered nonconventional (1cm 1cm).
Material and methods The measurement of the percentage dose at the surface was done indirectly with the following process, firstly the total scatter factors (TSF) were measured of the 3 different field sizes at 5cm depth of a water scanning phantom(MP3-XS PTW, Freiburg, Germany). The detectors used were in this part were two kind of ionization chambers, a semiflex of 0.125cm^3 (PTW, Freiburg, Germany) and a microionization chamber CC01 of 0.01cm^3 (IBA-Dosimetry, Germany). Thedaisy-chain method was used for the non conventional field size. The measure was done at source surface distance (SSD) of 100cm. The corrections according IAEA's 398 calibration protocol were applied to the chambers. Secondly, we determined if the EBT3 Gafchromic are energy independent, measurements at three different depths (1.5, 5, 10 cm) of a solid water phantom (CIRS, Inc) were done for a field size of 10cm 10cm. The doses used were in a range from 0.5 to 10Gy and they were verified with the semiflex chamber. The RF was handled according to the manufacturer specifications and the AAPM TG55 recommendations. The RF were digitized with a scanner in transmission mode with the three color components and 16 bit depth. The images were stored in TIFF format. To analyze them the optical densities (defined as $OD=\log_{10}(I/I_0)$) was obtained and only the red component was used. Finally, measurements at the surface for different doses with the RF were done. The doses were in the range of 0 to 6Gy for the three different field sizes. The same procedure of film analysis was applied. To calculate the percentage of the dose at the surface the dose measured at the surface was normalized with the LINAC output at 5cm depth and the TSF previously measured. The uncertainty is the standard deviation of the values.
Results The value of the TSF measured for the field sizes of 10cm 10cm, 5cm 5cm and 1cm 1cm are 1 0.1%, 0.978 0.05%, and 0.779 1.87% respectively. They are compared with MonteCarlo simulations and the differences for the field sizes of 5cm 5cm and 1cm 1cm are 0.06% and 1.4% respectively. Regarding the independence of the EBT3 with beam energy, the average of differences between the 5cm depth curve are 1.7% for the 1.5cm depth and 1.8% for the 10cm depth. The 5cm depth curve is taken as reference because is the calibration depth for the LINAC. In particular, for the 2Gy point the differences are 0.42% for the 1.5cm depth and 1.00% for the 10cm depth. Finally the values of the percentage of the dose at the surface (PDS) normalized at 5cm depth are presented in the next table

$FieldSize(cm \times cm)$10 × 105 × 51 × 1
PDS26.1 ± 1.321.3 ± 2.420.2 ± 2.6

It is also founded that for low doses (lower than 0.5Gy) the RF are less precise (differences up to 88% were founded). As it was expected the uncertainties increases as the field sizes diminishes. It is important to emphasize that the percentage doses founded here are at 135μm of depth, because this is the depth of the active layer of the EBT3 RF.

Conclusions

The EBT3 RF are suitable detectors for surface measurements. They are also a good candidates to use clinically because in common therapeutic doses they show an acceptable uncertainty. This study is part of an in vivo dosimetry protocol for a radiotherapy facility. Further studies need to be done to determine if EBT3 are good detectors to do in vivo dosimetry and design a protocol based in this detectors.

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Influence of detector specific correction factors in dose distributions for small photon beams

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Introduction
The problems related to the dosimetry of small photon radiotherapy beams are highlighted in the literature (Das 2008). To perform the dosimetry of such beams, the detectors employed with more frequency are silicon diodes. Nerveless, these detectors over-respond in non-equilibrium conditions. For that reason, it is necessary to apply correction factors according with the new formalism for small photon beam dosimetry. Particularly, the interest of this work is the application of the correction factors to depth and off-axis dose curves. The goal of this work was to assess the influence of theses correction factors in clinical dose distributions.

Material and Methods This study was divided in three steps: i) the collection of dosimetric data for circular collimators using a silicon diode (model SFD, IBA-Dosimetry, Germany), ii) the Monte Carlo calculation of depth and off-axis correction factors, and iii) the incorporation of the commissioning data sets into the planning system (iPlan RT 4.1, BrainLAB, Germany). The dosimetric measurements were performed in a Novalis® linac (BrainLAB, Germany) with nominal energy of 6 MV. For calculating of correction factors the Monte Carlo codes used were DOSXYZnrc and DOSRZnrC. The parameters used for the simulation Novalis were: 6.1 Mev monoenergetic with a circular symmetric Gaussian FWHM for 1.5 mm. The correction factors were calculated based in formalism proposed by Alfonso et al, and Francescon et al. to the total scatter factors (TSF), tissue phanom- ratios (TPR) and off-axis ratios (OAR). Finally, a clinical treatment plan was simulated based on an arbitrary patient head. The calculated dose distributions in the treatment planning system was compared and analyzed as following: a) measured data sets and Monte Carlo calculations, b) dose distributions analysis with and without corrections factors and finally c) monitor unit (MU) analysis.

Results The correction factors calculated in this work show a similar behavior to those reported in the literature, a quantitative comparison was not possible because there are no data reported for the accelerator and detector used in this work. The comparison of measured data sets and Monte Carlo calculations was done by an analysis of percentage differences for TSF and TPR. Particularly for OAR, a gamma index 1D analysis was made and a full width at half maximum (FWHM), the 80%–20% penumbrae and 90%–10% beam penumbrae comparison. All results of these data sets show no significant differences. For dose distributions, the gamma index analysis criteria employed 1%/1mm, 1%/3mm, 1%/5mm, 2%/2mm, 2%/3mm and 3%/3 mm. In all case except in 1%/1mm, the gamma index analysis show that 100% of the points meet the established criteria. Finally, the results of MU show a percentage difference up to 6%. The UM analysis shown the biggest differences found in this study.

Conclusions The new formalism for small photon beam established the necessary correct the response with a detector specific beam correction factors. In this work, evaluation of the influence of theses correction factors in dose distribution was performed. The biggest percentage difference was to MU. The rest of the analysis show no significant differences for the calculation dose distributions with and without correction factors. Therefore, these results suggest that the correction factors have influence on the TSF.

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Establishment of National Radiotherapy audit program at NMISA.

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Introduction Morden radiotherapy treatment of cancer involves different modalities. Some of these modalities have limited number of referral literatures. These modalities include advanced treatment like IMRT, Stereotactic, RapidArc, Gamma knife etc. Radiotherapy dosimetry audits play an important role in verifying the treatment chain of all these techniques. The National Metrology Institute of South Africa (NMISA) has embarked on establishing a national audit programme for radiotherapy. Five pilot centres were identified for performing on site audit measurements with procedures and protocols drafted and tested during measurements. For postal dosimetry audits, a Dose Ace system using radiophotoluminescent (RPL) glass dosimeters has been purchased by NMISA. This system will replace the Thermoluminescent dosimetry (TLD) system currently used by IAEA/WHO for audits.
Methodology On site Audit measurements were carried out for reference conditions, non-reference conditions and end to end using a CIRS phantom. For reference conditions, the IAEA TRS 398 protocol for absorbed dose to water was followed. Measurement were carried out using a Farmer type chamber for photons and an Advanced Markus chamber for electrons. A water phantom was used for photon beam measurements and a Perspex phantom for electron. Non-reference measurements were carried out for Wedge factors and Output factors. The auditing procedure for end to end entailed using a CIRS thorax phantom. The phantom was scanned using a CT scanner on site and data transferred to the treatment planning system (TPS) for verification. The planning staff were requested to create a plan per procedure provided and plan was transferred to treatment system upon completion. Staff members responsible for treatment were requested to execute the plan using the CIRS phantom. Farmer type ionization chamber was placed on different positions and the delivered dose was measured and compared with measured dose from TPS.
Results The action limits for reference conditions was 2% and for non-reference conditions it was 3%. For reference conditions measured doses were within 2% and for end to end dosimetry audit the maximum deviation was observed on areas with low electron density. However total contribution to a selected reference point was within 5% for most pilot centres. Commissioning of the RPL glass dosimeter system is still an ongoing project and the results will be presented in the conference.
Conclusions The establishment of onsite dose audit methodology for radiotherapy centres in South Africa using the ionization chamber was successful. All protocols were drafted and tested for consistency and reproducibility. Some of the challenges encountered during pilot study was the breakdown of the units, unwilling cooperation from some staff members and less understanding of the objectives of dosimetry audit by some staff members. A steering committee consisting of representatives from Oncologists, Radiation Therapists, Medical Physicists and regulatory has been formed. They regularly meet to discuss the progress for the establishment of the project and evaluate the procedures. They will also be responsible for any unresolved discrepancies in measurement results.

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Novel hybrid pixel detector design for the use in continuous on-line dose monitoring in radiotherapy.

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The description of the design of a lower resolution hybrid silicon pixel detector, designed specifically for the purpose of continuous spatial on-line dose monitoring during the whole treatment.

Accreditation of medical physics clinical training programmes in Africa: survey by the Federation of African Medical Physics Organizations (FAMPO) and the International Atomic Energy Agency (IAEA)

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Introduction: Accreditation of clinical medical physics training programmes is necessary to promote consistent quality training and to ensure conformance to a defined standard. The Federation of African Medical Physics Organizations (FAMPO), as the Africa Chapter of the International Organization for Medical Physics (IOMP), plays an essential role in the recognition and promotion of medical physics practice, education and training in the continent. Through Task Force Meetings organized by the International Atomic Energy Agency (IAEA) through the African Regional Agreement (AFRA), four publications on Education and Training of Medical Physicists in Africa were produced and endorsed by FAMPO. The publications were intended to harmonize the standard of academic education and clinical training of medical physicists in the region. A self assessment questionnaire prepared by FAMPO and the IAEA, was distributed in the region to assess the willingness of centres to provide accredited clinical training of radiation oncology medical physicists.

Methodology: A questionnaire was developed which focussed on the ability of a radiation oncology centre to competently undertake clinical medical physics training. The questionnaire contained eighty questions pertaining to as staffing levels, availability of equipment, levels of technology and medical physics procedures. The questionnaire was prepared using Google Forms in the English and French languages and distributed online to clinical medical physicists across Africa. Responses received were analyzed statistically. Centres which were identified to meet a set requirement by the Education and Training Committee (ETC) of FAMPO, were recommended to the Professional Development Committee (PDC) for full or partial accreditation.

Results: Twenty-six responses to the questionnaire were received, of which two failed the inclusion criteria and were rejected in the subsequent analysis. The twenty-four qualified entries were received from Algeria, Egypt, Ethiopia, Ghana, Mauritania, Morocco, Nigeria, Sudan, Tunisia and Zimbabwe. Fifty-eight percent (58%) of these countries are Anglophone and 42% are Francophone. Egypt had the most number of entries with responses from six radiation oncology medical physics centres. Ninety-two percent (92%) of the qualified entries had practicing clinically qualified medical physicists (CQMP) with a minimum of 5 years hospital-based independent practice experience. Eighty-eight percent (88%) of the radiation oncology centres analyzed in the study had a license to treat patients, with 83% having a comprehensive programme of quality assurance for medical exposures in all aspects of radiotherapy. Most of the entries had non-IAEA reference materials available to medical physics residents in their centres.

Varying responses were received on the availability and functionality of facilities such as immobi- lization devices, mould room equipment, conventional and fluoroscopic radiotherapy simulation, Computed Tomography (CT)-based 3D treatment planning systems, cobalt-60 teletherapy units, linear accelerators, kilovoltage therapy units, and low and high dose rate brachytherapy units, for the clinical training of medical physics residents. CT and MRI were identified to be the equipment predominantly used for pre-treatment imaging in the centres. The centres were identified to have a varying number of resident radiation oncologists, medical physicists and radiotherapists. More than 85% of the centres were found to have ion chambers, electrometers, thermometers, barometers, survey meters and water phantoms for dosimetry measurements. Forty-two percent (42%) of the centres have access to a CIRS phantom and 75% have diodes or a TLD system for in-vivo dosimetry. All respondents have radiation protection systems in place at their radiation oncology centres, with 96% indicating availability of a national regulatory framework in radiation protection. Varying responses were provided to the

availability of procedures for fetal dose evaluation, I-131 therapy, personnel dose monitoring, reporting of incidents and near accidents, risk assessment, and internal and external audits. Seventy-five percent (75%) of the centres have written procedures to ensure patient confidentiality, practice regular multidisciplinary meetings and hold regular QA meetings. All of the twenty-four centres declared an interest in being either fully or partially accredited by FAMPO to undertake clinical training of medical physics residents. Full accreditation implied that all radiotherapy modalities (i.e. cobalt-60 teletherapy, linear accelerator, kilovoltage therapy, and low and high dose rate brachytherapy) were available. Seventeen percent (17%) of the respondents were interested in being offered full accreditation. In addition, sets of questions centering on the available equipment, clinical procedures and medical physics procedures were also fielded. The medical physics procedures covered performance of acceptance testing, commissioning, quality assurance, calibration, treatment recording and reporting, dose verification, radiation safety, emergency procedures, etc. Responses provided to the sets of questions were analyzed by the ETC and approximately 50% of the entries were forwarded to the PDC of FAMPO for further processing.

Conclusion: Instituting accredited medical physics clinical training programmes in Africa by FAMPO would go a long way to improve the quantity and quality of trained personnel who would readily be in position to practice competently and independently, and contribute to improved radiation oncology treatment delivery.

Treatment options in resource sparing setting for post-prostatectomy salvage radiotherapy: biochemical nadir and toxicity results from a non-randomized observational study

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Background: Limited information is available for hypofractionated radiotherapy after prostate- ctomy. We aimed to compare hypofractionated and conventionally fractionated radiotherapy regimens in salvage setting for biochemically recurrent prostate cancer after previous prostatec- tomy and record acute and late toxicity results.

Methods: A retrospective analysis was performed in a total of 112 patients with proven PSA recurrence treated with radiotherapy to the prostate bed. Patients were non-randomly, in an alternating fashion, subjected to either 52.5 Gy in 20 fractions of 2.625 Gy over 4 weeks (N=60, hypofractionated group) or 66 Gy in 33 fractions of 2 Gy over 6.5 weeks (N=52, conventionally fractionated group). There was no statistically significant difference in pathologic T-stage and Gleason score distribution between the groups. In the conventionally fractionated group there were more patients with positive margins (p=0.01), more prevalent concomitant hormonal therapy (51.9% vs 62.2%, p=0.001), but less long-term hormonal therapy (20% vs 84%, p<0.001), compared to the hypofractionated arm. Median follow-up was 22 months (range 6-38 months). Treatment failure was defined as biochemical PSA nadir + 0.2. Failure rates between the groups were compared using Cox proportional hazards model. Acute genitourinary and gastrointestinal toxic effects were scored according to RTOG scoring scale from case report forms and patients' self-assessment questionnaires, at baseline, twice during radiotherapy, 3 months and 12 months after completion of radiotherapy.

Results: At this early point, 15 patients (25%), and 7 patients (13%) experienced biochemical treatment failure in the hypofractionated group and conventionally fractionated group, respectively (HR 3.3, 95%CI (1.1-6.1). Due to the different fractionation regimes the dose volume histograms (DVH) have been analyzed in both arms. In the hypofractionated arm the following objectives were followed: bladder V40<80%, V48<50%; rectum V24<80%, V32<70%, V40<60%, V48<50%, V52.5<30%, and in the conventionally fractionated group: bladder V65<50%; rectum V50<50%, V60<35%, V65<25%. There were no difference in acute toxicity outcomes and no correlation between results of the DVH analysis and recorded side effects in both groups. More late grade 2 gastrointestinal and genitourinary side-effects were observed in the conventionally fractionated arm. No grade 3 toxicities were observed.

Conclusion: A higher rate of biochemical failures was observed in the hypofractionated regimen compared to the conventionally fractionated regimen (non-significant; p=0.1), in salvage radio-therapy of biochemical failure following prostatectomy, despite a higher proportion of patients with positive margins in the latter group. Baseline heterogeneity between the groups and short follow-up preclude any causal conclusions of differential efficacy between these two schedules. Both

radiotherapy regimes had similar grade 2 acute and late genitourinary and gastrointestinal toxicities. We plan to conduct a randomized phase II trial to prospectively compare these two regimens controlling for possible confounders.

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Workshop summary - Design characteristics of novel radiotherapy technology for challenging environments: improving access to radiotherapy

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Many low-to-middle income countries (LMICs) suffer from a debilitating lack of radiotherapy. This problem will only be exacerbated with the increase in cancer incidence expected in these nations. The Global Task Force on Radiotherapy for Cancer Control, a Commission of the Lancet Oncology, estimated 12 600 megavoltage treatment machines are needed to meet the radiotherapy demands in LMICs by 2035. Limiting factors to the development and implementation of radiotherapy in lower resourced nations include cost of equipment and infrastructure and the shortage of trained personnel to deliver high quality treatment. The Lancet report was one of several publications that discuss the need for radiotherapy in LMICs, however less frequent in the literature are insights into how these barriers can be overcome. CERN and the International Cancer Expert Corps will be hosting a workshop on November 7 and 8, 2016 to have a fulsome discussion on the needs for radiotherapy and possible solutions to conquer the challenges faced by LMICs.

The two day workshop will bring together a group of invited experts in radiation oncology, engineering, telecommunications, and particle accelerator technology to discuss the design requirements of linear accelerators and other technologies in LMICS. The 11 distinct sessions in the workshop explore all facets of issues faced by LMICs who want to include external beam radiotherapy as part of their cancer control strategy. The wide breath of topics include a descrip- tion of the global radiotherapy gap, reviewing past experiences of implementing radiotherapy into LMICs, understanding what technology requirements are essential for radiation treatments in low resourced environments, and exploring novel techniques to develop a skilled workforce. Advances in particle accelerators, designed to function in areas with limited infrastructure, will be presented by members of CERN followed by discussions on the practicalities around bringing innovations to these settings. Findings from the meeting will be summarized in a subsequent report – its contents will be the subject of this session.

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Accuracy in clinical small field data

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Introduction

Developments in radiotherapy have contributed to an increase in the use of small fields. Small fields are used in stereotactic treatments and large uniform or non-uniform fields that are composed of small fields such as for intensity modulated radiation therapy (IMRT). There has been an increasing availability in the clinic of standard, mini and micro-multileaf collimators on conventional accelerators as well as the introduction of treatment units specifically designed for stereotaxy (GammaKnife, CyberKnife, Radiosurgery System) or intensity modulated treatments (TomoTherapy). There is therefore an increasing demand to characterize small fields in dosimetry more accurately.

There is currently no published international Code of Practice (CoP) for small field dosimetry. There are guidance publications for absolute and non-reference dosimetry measurements e.g. IPEM 103. However, some clinics have been using extrapolated data from CoPs that were published to perform absolute dosimetry in much larger reference field sizes, typically 10 cm x 10 cm e.g. IAEA TRS 398.

In this study, we considered the accuracy with which clinical small field data could be obtained.

Methodology

Measurements were performed using an automated beam scanning system in linear accelerator and Co-60 beams. Different detectors were used to obtain the data and the results were compared. The manufacturer's engineering diagram was used to position the detectors at their reference point of measurement. Profiles of a range of small fields were measured in the in- and cross-plane directions to obtain the Full Width Half Maximum (FWHM) and to determine the exact position of the Central Axis (CAX) of the beam. A Farmer-type reference instrument, was used to cross-calibrate detectors in a 6 cm x 6 cm field size. Relative dose measurements were also obtained for the different detectors to determine the output factors. All the detectors that were used were waterproof.

The machines used were an MDS Nordion Equinox Co-60 unit and two Siemens Primus linear accelerators operated at 6 MV. The Co-60 unit was equipped with four standard independent jaws and is capable of a 1 cm x 1 cm smallest set field size. One accelerator was equipped with two standard independent collimators in one direction and an 82-leaf multileaf collimator (MLC) in the other.

The detectors used were: • Synthetic single crystal micro-diamond with a sensitive volume of 0.004 mm^3, Unshielded disk-shaped silicon diode detector with sensitive volume of 0.03 mm^3, 3-Dimensional cylindrical ion chamber with a vented sensitive volume of 0.016 cm^3, Semiflex Ionization Chambers with a vented sensitive volume of 0.125 cm3 and 0.07 cm3, Farmer type ionisation chamber, with a vented sensitive volume of 0.6 cm3. The data obtained from each detector was compared with its associated uncertainties.

Results

The engineering diagrams for detectors and the mechanical machine settings are not adequate to determine CAX within acceptable uncertainties. It is crucial that beams are scanned using a motorised water phantom to determine the FWHM and calculate the CAX from that data during each measurement set up for each detector. The collimator settings contribute highly to the accuracy of measurements. A good understanding of the MLC design and limitations in the calibration methodology is crucial in order to determine the correct CAX.

There were challenges with positioning detectors in solid phantoms, particularly in a parallel orientation. The ability to precisely position and verify the detector position at its reference point was not possible using film or electronic portal imaging.

Each correction factor contributes to the overall uncertainty of measurements performed using that detector. The more correction factors and the higher the value, the higher the risk of decreased accuracy in the measurements performed using that detector.

Conclusion

The accuracy of the clinical beam data is both dependent on the equipment used and vigilance during measurements. It is crucial that those adopting to use small field dosimetry select and

characterise their detectors before they use them for clinical dosimetry. The design of the machine and whether the planning system to be used with that machine will be able to support the small field treatment techniques must be established before commissioning. It is critical that medical physicists are trained to understand the nuances of small field dosimetry and that data are validated through audit programmes before patients are treated. Accurate dosimetry in a solid phantom depends on the ability to visualise and verify the positioning of the chamber in the phantom in addition to the accurate mechanical set up of the machine.

Features of 18-FDG PET/CT application for recurrence detection, radiation therapy planning and its effectiveness monitoring in patients with tumors of the anorectal localization

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Background. Experience of 18f-FDG PET/CT clinical application confirms the usefulness of this imaging in oncology, namely: for the differential diagnosis, staging before surgery or radiation therapy, restaging after treatment. Also 18-FDG PET/CT showed high sensitivity for the efficacy monitoring of chemotherapy and radiotherapy. The numerous studies on the use of 18-of FDG PET/CT images for further dynamic control and radiotherapy planning proved higher results' accuracy of systemic and loco-regional staging compared with conventional CT and MRI techniques. It was found that the macroscopic tumor volume determined by PET/CT is statistically significantly larger in the CT MPO with mean difference of 25%.

Materials and methods. Between 11/2011 and 01/2016 the 18 FDG PET/CT was performed in 277 patients with colorectal cancer. Of them men were 154, women - 123; patients age was from 24 to 82 years. In overall 388 examinations were performed in 277 patients, including 94 without contrast and 294 with contrast. Average activity per injection was 373.98 MBq; in men - 402.75 MBq, in women - 332.62 MBq. We used Cyclotron Siemens Eclipse RDS for obtaining radiopharmaceuticals 18-FDG; and PET/CT Scanner Siemens Biograph 64.

Results. Functional 18-FDG PET/CT images were used during planning of radiotherapy for rectum and anal canal carcinomas (Fig. 1). It is found that the PET/CT by sensitivity and specificity is more informative compared with conventional structural imaging techniques. Mean sensitivity and specificity of 18-FDG PET/CT for the main focus were 83% and 91%, respectively, while the corresponding indices for the basic CT method were respectively 64% and 74%. The sensitivity of lymph node involvement evaluation using CT method was 65% and PET/CT - 53%. It should also be taken into account the risks of false-negative results of PET/CT for lesions in the lungs less than 1.0 cm, small lesions in the upper sections of liver, located predominantly subcapsularly, and in histological tumor type - mucinous adenocarcinoma. It was found that applying PET/CT for staging caused changes of the treatment tactics in 55.4% of patients, of them in 15 – due to higher disease stage, and in 5 - scheduled surgery was not performed.

Fig. 1. Planning of radiotherapy for rectum and anal canal carcinomas.

Conclusions. 1. It was found that the 18 FDG PET/CT method possesses significant advantages concerning the disease recurrence detection and restaging in the cases when CT and MRI data are inconclusive. 2. It was proved that by sensitivity and specificity the PET/CT method is more informative for planning radiotherapy compared with conventional structural imaging techniques.

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The role of low dose rate brachytherapy for carcinoma of the cervix at Zaria, Nigeria

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Introduction: This is a retrospective study at the Radiotherapy and Oncology Centre, Ahmadu Bello University Teaching Hospital, Zaria, Nigeria using Low Dose Rate (LDR) remote after- loading brachytherapy for the treatment of carcinoma of the uterine cervix. This is a resource poor setting with patients usually presenting with advanced stages of cervical cancers. Factors supporting the existing LDR brachytherapy at Zaria include ease of application, economic consideration, waste management and radiation protection.

Methodology: From October 1995 to September 2015, four hundred and ten (410) patients with histologically confirmed carcinoma of the cervix were treated. The patients were staged according to FIGO staging system following clinical examinations and investigative work-up. The treatment was by intracavitory insertion using Caesium-137 radioisotope with Delouche type or Vaginal cylinder applicators after external beam radiation. 85% of the patients presented at advanced stages of their diseases. A single fraction of 20-25 Gy to Manchester Point A or surface of the cylinder was prescribed. Bladder and Rectal doses were not recorded during the applications. The patients were analysed for local control and late radiation complications.

Results: The median follow-up was 70 months (12 to 240 months). The overall local control achieved was 65%. The overall vesico-vaginal fistulae recorded was 20% and recto-vaginal fistulae was 15%.

Conclusion: The LDR brachytherapy is a useful component and retains a significant role in the treatment of cervical cancer in a resource poor setting. The bladder and rectum should be properly displaced during brachytherapy. No need for source exchange since installation of equipment but weekly QA checks done. Equipment down times and excessive industrial unrest in the health sector were responsible for the number of patients treated during the period. Treatment interruption was responsible for the longer period patient spent for treatment and the treatment interruption chart developed by our centre is useful.

Evaluation of treatment planning systems using in-house software "Eat Pie"

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Introducion: Usually, neither treatment planning systems (TPS) nor water phantom related software is capable of comparing measured and calculated data by means of dose difference or gamma index. Microsoft Excel is an option, but for a large amount of data analysis can become quite cumbersome. For this reson we created a software called "Eclipse Analysis Tool with Pinnacle Extension" (EAT PiE)

Methodology: Using Python 3.4 and QT 4, we created a software which is able to read profile data (percentage depth dose (PDD) and profiles) from Varian Eclipse 11 and 13, Philips Pinnacle 9.8 and the PTW Freiburg Mephisto water phantom software. Those curves can be compared among each other by means of dose difference and gamma index, respectively.

Results: We found good agreement between Eclipse calculated data and measured data using 1mm/1% and 2mm/2% local gamma criteria. We found good agreement between Eclipse calculated data and Pinnacle calculated data using 1mm/1% and 2mm/2% local gamma criteria We now have the possibility to compare different algorithms (e.g. AAA, Acuros XB, Pinnacle Adaptive Convolve) in a water phantom or from real patient calculations as well as different detector types

Conclusion: EAT PiE can help evaluating and commissioning a Treatment Planning System, new algorithms or new versions of an existing system. It can also be a useful tool in plan comparisons among different treatment planning systems or different algorithms in one planning system. Even measurements with different types of detectors can be compared using the gamma index method and dose difference analysis.

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Accessibility of radiotherapy in 16 asian countries: current update on the existing scenario

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Introduction of the Study: Despite being home to about 60% of the world's population, an estimate of only 27% of the world's radiotherapy facilities are found in Asia. Radiotherapy is an essential part of the treatment of cancer. It is estimated that for every 1,000 new cancer patients, about 60% should receive radiotherapy as part of their treatment, out of which 23% would require a second course. Radiotherapy for cure or palliation has been shown to be cost effective. Many countries in Asia have limited access to radiotherapy, while there are some countries with no service at all.

Methodology: A survey was conducted among 16 Asian countries in September of 2016. The responder was either a radiation oncologist or a medical physicist. They were asked questions pertaining to the current radiotherapy setup in their respective country. The following data were collected: (1) number of megavoltage machines (cobalt or linear accelerator) (2) number of existing radiotherapy personnel (radiation oncologist, medical physicist and radiation technologist) and (3) current healthcare payment system specifically for radiotherapy.

Result: In this survey, in 16 countries with available data, 1,011 megavoltage machines (cobalt or linear accelerator) were available for an estimated demand of nearly 2,300 machines. These countries have difficulty in meeting the staff requirements for a radiotherapy clinic as well, with a shortfall in radiation oncologists, medical physicists and radiation technologists. Also many of these countries do not have local health insurance supported by the government and patients pay mainly out-of-pocket.

Conclusion: Strategies for the development of radiotherapy services and substantial investment for staffing, training and equipment are still needed for many of these countries in Asia.

Comparison of points and volumetric doses using CT and MR images for 3D planning brachytherapy: A Brazilian experience

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Introduction Uterine cervix cancer, one of the most common tumors in the female population worldwide, is where brachytherapy plays a major role for local control and survival of these patients. Due the high dose-gradient of brachytherapy, it is possible to achieve the major challenge in radiation therapy to treat lesions with a high effective dose, while minimizing the dose in adjacent normal tissue or organs at risk (OAR). Image-guided (IGBT) or 3D gynaecological brachytherapy, that uses plans based on computed tomography or magnetic resonance has the potential to improve local control and survival in these patients, since it is possible evaluate the dose volume and then optimize the cost-benefit ratio between dose at tumor and organs at risk. **Materials and Methods** Alternated magnetic resonance images (MRI)and computed tomographies (CT)were performed for 12 patients that were treated for cervix cancer with 2D planning brachytherapy from April to September of 2010 using ring and tandemCT/MRI compatible applicator Nucletron R . Totally, 23 CT and 22 MR acquisitions were made after the insertion and fixation of the applicator in a specific support. The patients were then immobilized with the applicators in place in a vac-fix. For treatment, bladder was fulfilled with 50 cm3 of saline solution and a urinary catheter with a balloon with 5 cm3 of saline solution and 2 cm3 of contrast solution. 3D plans were performed on TPS OncentraMasterPlanNucletron R , using TC and MR images and applicatorsreconstruction were based on applicators library and prescription dose was 7 Gy at point A. However, this system was not commissioned at the beginning of this work, in such a way that all patients were treated with 2D planning performed on TPS Plato Nucletron R . The 2D evaluation points, ICRU points (ICRU 38, 1999), bladder (ICRUBladder) and rectum (ICRURectum), and sigmoid point (Sig) (Guimarães, et al, 2009) were added in 3D images in order to compare to a dose volume in each organ at risk (OAR). The volumetric comparison was made for 0.1 cm3 (D0.1cc) and 2 cm3 (D2cc) (Pötter, et al, 2006).

Results The data analysis showed that CT and MRI based plans were statistically equal when comparing dose delivered to OAR´s, so the comparison was made using all data. Table 1 presents the results of the comparison of points and volumes doses.

Table 1: Comparison of points and volumetric doses for OAR´s in CT and MRI based plans. The dose delivered to points in 2D plans was different from the volumetric dose in the OAR´s ($p<0.05$). The bladder point received dose lower than the volumetric dose for this specific organ, because when fulfilled, the bladder falls over the applicator in a high dose region while the vesical balloon stays in a low dose region. Even if the bladder point doesnot estimate the volumetric dose, it is still important to use this point when 2Dplans are performed in order to try to decrease the dose delivered to the bladder. The dose delivered to the rectum point was higher than the dose delivered to 0.1cc and lower than dose delivered to 2 cc, probably due to the fact that the rectum is an organ with less mobility. Therefore the rectum point is more representative of volume dose. The sigmoid is an organ with high mobility and the sigmoid dose point did not correspond to the volumetric dose for the organ.

Conclusion 3D plans based on CT or MRIfor brachytherapy can help to spare OAR. In terms of OAR´s dose evaluation, the use of CT or MR showed to be equivalent. As consequence, both of them can be used to decrease volumetric dose at OAR´s. Since the points used in 2D plan did not show great correlation to volumetric dose, D0.1cc and D2cc respectively, the implementation of a 3D planning for brachytherapy seems to be very promising in order to improve gynecological brachytherapy treatment.

Session 8 - Education and training **/** 100

Competency based education and training in radiation oncology

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Introduction: As in any field, errors happen in radiation oncology despite our best efforts to prevent them. It is well known, and well documented, that appropriate, adequate training can reduce the likelihood of errors.. The World Health Organization (WHO) published the manual Radiotherapy Risk Profile in 2008 and in this manual it lists competency assessment as one of the top three interventions that is likely to be an effective safety barrier. But what is competence? Competence is the ability to do something successfully and efficiently. Hence, competency based education and training must offer comprehensive training as well as be able to determine whether an individual can successfully complete a task independently and do so in an efficient manner. Radiation oncology is a technology centered specialty that is continuously evolving and requires continued education and training to stay up to date with current technology, improved techniques, and/or to increase efficiency as well as improve overall safety.

Methodology: An online system was setup in order to establish specific training modules and track users' progress throughout their competency development. Various media was used to convey information to users such as text files, presentation slides, and videos. Additionally, certain modules included quizzes based on educational material as well as assigned clinical observations where an individual would be followed and assessed in the clinic for a particular procedure. To test which media was most effective at communicating information, members of the department of radiation oncology was randomly assigned to 1 of two groups. Each group was assigned a general radiation safety module, where one group's assignment was text/slide based and the other group's assignment was video based. Each group had the same quiz administered after the content was reviewed. Additionally, brachytherapy modules were given to new medical physics residents with no prior brachytherapy experience. Program compliance and overall assessment was measured and residents were surveyed about the program.

Results: The online system was deployed in the department with various module assignments given to specific groups. Various metrics were measured including program compliance, individual assessment after the program (competence), and survey feedback from users and will also be discussed.

Conclusion: An online competency based education system utilizing multimedia content, along with hands on assessment, is an efficient and effective tool to implement in radiation oncology.

Session 14a - Imaging for planning and treatment delivery in External Beam Radio- therapy - Part 2 **/** 101

Digital portal imaging in Cobalt-60 radiation therapy

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Introduction: Prior to the introduction of on-board kilovoltage X-ray imaging, portal imaging (that is, radio- graphic imaging with the megavoltage (MV) treatment beam) was the most effective way to verify the patient's position for external beam radiation therapy. Portal imaging began with film based detectors and evolved to digital detectors known commonly as electronic portal imaging detectors (EPIDs). While the use of EPID based portal imaging has diminished somewhat in modern radiotherapy delivered on kV imaging equipped linear accelerators, MV portal imaging continues to play an important role since it directly relates the treatment beam geometry to the patient boney anatomy. Cobalt-60 (Co-60) therapy machines (which are still in widespread use in many parts of the world, due to their simplicity, reliability and relatively low cost) are generally not equipped for digital portal imaging. In this work, we show that the Co 60 unit's large source size and high energy are not insurmountable obstacles to effective digital portal imaging. An amorphous silicon EPID whose output is sharpened and histogram-equalized, produces Co 60 digital portal images that clearly show the necessary bony anatomy in the pelvic, thoracic and cranial regions. These results suggest a simple EPID-based workflow for treatment verification that is compatible with conventional x-ray simulation for treatment planning.

Methods: The experimental setup comprised of a Theratron 780C cobalt-60 irradiator (BEST Theratonics, Kanata, ON) equipped with amorphous silicon EPIDs mounted on a free-standing cart. The EPID was either a XRD1640 panel (Perkin Elmer Optoelectronics, Fremont, CA) or an aSi500 unit (Varian Medical Systems Palo Alto, CA). The phantoms to be imaged were mounted on a 3-axis computer controlled positioning stage. The phantom and the panel were positioned at various source to axis/source to detector distances to investigate effects of imaging geometry. Specifically, SAD/SDD was set at 80/100, 80/120, 100/125 and 100/140 (dimensions in cm). The frame integration time for EPID acquisition was 133ms for the XRD1640 experiments (100ms for aSi500 runs) and 4 frames were averaged for each image. The phantoms imaged were the anthropomorphic CIRS 801-P pelvis (CIRS, Norfolk, VA) and SBU-4 (Kyoto Scientific Specimens). These phantoms are designed to be representative of natural human anatomy.

Raw images from the EPID required post-processing to yield viewable images of acceptable quality. Image processing was done using in-house software written in MATLAB (Mathworks, Natick, MA). Global contrast adjustments (window and level) were found to be important, but not always sufficient, for extracting useful images from the raw EPID data. Additional techniques, such as iterative deconvolution and contrast-limited adaptive histogram equalization (CLAHE) were used to enhance images. For comparison, some images were also taken on a Varian 6MV linear accelerator with a built-in aSi500 panel.

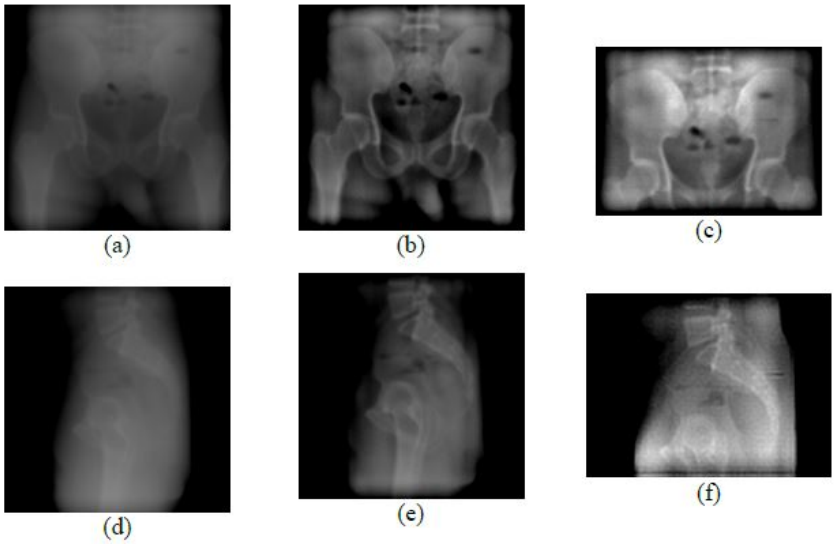

Figure 1: AP and LAT images of the CIRS 801-P pelvic anthropomorphic phantom taken at SAD 100 and SDD 140 cm. **(a), (d)** Raw Co-60 portal with XRD1640. **(b), (e)** Co-60 portal with XRD1640, enhanced. **(c), (f)** Co-60 portal with aSi500, enhanced.

Results: Qualitatively, it was found that the post-processed Co-60 images were comparable to the ones obtained with the 6MV portal imager and that they are sufficient to identify bony anatomy. Deconvolution sharpening increased image quality as determined by measured point spread func- tions. CLAHE processing improved local contrast, thus overcoming the two main disadvantages one would expect of imaging using the Co 60 source.

Conclusions: These results suggest that portal imaging in the treatment beam of a cobalt 60 unit, using modern amorphous silicon EPIDs, is possible and potentially useful. With some post-processing to enhance sharpness and contrast, the image quality achievable with the Co-60 system approaches that of a 6 MV linear accelerator's portal imager, and is adequate to identify key parts of the bony anatomy relative to the treatment beam.

It is not necessary to have a fully integrated, gantry-mounted EPID system to achieve some of the benefits of portal imaging. An independent EPID mounted on a mobile stand would be sufficient to produce portal images and double-exposure fields like those shown here. The only electrical interface required between the EPID and the Co-60 unit would be a source-out synchronization pulse.

Characterization of a Cobalt-60 radiotherapy unit upgrade: BEST Theratronics T780C to Equinox100

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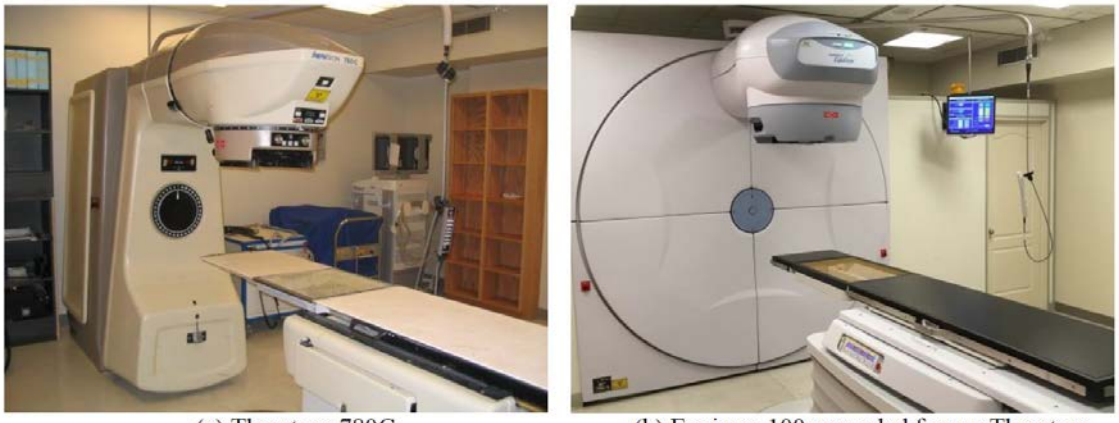
Introduction: We have been investigating Cobalt-60 (Co60) based radiation treatment for some time through measurements on a Theratron 780C (T780C) Co60 teletherapy unit (Best Theratronics, Kanata, ON, Canada) installed at the Cancer Centre of Southeastern Ontario. Purpose built equipment was added to the unit to emulate serial tomotherapy dose delivery and enable imaging with electronic portal imaging devices. The research was complemented by Monte Carlo simulations. Results clearly indicated that modern radiation delivery is achievable using a Co60 source. In the past year our T780C unit has been upgraded by Best Theratronics to an Equinox External Beam Therapy System (Equinox100). This is the first full upgrade of an existing T780C unit into an advanced



(a) Theratron 780C (b) Equinox-100 upgraded from a Theratron 780C

Figure 1: Original and upgraded Cobalt-60 radiotherapy units at the CCSEO.

computerised Co60 unit (see Figure 1). The upgraded unit has an increased source-to-axis distance of 100 cm (previously 80 cm), new beam collimation and motion control, a motorized 60˚ wedge, and a new Avanza Patient Positioning Table (couch). The Equinox upgrade allows the unit to be equipped with a DICOM-RT compatible multi-leaf collimator (MLC), which is being incorporated into the unit. The MLC will enhance the unit's three dimensional conformal radiotherapy capabilities and provide the potential for intensity modulated dose deliveries on the unit. At installation, the upgraded unit passed all acceptance tests specified by Best Theratronics for a new Equinox100 unit. In this paper we present the results of further commissioning tests performed to assess the upgraded unit's readiness for clinical use.

Methods: The commissioning of the upgraded Equinox100 unit closely followed the process and procedures used for clinical linear accelerators at our centre. Steps included testing of mechanical and radiation beam/dosimetric parameters of the system critical to accurate treatment delivery. Mechanical testing included evaluation of the accuracy of optical distance and field size indicators along with couch position and gantry, collimator, and couch angle readouts. Couch deflection was measured with a distributed load of 75 kg. Comparisons of gantry, collimator and couch mechanical and radiation isocentres were performed using EBT3 Gafchromic film (Ashland Specialty Ingredients, Bridgewater, NJ, USA). Radiochromic film was also used to evaluate the coincidence of radiation and light fields.

Percent depth dose for different field sizes and in-plane and cross-plane dose profiles at multiple depths were measured using an ion chamber in a Blue Phantom2 water tank (IBA Dosimetry GmbH, Schwarzenbruck, Germany). Dose profiles were also recorded with the 60˚ wedge in place.

Relative dose factors (RDF) were determined at depths of 0.5 cm and 5 cm. All measurements were repeated for the relevant range of square fields (3x3 cm2 to 40x40 cm2). Additional data is being

acquired to commission the unit in the Eclipse external beam treatment planning system (Varian Medical Systems, Palo Alto, CA, USA).

Results: Optical Distance Indicator (ODI) readings were in agreement with mechanical measurements within tolerances of 1mm at 80 cm and 100 cm and 4 mm at 120 cm. Field size readouts were found to be accurate to within 1 mm for all field sizes. Light and radiation fields were found to be coincident within 2 mm for 5x5, 10x10 and 20x20 cm2 fields. At all positions, couch, collimator and gantry angle readouts were found to be accurate within 0.5° . Couch positioning was accurate to within 1 mm over a range of 20 cm from isocentre in all three directions. A distributed load of 75 kg produced a maximum couch deflection of 8 mm. Radiochromic film measurements showed radiation isocentre sizes of 0.23 mm, 0.44 mm and 0.05 mm for the gantry, collimator and couch systems, respectively. Radiation isocentre, indicated by starshot film measurements, to mechanical isocentre distances were measured as 0.56 mm, 0.70 mm and 0.19 mm for the gantry, collimator and couch systems, respectively. Measured percent depth dose curves showed good agreement with reference data published in the British Journal of Radiology Supplement 25. RDFs compared to the output at depth of maximum dose (0.5 cm) of a 10x10 cm2 field measured for the upgraded Equinox100 varied by less than 0.75% from the RDFs of the pre-upgrade T780C unit.

Conclusions: All tests indicate that performance from the upgraded T780C unit was equivalent to that expected from a newly installed Equinox100 unit. In all mechanical testing the upgraded Equinox100 met or exceeded the manufacturer's acceptance testing tolerances. Dosimetric measurement results show that the beam is identical to Co60 units referenced in medical physics literature as well as the pre-upgrade T780C unit. This confirms the expected advantage of Co60 radiation therapy: units have consistent well established radiation delivery properties. Current work is underway to extend measurements to MLC defined radiation beams on the Equinox100, incorporating and validating the upgraded Equinox100 in our Monte Carlo modelling, and evaluating various commercial treatment planning systems.

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Image comparison of 3 different known geometrical shapes contoured on different imaging modalities on a phantom for stereotactic frameless procedure of AVM

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Objective: To compare the accuracy of 3 different known geometry objects drawn on CT (Computed tomography), MR (Magnetic Resonance) and DSA (Digital subtraction Angiography) images on a phantom with stereotactic frameless mask on Brainlab iPlan RT Image contouring workstation.

Methods and material: A phantom study was done for images registration and contouring accuracy for SRS case of Arterio-Venous Malformation (AVM) treatment. Phantom was designed in such a way that it contains 3 different shapes; 1. Spherical plastic ball filled with water, 2. Egg shaped (ellipsoidal) gel ball, 3. Irregular electron p-orbital shaped (px, py, pz) structure made with olive oil capsule. All three different shapes material were chosen in such a way that all contains hydrogenous material which could be imaged in MR machine and at the same time DSA and CT images could also be acquired of the same material. DSA images were taken with two standard anterio-posterior and lateral pair. CT was taken with 1 mm slice thickness in Philips CT scanner, and MR was taken in sagittal section with 3 Tesla MRI machine (Philips). All images were imported in iPlan RT image (v 4.1.1) contouring workstation. CT images were localised using Brainlab head and neck localiser, afterward standard x-Ray pair were imported, localised with CT-Angio localiser and at last MR images were imported, fused with CT images. All the three imaging modalities CT, MR and x-Ray pair were fused and localised. Thus, contouring on any imaging modalities would reflect on other modalities also. All different objects were contoured independently on MRI, CT and DSA and their volumes were measured and noted. Afterward intersecting volumes between all three structures were measured by creating intersecting objects between images over all the 3 imaging modalities (CT, MRI and DSA). So total 9 single objects images and 9 intersecting images were generated and their volumes were calculated. The intersection volumes denoted the accuracy between two different imaging modalities that two volumes look like similar on both.

Result: It was found that standard x-Ray pair could not form irregular images, they were good for spherical and ellipsoidal objects but for irregular tumor they were providing only outer boundaries and the actual tumor could be drawn on 3-dimensional set of images obtained from MR and CT. The volume of spherical ball in CT, MR and DSA image were 37.4 cc, 30.9 cc, 32.9 cc respectively and the volumes of ellipsoidal ball were 62.4 cc, 57.2 cc, 51.6 cc respectively and volume of p-shaped orbital structure were 5.9 cc, 3.2 cc and 6.6 cc respectively. The intersection volumes between MR and CT for ellipsoidal, spherical and p-orbital shape were 56.8 cc, 30.7 cc, and 2.5 cc respectively. The intersection volume for MR and DSA images for ellipsoidal, spherical and p-orbital shape were 49.7 cc, 30.4 cc, 2.1 cc respectively. The intersection volume in CT and DSA for ellipsoidal, spherical and p-orbital shape was 51.4 cc, 32.9 cc, 3.7 cc respectively.

Conclusion: The study concluded that for contouring of irregular tumor on DSA will not give the precise picture of tumor, although it can provide an envelope around tumour which can further be contoured on MRI and CT imaging modalities more accurately.

Session 10a - Breast and Cervix **/** 105

Left breast radiation therapy - institutional analysis of doses to heart and LAD

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Background. Respiratory motions and free breathing during radiation therapy treatment of sites in the proximity of lungs, influence significantly on treatment of tumor volumes (in terms of sizes of PTV margins and also in possible under dosage of tumor volumes). It also influences the dose received by normal tissues surrounding the tumor volumes. This is particularly important in patients undergoing radiation therapy of the left breast, since these patients have long life expectancy in one hand, and on the other hand, the unintended irradiation of the heart and LAD artery, may cause later cardiac failure and other cardiac side effects. Since one of four cancer patients, in Serbia and its northern province of Vojvodina, in female population is suffering from the breast cancer, and approximately half of them are left breast patients, we have conducted retrospective analysis of treatment plans of patients treated in our center in 2007-2010. These patients will be examined by cardiologists in following 3 years, and their current status evaluated, and if necessary treated cardiologically in order to prevent cardiac failure or other cardiac problems. Another prospective study which follows in future months, will show how current practice in radiation therapy treatment planning is reflecting in the doses to critical organs, and this will be also presented to public. Another step which is planned to be conducted based on the results of the study, is to prepare protocol and implement the deep inspiration breath hold, for the left breast patients whenever possible, in order to exclude the critical structures from the treatment field. Methods and materials. The patients presented in this study were treated during 2009. Treatment was delivered by linear accelerators of Radiotherapy Clinic, Institute of oncology Vojvodina, Sremska Kamenica. The machines were manufactured by Varian Medical Systems, and accelerators are of series 2100C and 600 DBX. The treatment planning system used, was of manufacturer Elekta, XIO v 4.62. The treatment planning system was verified according to the IAEA recommendations, and machines are regularly calibrated, and checked biannually in IAEA TLD audits. There were in total 114 left breast patients in 2009, of which 92 could be successfully de-archived 7 years after treatment, and returned to treatment planning system, without any error during de-archiving procedure. Since at the time of treatment planning for these patients, in 2009, the LAD artery was not delineated, the radiation oncologists delineated LAD structure on de-archived plans as they could recognize it, or where it should be anatomically (if not visible), and re-delineated heart, according to current practice and protocols at the Institute. Accordingly, the treatment plans were re-calculated and reviewed by medical physicists, to obtain doses to these two new structures, and results noted. Results. The results of evaluation of radiation therapy treatment plans, of left breast patients, whose patient plans were generated during the period January 1st 2009-December 31st 2009 are presented. The patients were prescribed different therapeutic doses, from 50 Gy to 60 Gy, depending on the stage and type of illness. The dose range to the heart was maximum 62.4 Gy and minimum dose was 3.6 Gy, while mean dose to heart as whole organ was 3.9 Gy. The mean volume of the heart was 687 cm3. As for the left lung, the maximum dose found was 65.5 Gy, minimum dose 0 Gy, and mean dose 6.9 Gy. Left anterior descending artery (LAD), which was newly delineated, after the de-archiving of the treatment plans, has received a dose range of: maximum dose 62.1 Gy and minimum dose 0.2 Gy, while mean dose was 20.3 Gy. The volume of delineated LAD was 4.8 cm3. We did not record distances of the heart to the treatment field edge at this stage, which will be done in the next weeks. Discussion. Breast cancer is the most common cancer throughout the world female population. It is nowadays illness which can be treated successfully, and life expectancy is long after treatment. If a patient is treated in such a way that she is free of cancer after treatment, and another life threatening illness is caused by the treatment of primary disease, then the result of cancer treatment is practically annulled. The dose to the neighbouring tissues depend mainly on anatomical structure of the patient, but there are now techniques which can improve the outcome to heart, LAD and lungs, as the most affected

organs. This study will be continued, and these results are preliminary.

Age and insulin levels in breast cancer women and healthy women

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Introduction: Breast cancer is a common type of cancers among women; it is a heterogeneous disease lead to cause morbidity and mortality. Role of insulin in breast cancer etiology and prognosis has received attention. Insulin is an important hormone that controls blood sugar, fat and protein metabolism. Insulin release has reported to decrease with increasing age. However, age is considering the strongest risk factor for breast cancer after gender. Aim of this study to determine the age and serum insulin levels in breast cancer women and healthy women among Sudanese subjects.
Methods: 130 newly diagnosed breast cancer women selected randomly in age range between 20-80 years, and 109 normal women in same age range as control. Population study classified to six age groups as (20-29),(30-39),(40-49),(50-59),(60-69)and ≥ 70 years . Excluding criteria includes diabetes, hypertension, heart diseases, thyroid diseases and fertility disorders. Information from questionnaire for patients and control group include dietary habits and physical activity. Insulin level measured by using radioimmunoassay, the normal range of insulin serum level is 4.0-16.8 mIU/L.
Results: Insulin serum levels were normal in two age groups of (60-69) and 70 years for breast cancer patients. Elevation of insulin levels in breast cancer patients observed in age group of (20-29) years and decline seem to be constant in age groups of (30-39), (40-49) and (50- 59) years. All breast cancer patients were lake physical activity and low nutrients intake. Among control groups, the normal levels of insulin observed in two age groups of (20-29) and 70 years, insulin levels were normal in young women have physical activity and good nutrition. Women in old age 70 years have normal levels of insulin due to physiology of elderly such as menopause or b cell function. While, serum insulin levels elevated gradually in age groups of (30-39), (40-49) and (50- 59) years , and then decline in age group of (60-69)≥years, serum insulin levels were elevated with age increasing due to the nature of work, a lot of responsibilities and stress in these age stages. All these factors lead to low exercise activities and poor habits dietary. The mean levels of insulin among breast cancer women and healthy women explain in figure1. Figure 1: Insulin levels in different age groups among study population
Conclusion: Elevation of serum insulin levels observed in both breast cancer women and healthy women,these results not support that high serum insulin level is directly associated to breast cancer; further studies need to clarify whether cases of high insulin levels enhance cell proliferation and associated to breast cancer etiology. Constant of insulin levels in age range between 30- 59 years in newly diagnosis breast cancer that may link positively to hypoxia, and then after therapy the concentrations of insulin in blood circulation may increase significantly with acute hypoxia. This findings suggest that, future studies recommended to explain the association between hyperinsulinemia and hypoxia intermediated with nutrient agents like trace elements, especially those are affect insulin levels as chromium, zinc, copper and selenium, beside others minerals as iron. Pharmacology should be considered for hyperinsulinemia to improve outcome of radiotherapy for breast cancer patients, and to protect the women having high insulin levels from breast cancer development. Several factors may increase breast cancer risk by affecting insulin levels combined to lifestyle factors include lacking physical activity and poor nutrition. It is important to care with health in all ages of life.

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Clinical implementation from the regional (AFRA) training course on quality assurance of record and verify systems

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In equipping clinical medical physicists across the African Member States with both theoretical and practical information on the quality assurance (QA) procedure of records and verify systems (R&VSs), the International Atomic Energy Agency (IAEA) organized a regional (AFRA) training course. The main focus of the course was to equip participants to validate data integrity that will be followed for patients from the time of finalizing a treatment plan until just before and during treatment. The participants from Ghana and Kenya with similar radiotherapy setup carried out a joint comprehensive R&VS QA and an end-to-end test (i.e. from TPS to R&VS) after the course. A CIRS thorax phantom was CT scanned head first supine and imported into Oncentra MasterPlan Treatment Planning System (TPS). 3D treatment plans were generated to include different fields to test all relevant geometric settings of the treatment unit that are applied clinically. The approved plans were exported from the TPS and imported into MosaiQ R&VS. The plans were then transferred unto the Linac treatment console and treatment fields set up and checked. These checks were classified as general (demographic), geometric and dosimetric, and dose delivered error sections. The transfer of fundamental treatment parameters (e.g. energy, gantry angle, collimator angle, couch angle, field size, wedge, MU) were manually checked by comparing the data in the R&VS with TPS printouts prior to the treatment. The light field (e.g. X and Y jaws and MLC) pattern on the treatment unit was verified against printouts of the light field projection generated in the TPS. From a total of 30 items checked with the end-to-end test, no mismatch between treatment planning system data and R&VS data were observed. For the R&VS QA, out of a total of 34 tests conducted, the relative discrepancies of items checked were 8.5% in the general section, 13.3% in the geometric and dosimetric section, and 4.9% in the dose delivered section. There was a high data integrity observed for the end-to-end test between the TPS and R&VS due to the two systems sharing a single DICOM database. The observed discrepancies in the QA test points out the system's inability to totally eradicate all errors, hence extra vigilance on the part of radiotherapists and medical physicists. These QAs and tests contributed to achieving a better understanding of the system and helped resolved issues related to its data integrity.

Breast cancer recurrence monitoring a corroding to tumour subtypes: Role of serum tumour markers CA 15-3 and CEA using radioimmunoassay

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Introduction: Breast cancer is one of the most common types of cancer worldwide, with increasing incidence and mortality. Breast cancer patients concerned to avoid of breast cancer recurrence. Tumor markers are substances found in the body and produced by cancer cells. Tumor markers and imaging tests such as Computed Tomography (CT) , Positron emission tomography (PET) and bone scans have been used for monitoring breast cancer recurrence after therapy, these imaging have risk and cost, while tumor markers is easy and cost-effective. The aim of this study to detect the early breast cancer recurrence using tumor markers Cancer Antigen15-3 (CA 15-3) and Carcinoembryonic Antigen (CEA) during therapy

Methods: Forty six of breast cancer women in age ranged between 17 and 65 years, were selected randomly to participate in this study, 23 of them were on treatment for 3 months (Chemotherapy doses) and 23 were complete the first line of therapy about 6 months (Ionizing radiation and chemotherapy doses/or complete chemotherapy regime). Clinical data information including age at diagnosis, stage , estrogen receptor (ER), progesterone receptor (PR) and human epidermal growth factor receptor 2 (HER2) status. Radioimmunoassay used for measuring the concentration of serum CA 15-3 and CEA in breast cancer patients, the reference range of serum CA 15-3 is < 30 U/Ml and CEA is < 3.0 ng/ml. Patients were followed up by observed them in the clinic for 24 months.

Results: The mean and standard deviation of CA 15-3 of breast cancer patients on treatment were (18.0±11.3), while in the patients after treatment were (16.0±9.0). The mean and standard deviation of CEA for the patients on treatment and after treatment were (4.3±5.0) and (4.5 ±5.5) respectively. Twenty-two patients were luminal B and Twenty-four patients were triple negative subtypes. Twenty of the patients suffered the early recurrence in a period less than 24 months. High levels of CA 15-3 seen only in five patients in stage3 and luminal B subtype (ER+, PR+/ PR-, HER2+). While elevation of CEA levels observed in, tow patients were luminal B and twelve patients were tribal negative breast cancer subtypes. However, three patients suffered distance recurrence in bone and lung, were have normal serum levels of tumor markers CA15-3 and CEA during treatment, and tow patients of them died during follow-up period . Figure (1)
explains the mean levels of CA15-3 and CEA among breast cancer subtypes in this study.

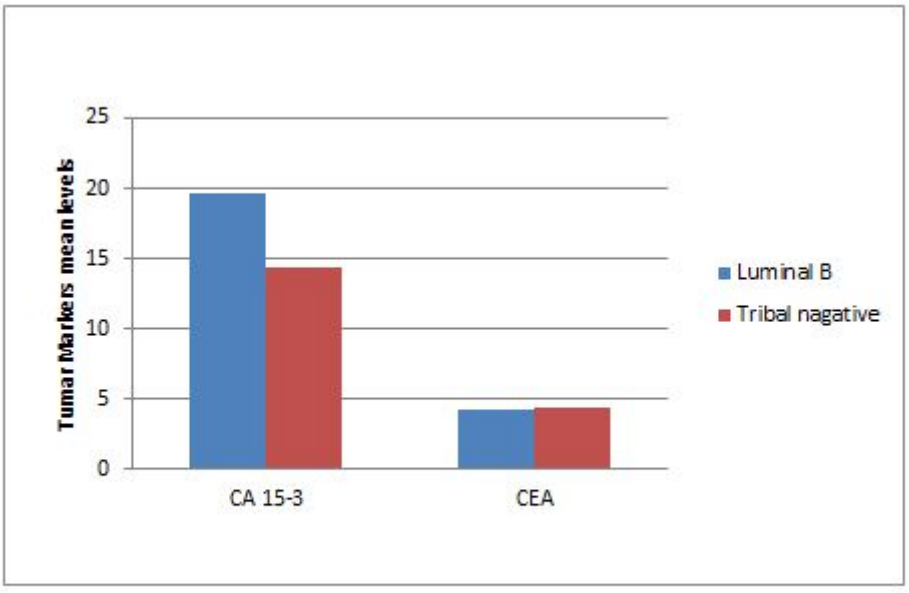

Figure1: Mean levels of Tumour Markers CA15-3 and CEA among breast cancer subypes

Conclusion CA 15-3 may be useful for monitoring breast cancer recurrence at initial recurrence diagnosis in luminal B subtype. Elevated CEA serum levels during treatment were associated with early recurrence in luminal B and tribal negative breast cancer subtypes. Tumor markers CA 15-3 and CEA cannot monitor breast cancer recurrence in some cases such as distance recurrence in bone or lung.

Session 11b - Quality in Radiotherapy: various dimensions **/** 109

Cost-effective public procurements of equipment for radiotherapy: starting point of patient's safety

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Introduction Preparation of tender documentation for public procurement of expensive radiological equipment (e.g. linear accelerators, MRI and CT systems, etc.) is an important and highly demanding task. Involvement of senior professionals with broad knowledge, expertise and understanding of radiation therapy procedures and technology is essential for optimal outcome of the particular procurement. Hence, Radiation Oncologist, Medical Physics Experts (MPE) and Radiotherapy Technologist usually work as a team, which governs procedures related to such public tenders. Among them, MPE has pronounced role and responsibility for the preparation of technical specifications for the equipment as well as for the evaluation of offers. The competency of MPE has been underlined also in the latest 'International Basic Safety Standards' (IAEA, 2014) as well as within the European 'Basic Safety Standards' (EU Council Directive 2013/59/ EURATOM). In addition to technical specifications, it is worthwhile that tender documentation contains also a binding and cost-effective post-warranty maintenance contract sample, to assure, that the equipment performance remains at a high level throughout its life-period. Such approach could enhance the output of health service, shorten waiting lists and contribute to the overall well-being and safety of patients as well as to assure a higher quality of radiological procedures. The aim of this work was to find a simple analytical evaluation point system for a public tendering process when medical radiological equipment needed in radiotherapy is to be purchased. Such system should be fair and transparent on one hand and financially acceptable for hospitals on the other. Methodology It is assumed that apart from technical specifications, the price for the equipment and for the post-warranty maintenance contract are the most important parameters for the evaluation of offers for medical radiological equipment. Transparent tender procedures along with adequate management policy and system for the financial evaluation of bids is of paramount importance in a nowadays very fragile economic situation in many countries. Three main criteria were followed in our attempt to find adequate point system for the evaluation of bids: (i) it should simple, transparent and fair (ii) it should reflect hospitals' needs (iii) it should be structured in such a way to eliminate the possibility of unreasonably high prices of the equipment or post-warranty maintenance. These considerations were analysed in order to find adequate formulas for the evaluation of final bids and to fulfil the aim of this work. Results (i) Our goal, to construct a system which is simple, transparent and fair was achieved in elaborating formulas which are linear without containing any complex analytical function. Such approach eliminates possibilities of misunderstanding or misinterpretations of the system. In addition, having in mind manufacturers of the equipment, transparency and fairness can be achieved by publishing complete evaluation system together with needed explanations already within the official public tender documentation. (ii) Hospital needs and available financial resources have to be identified and consequently, technical specifications for the equipment shall follow demands of modern radiation therapy and comply with financial restrictions. Hence, it is obvious, that management of the hospital and professional staff have to work hand in hand to use their financial assets in a cost-effective way, ultimately for the benefit of patients. It was assumed, that tender specifications are written in a way which allows, that at least two bidders (manufacturers) can fulfil all technical requests, considering also the conditions for the specific and general functionality of the equipment. (ii) Most challenging part of the evaluation point system was the question, how to avoid potentially unreasonably high prices of the equipment and post-warranty maintenance contracts. To overcome this problem, we have provided two sets of formulas. Within the first set, points are granted on the basis of normalising particular price to the average price of all bids. Within the second set of equations, prices for maintenance contracts are included in such a way to encourage bidders to offer financially acceptable prices. Taking into account both sets of formulas, it is virtually impossible that financially unfavourable bids would receive a high number of points. Formulas for the evaluation point system of bids are presented in Table 1. Conclusion Governing public procurements of expensive radiological equipment is demanding task for hospitals. On one hand, hospital management has to take care of financial sustainability of their services, on the other hand, a rapid development of technology in radiation oncology forces radiotherapy professionals to strive for best possible equipment and technical support for their patients in order to raise overall cancer cure rate. Within our study, simple formulas are presented, which could help hospitals to avoid high pricing and to purchase expensive equipment for the reasonable and competitive price. Additionally, such system provides a warranty that also the prices for post-warranty maintenance will be kept at reasonable and acceptable

level.

Table 1

A system of equations for the calculation of points *T* assigned to certain bid among *n* valid offers for radiological equipment. *P* stands for the price of the equipment, *M* is the price for the post-warranty maintenance contract for five years, subscript *i* refers to *i*-th bid while subscript *max* denotes the bid which has received the highest number of not normalised points within the first step (subscript 1) of the financial evaluation of offers. Parameter *a* is estimated percentage of the total price of the maintenance contract for five years and usually ranges from 30% to 50% of the equipment's price, which depends on the expected lifespan of particular equipment. Parameter *b* is the estimated percentage of the equipment's price itself, where the condition $a + b = 100$ has to be fulfilled. A number of points are normalised within the second step (subscript 2) while the final number of received normalised points $\sum_i T$ for *i*-th offer is calculated in the third step of the evaluation system.

	NUMBER OF POINTS	
	NOT NORMALIZED	NORMALIZED
EQUIPMENT PART	$T_{A,i,1} = a\frac{\sum_{k=1}^{n} P_k}{P_i \cdot n}$	$T_{A,i,2} = a\frac{T_{A,i,1}}{T_{A,\max,1}}$
MAINTENANCE PART	$T_{B,i,1} = b\frac{\sum_{k=1}^{n} \left(\frac{M}{P}\right)_k}{\left(\frac{M}{P}\right)_i \cdot n}$	$T_{B,i,2} = b\frac{T_{B,i,1}}{T_{B,\max,1}}$
$\sum_i T$ for *i*-th offer	$T_{A,i,2} + T_{B,i,2}$	

Friday morning - Poster Presentations - Screen2 **/** 110

Medical physics education and training in Bangladesh - An overview

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Introduction: In the present day Medical physics is one of the most demanding and rewarding applications of physics in society. As a professional, Medical Physicist who works in the hospital environment is a member of a wide clinical team which is responsible for the accurate diagnosis and the therapeutic methods applied using radiation.

Medical physics activities in country: The Medical physics activities originated in Bangladesh at 1954 where the first X-Ray machine was established in Kumudini hospital. The first Radiotherapy department was set up at 1957 in the same hospital and in 1960 the first Nuclear Medicine Centre was established in Dhaka Medical College Hospital (DMCH). At present, there are 20 Nuclear Medicine facilities in different part of the country. Under these facilities, 45 Gamma Camera/SPECTs and 5 PET/CT were installed. There are 28 Radiotherapy centres in our country where 19 linear accelerators, 8 CT-Simulators, 9 Tele-Cobalt machines and 13 Brachytherapy units have been equipped. Around 5000 X-ray unit and 150 CT have been installed in our country so far.

Medical physicist in Bangladesh: Around 60 Medical Physicists are working in all radiation oncol- ogy establishments and 19 Medical Physicists are working in all Nuclear Medicine departments. 150 millions people's country of Bangladesh, we need around 300 radiotherapy centres and 600 medical physicists in oncology but we have achieved very little. Medical Physics education in the country: In Bangladesh there are 37 public and 92 private universities, however, they offer limited courses on medical physics. A few courses offered by the public universities cover some aspects of medical physics, while only one private university, Gono Bishwabidyalay (University) has a B.Sc and M.Sc degree program under the full faced Medical Physics and Biomedical Engineering Department. Research work in Medical physics was started in Department of Physics, University of Dhaka at 1978 and first M.Sc. student started thesis work in Medical Physics in the same department in 1981. Inception of Medical Physics courses in M.Phil. and Ph.D levels started in Bangladesh University of Engineering & Technology (BUET) under the division of Health & Medical Physics in 1982. In 2008 University of Dhaka (DU) opened a new Department of Biomedical Physics and Technology offering M.Phil. and Ph.D program. In 2014, DU has started MS program in Medical physics.

Clinical training in hospital: The university programs are however not coupled with appropriate clinical training, making these curricula inadequate for practical clinical application. Under the MS program in DU, students are going for only 3 months internship in radiotherapy and nuclear medicine. Structured clinical in-service training program for medical physicists are also not sufficient. Hands-on-job training or training at home and abroad are the main sources of clinical medical physics learning.

Clinical training supported by IAEA: International Atomic Energy Agency (IAEA) has developed three clinical training program guide books for medical physicist in the fields of Radiation Oncology, Diagnostic Radiology and Nuclear Medicine. This was done under a Regional Cooperative Agreement (RCA) program on strengthening of medical physics through education and training. In 2011, Bangladesh commenced the first pilot clinical training program of medical physics in nuclear medicine based on the IAEA's training course. Under this program 4 medical physicists successfully completed the clinical training.

AMPLE e-learning training program in Bangladesh: Recently Bangladesh has joined the Advanced Medical Physics Learning Environment (AMPLE) e learning program which was run by IAEA under a RCA project named "Strengthening the effectiveness and extent of medical physics education and training". AMPLE e learning program is an online base clinical training program for medical physicists of radiotherapy, nuclear medicine and diagnostic radiology. 13 medical physicists from different

hospital are involved as students (resident) in this project and 7 senior medical physicists are performing as their supervisors.

Certification/Accreditation for medical physicist: Still now there is no accreditation program for medical physicist in Bangladesh. Bangladesh Medical Physics Association (BMPA) which is the National Organizational Member of International Organization for Medical Physics (IOMP), is trying to establish a recognition procedure for clinically qualified medical physicist with collaboration through the government of Bangladesh. BMPA has taken necessary steps for this certification procedure of medical physicist. BMPA is also working for creation of medical physicist post in all radiotherapy centre. BMPA also plays an important role in creating awareness and proper communications with higher authorities.

Conclusions: The role of a Medical Physicist is multifold and consists of the measurement of the dose received by the patients and personnel, quality control of radiological equipment, shielding requirements study, ensure radiation safety in the department and the training of several health professionals. Education and training are the important part for adopting, using and supporting medical physics activities. Education of medical physicists should be adapted towards the requirements of healthcare institutions.

Peripheral dose of moving target simulation using In-House dynamic thorax phantom

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Purpose The aims of this study were to explain the interplay effect at peripheral dose characteristics of target and organ at risk for target movement.

Materials and Method This work was performed at MRCCC Siloam Hospital using Varian RapidArc Linear Accelerator with 6 MV photon energy. The dynamic in-house thorax phantom was employed to simulate the radiotherapy of lung with organ at risk present. It was designed with movable tumor target in the phantom in right lobe. The dose simulation was generated using Varian Eclipse 11.0 with Progressive Resolution Optimizer (PRO) and Anisotropic Analytical Algorithm (AAA) algorithm methods for optimization and dose calculation, respectively. The total dose was simulated using 60 Gy for 30 fractionations or 200 cGy per fraction. For IMRT planning, 7 fields were planned with 2 MLC angles of 0o and 90o, whereas the VMAT plan used double partial arc technique. Experiments were carried out to measure the target dose in static and dynamic target movement simulation. For the dynamic mode, the target was in harmonic motion with amplitudes of 5, 10, and 20 mm for periode of 1, 1.5, and 2 seconds, respectively. For measurements, TLD 100 LiF:Mg,Ti rod and GafChromic EBT3 film were employed. The GafChromic EBT-3 film was cut and equal with size of target of the tumor to cover all of target areas, whereas the TLDs were inserted into 5 points of target at the center, peripheral areas and also at OAR area.

Result and Discussion A calibration curve was generated by plotting optical density at the center irradiated calibration film and prescribed dose. The output of linac machine indicated the accuracy with discrepancy less than 2%, being still in tolerance range. For optimizing the planning of IMRT and VMAT at MLC 0o, we found that the dose of Planning Target Volume (PTV) in the range of 194,5 to 208,0 cGy and average dose of 203,6 cGy for IMRT techniques, whereas the PTV dose in the range of 194,9 to 208,7 cGy and dose average of 201,9 cGy for VMAT techniques. On the other hand, the OAR dose were in the range of 0,49 to 49,9 cGy and between 0,4 cGy to 54,7 cGy for IMRT and VMAT, respectively. Futhermore, for optimization of MLC 90o, the PTV dose between 161,4 cGy and 210,2 cGy dan OAR dose between 0,3 cGy and 51,0 cGy for IMRT technique, whereas it was in the range of 174,3 cGy to 207,9 cGy and between 0,3 cGy to 49,9 cGy for VMAT technique. For the comparison of dose measurement between MLC 0o and 90o for IMRT technique, we found that the PTV dose at the center tend to be lower than the peripheral dose. Subsequently, the PTV and OAR dose at MLC 0o is lower than to PTV and OAR dose at MLC 90o. In line with IMRT technique result, it also tend to give similar pattern for VMAT technique at MLC0o and 90o. For target of dynamic motion in superior–inferior direction, we explored that the dose was increased linearly with amplitude of the motion. In all measurements, the dose with an amplitude of 20 mm was the greatest values in both film and TLD detectors. Discrepancy of PTV dose at inferior position between the planned and the measured dose at MLC with 90o tend to be higher in comparison to the other areas, meaning that the MLC tend to interact with the inferior part of the target during exhalation process and dose in this area was attenuated by MLC, thus becoming underdose. On the other hand, the discrepancy between planned and measurement dose of MLC 0o presented a small deviation for superior and inferior region in same direction of respiratory motion. This result explained that interplay effect would be easy to see when the leaf is moving perpendicular with the tumor movement direction. Then, the interplay effect at parallel movement can be neglected. For OAR dose, this study presented a similar indication as the target dose measurement, i.e. the dose was influenced by the rise of amplitude of the traget motion. All of the measured dose at target movement was significantly different to TPS. This difference took place because of the planned dose was calculated the static position of the phantom, while it was being a harmonic oscillation during the measurement.

Session 8 - Education and training **/** 112

Competency-based education of RTT's in Romania: changing the paradigm to prepare the future

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Background: In Romania cancer patient's access to radiotherapy services is far below the standard of EU countries. Access to radiotherapy of cancer patients is currently approximately 30% compared to 47-50% according to international recommendations. Radiotherapy centers network in Romania is currently in development in both the public and private sectors. Cobalt devices have been replaced in most centers, 3D conformal techniques are standard in most of them and in some centers IMRT techniques are used. In these circumstances the training of human resources involved in radiotherapy services (doctors, medical physicists, RTT's) should be a major concern of universities and other institutions providing services is education. Competency based RTT's education Traditionally RTT training in Romania was not specific for radiotherapy most of these specialists being educated as radiology technicians. University of Medicine and Pharmacy "Iuliu Hatieganu" in Cluj-Napoca is still educate since 2000's radiology technicians in the frame of a study program of 180 European Credit Transfer and Accumulation System (ECTS) Beginning with the academic year 2016-2017 curricula of training of this study program was restructured to include more theoretical concepts and practical applications dedicated to radiotherapy. The total number of 180 ECTS is preserved and is performed over 3 years. The umber of hours of courses and internships to develop skills related to radiotherapy has been increased and represents 40 ECTS, which is double compared to the previous curricula. To establish the new curricula, the IAEA recommendation for training and education of RTT was used. The purpose of these changes was to provide future professionals a basic level of skills that enable them on the one hand a safe practice of radiotherapy activities and on the other hand to possess the cognitive skills necessary for lifelong learning in a professional environment in constant change. Beginning in academic year 2017 is scheduled to introduce a master program degree study for RTT's order to increase competencies specific to radiotherapy after graduation. Conclusion The development of technical infrastructure of radiotherapy departments in Romania requires adapting the educational offer to the needs of the labor market. RTT's must have knowledge and practical abilities to adapt to a complex work environment. At the University of Medicine and Pharmacy in Cluj Napoca there is a study program of 180 ECTS that has been modernized starting with academic year 2016 to include an increased number of courses and practical activities dedicated to radiotherapy. It is so far the only University in Romania that offers such a program of study and we believe that extending it to other Universities will be mandatory in the coming years as a necessity required by the practical realities of the development of radiotherapy activities.

Hypofractionated conformal radiotherapy and chemotheapy in treatment of malignant gliomas

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Background: patients with high-grade gliomas are generally elderly patients with poor performance status and associated morbidities. We compared results of hypofractionated radiotherapy with standard fractionated radiotherapy. Hypofractionated radiotherapy with or without chemotherapy could be an appropriate treatment option for these patients with poor life expectancy.

Patients and Methods: Sixty -five patients with malignant gliomas, treated in our Institute between 2005 and 2010, have been identified for this study. Median age was 69 years (between 65 and 81 years). Karnofsky Index (KI) was more than 70% in 38 patients (58.46%) and equal or less than 70% in 27 patients (41.54%), better for patients under 74 years old. Most frequent associated morbidities have been high blood pressure, cardiovascular diseases and diabetes, 54 patients (83,1%). Depending on histological types there have been 44 patients with glioblastoma multiforme (67.69%) and 7 patients with anaplastic astrocytomas (10.77%) and 14 patients (21.46%) with less frequent histological types. Complete resection of tumor was performed in 50 patients (76.9%), partial resection in 13 patients (20%) and biopsy in 2 patients (3.1%). Postoperative treatment was performed as radiotherapy and chemotherapy in 41 patients (63.08%) and radiotherapy only in 24 patients (36.92%). Radiotherapy (RT) was performed as standard fractionated conformal radiotherapy (CRT) with median total dose of 58,5 Gy (minimum 40 Gy, maximum 60 Gy) with 2Gy/fr in 22 patients and hypofractionated CRT with median total dose 30.0 Gy, (minimum 16 Gy, maximum 45 Gy) with 2.66 to 4 Gy/fr, in 43 patients. Chemotherapy with temozolomide was performed in 41 patients (64.08%): concomitant and adjuvant in 22 patients (33.85%), concomitant only with RT in 15 patients (23.08%) and adjuvant to RT in 4 patients (6.15%). The following parameters have been observed: 1) KI, measured at the beginning and the end of treatment; 2) toxicity of RT, appreciated using RTOG scale and 3) toxicity of chemotherapy (hematological, digestive, renal and other) during concomitant and adjuvant phase, appreciated after CTCAE version 3.0. The end points of treatment have been overall survival and toxicities of treatment.

Results: The median follow-up was 32.6 months with 55 deaths and 10 patients alive. Overall survival (OS) at 36 months was 13% (CI: 7%-25%) for the entire group of patients. The OS depending on treatment type was: 20% for patients treated with RT and concomitant chemotherapy; 16% for those treated with radiotherapy only and 7% at 36 months for concomitant and adjuvant chemotherapy, p=0.35 (NS). The shortest survival was seen in patients treated with adjuvant chemotherapy to RT, less than 1 year. The OS versus type of RT was 20% for patients treated with standard fractionated RT and 9% for those with hypofractionated RT, differences not statistically significant (p=0.02). Toxicity of radiotherapy (RTOG scale) was 0 and 1 in 41 patients (63.07%) and 2 and 3 in 24 patients (36.92%) with no statistically significant differences between the two types of fractionation: p=0.25. OS depending on toxicities was between 16% and 11% at 36 months, p=0.10. There have been 7 patients with grade 3 and 4 toxicities in chemotherapy treated group (41 patients): 4 in concomitant phase and 3 in adjuvant phase.

Conclusions: Hypofractionated radiotherapy was well tolerated with or without chemotherapy with acceptable toxicities and could be a good treatment option for elderly patients with high- grade gliomas. Important decisions factors for fractionation type and total dose administered are performance status, associated diseases and generally life expectancy of patients.

Thursday afternoon - Poster Presentations - Screen3 **/** 115

Characterization of a portal imager Amorphous Silicon Por- tal Vision aS 1000 for in vivo dosimetry for IMRT

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Background of the study: The complex and individualized photon fluence patterns constructed during intensity modulated radiation therapy (IMRT) treatment planning must be verified before they are delivered to the patient. The aim of this work is to implement the Amorphous silicon (aSi) Electronic Portal Imaging Devices (EPIDs) in the process of IMRT treatment plans verification. The aim of this work is to evaluate the influence of irradiation parameters on the response of portal imager amorphous silicon, the PortalVision aS 1000, on a Varian iX21 linac used for IMRT treatment at Radiotherapy Department of Chahids Mahmoudi hospital (Tizi Ouzou, Algeria). Methodology: The image on the EPID results from the combination of the primary and scattered radiation. This later varies with various parameters inherent to the treatment. The materials downstream of the imaging plate are not of a homogeneous composition and geometry. The result is local variations in the backscattered signal as a function of various parametrs. The study consists to compare the gray level of portal imaging G [U+0305] to the portal dose Dp (measured using ionization chamber) by calculating the ratio G [U+0305]**/** Dp for each physical parameters (in the range of UM used in clinical on central axis) and to study its behaviour. Results: Parameters taken into account in this study are: variation of field size, source detector distance, the energy and the backscatter photons on the walls and floor. The results show that the relationship between the gray level G [U+0305] of the image acquired by the portal imager (PortalVision aS 1000) and the measured dose portal is stable for all parameters. Conclusion: The extensive tests performed in this investigation show that the electronic portal imaging device is a reliable detector and could be a useful tool for the quality assurance and the verification of radiotherapy plans (in vivo dose and patient position) for IMRT treatments.

Methodology for acquisition of appropriate technology for radiation therapy in developing countries

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Introduction It has been estimated that about 60 % of all cancer patients in the world can benefit from radiotherapy treatment. Unfortunately, not all patients can get access to this effective treatment modality because of lack of radiotherapy facilities and associated resources. Driven by improving economy and with supports provided by international and professional organizations in recent years, radiotherapy services are becoming more accessible to patients in the developing countries. At the same time, major advances in technologies and treatment techniques have taken place in the field of radiation oncology. A full range of innovative and effective new treatment modalities such as IMRT, IGRT, SRS, helical Tomotherapy, particle therapy, etc. have been developed and becoming standard treatments in the clinics in some countries. Such sophisticated treatment modalities are also gradually being introduced in developing countries. Implementing advanced radiotherapy treatment service in the public hospital system can be costly and hard to sustain. Furthermore, such investments may not always achieve the expected clinical outcomes for various reasons. The common reasons may include inadequate QA due to lack of staff, inadequate staff training, service bottle neck due to inconsistence in standard of service amongst the supporting clinical services, inadequate supporting infrastructure needed for proper and efficient implementation and operation of advanced treatment service. Implementation of a cost effective and sustainable radiation therapy service, particularly in public healthcare system requires careful planning & implementation of appropriate technologies. The latter should be determined and selected based on a set of country specific criteria and conditions such that service capacity & quality can be maximized to meet service needs with limited resources. A methodology is described which may be used to develop a set criteria for technology acquisition. **Methodology** An important consideration in technology acquisition in medicine is maximizing radiation therapy service to cover clinical needs with the allocated resources. The aim is to balance between service demands, service quality and resources limitations. The question is how to determine the right balance and what standard and yardstick should be used in guiding decision making, particularly on selection of high cost radiotherapy technologies. Optimizing the effective use of budget on high cost RT technologies is a complex issue and there is no simple solution that works for every country or for different regions of a country. A possible approach to resolve the problem is to establish a radiotherapy technology advisory panel within the national framework for planning and implementation of radiotherapy service to research and develop a set of technology acquisition criteria and strategies. Figure 1 shows an example of a national framework for public radiotherapy service. A mechanism should be established within the national framework for radiotherapy service to research and develop a set of criteria, conditions and strategies that can be applied for guiding the planning and selection of the RT technologies that are most appropriate and cost effective in meeting national service demands within constraints.

Figure 1: Typical framework for management of public radiotherapy services.

Building an appropriate set of the technology selection criteria should take into account the key parameters and baseline conditions of the country and different regions of the county, including the following: 1 Compatibility with national policy on quality of healthcare service, including scope and quality of service of other clinical specialties. 2 Consistent with clinical needs, including case load, and type and staging of diseases. 3 Compatibility and consistency in quality and scope of service provision amongst all supporting clinical services, including diagnostic imaging and laboratory test services. 4 Compatible in quality and connectivity amongst all radiotherapy technologies within service clusters, e.g. simulators, TPS, QA, dosimetry, treatment record andverification system. 5 Compatibility with local infrastructure and environmental conditions reliability of electricity supply, adequacy of building and building services on such issues as temperature and humidity control, and availability and reliability of IT infrastructure. 6 Manpower status and conditions, including requirements on headcount, professional knowledge and competence, and resources on staff training for implementation of each type of technology. 7 Compatible with level of expertise in local maintenance service standard and available manpower. Availability and reliability of local supply of replacement parts to secure service reliability with minimum equipment down time. 8 Sustainability of the treatment service within resources constraints. 9 Compatibility with existing quality and risk management system.

Development of a set of meaningful country specific technology selection criteria requires a good

understanding on the strength and limitations in existing practice and service and a correct interpretation on the implications of all the research findings. To achieve this objective, a panel of experts who are familiar with national radiation therapy services should be established to performed this important task and to update the criteria if found necessary. Members of the expert panel should include key healthcare professionals practicing in radiation therapy, including radiation oncologist, medical physicists, therapists, and nurses as well as some supporting personnel including IT expert and engineers.
Conclusions In resources limited countries, selection of radiotherapy technologies in public healthcare system could be optimized for cost effectiveness in meeting service needs within budgetary constraints. The optimization process is aimed at acquiring the technologies that best meeting a set of criteria which is developed based on the principle of balance and consistence in radiotherapy practice and facility. The objective is to implement the 'best' or most appropriate technologies that meet clinical needs within given resources. A methodology is proposed to develop a country specific optimization criteria.

Session 16b - QA from simulation to delivery **/** 118

SRS in Tomotherapy: What we gain, what we lose comparing to Linac based SRS?

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INTRODUCTION Brain SRS has been done at our institution since June 1996. In a first phase (1996-2003) circular cones were used. Since February 2008, SRS has been performed using an add-on micro-MLC m3, from Brainlab, with full advanced integration in a Siemens linear accelerator. A total of 498 brain lesions have been treated with this technology, with outcomes in terms of overall survival and local control in close agreement with published results. With the announced end of support for m3 and given the recent installation of a Tomotherapy HD machine, the possibility of performing SRS in Tomotherapy was raised by the clinical team. Different studies on SRS in Tomotherapy have been published [1-7] but in recent years a shift towards newer technologies seems to have withdrawn the interest to use Tomotherapy for this clinical application. Nevertheless, Tomotherapy has evolved technologically with improved performances in terms of accuracy and efficiency, providing sub-millimeter accuracy and precision in couch movements and improved dosimetric accuracy. In this work an evaluation of the dosimetric consequences of an eventual change from linac based towards Tomo based SRS is presented.

METHODS AND MATERIALS For Linac based SRS the standard used planning technique consisted of six dynamic conformal arcs rotating about a single isocenter. The plan assessment included coverage (CI), homogeneity (HI) and conformity (COIN) indices proposed in the literature and published elsewhere [8]. 26 brain lesions have been chosen and divided in six groups depending on the volume and the proximity to critical structures as: group I – PTV smaller than 1cc; group II – PTV between 1 and 3cc; group III – PTV between 3 and 7cc; group IV – PTV greater than 7cc; group V – metastases close to the brainstem, a critical structure with a maximum tolerance dose of 12 Gy, which is a limiting factor for treating brain metastases with a dose greater than 20 Gy; group VI –neurinomas, usually close to the brainstem but with a prescription dose of 12 Gy. All clinical cases have been replanned for Tomotherapy, in the high performance Volo Planning station, using surrounding rings as planning aid structures to push the dose inside the PTV. A modulation factor of 2.0 and a pitch of 0.1 have been used. Given the clear larger dose gradients obtained in Tomo, the gradient index (GI) proposed by Paddick [9] was also calculated for all cases in both treatment techniques. Also the ratio V20%/V50% was used for dose comparison assessment.

RESULTS It is very interesting to note that V20%/V50% ratio between iPlan and Tomo plans was always around 1.4 0.1 which means that this index may be considered as an indicator of the delivery system physical constraint in terms of dose spread. In Tomo the gradient index (GI) was around 2.0 times the GI with m3. This was the main drawback of Tomo plans which was counterbalanced by the gain of 19.6 % 6.5% in the conformity index, COIN. These values for COIN reported to the 18 studied lesions that were away from critical structures, had volumes from 0.66 cc up to 21.1 cc and for which COIN values in iPlan were usually above 0.6 (the lower limit for conformity). The conformity in Tomo was expressively improved. This was even more advantageous for lesions close to critical structures. Neurinomas, where the close proximity of the brainstem led to COIN values below conformity, would have benefited in Tomo of an increase of around 6%, leading to conformal plans. This improvement in conformity was coupled with a better coverage (CI usually exceeds 99% in Tomo whereas it was most of the times in the range of 97-98% in iPlan). Minimum dose in the PTV also highly benefited from Tomo plans. Concerning treatment times (TT), Tomo plans did not bring in general any special advantage when compared with linac based plans – the overall averages for the studied lesions were 19.7min for Tomo plans and 16min for iPlan. If we add to these times (that just concern the beam-on time in both systems) the required imaging time in Tomo (around 3-5 min) and localization time in the linear accelerator (around 10-12 min) we could come up with very similar times to be allocated for the treatment delivery in both systems.

CONCLUSIONS SRS is feasible in Tomotherapy as it have been reported in the literature. From the dosimetric point of view, the larger gradients around the brain lesions specially in transverse plans which constitute the main loss when compared with linac based SRS plans are counterbalanced with higher conformity specially around irregular lesions. Concerning treatment times they are similar for the overall treatment delivery for single lesions but would be considerable reduced for multiple lesions in Tomotherapy.

Enhanced dose measurement of Zinc Oxide nanoparticles by radiochromic dosimeter in small radiation fields

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Introduction of the study Radiotherapy techniques have been improved with the goal of escalating tumor dose and minimizing normal tissues complications. Among these methods, the use of nano-materials such as ZnO nanoparticles offers some features including the opportunity of destroying cancerous tumors with minimal damage to healthy tissues. It is demonstrated that high Z materials absorb X-ray remarkably. Therefore, it seems that dose enhancement originating by incorporating ZnO NPs in irradiated volume would increase the therapeutic ratio. Dose enhancement factor is more important in small radiation fields where lack of lateral electronic equilibrium condition leads to employing higher numbers of monitor unit (MU) to deliver a certain amount of absorbed dose. It seems that using the water equivalent radiochromic dosimeter would be a proper method to evaluate the effects of ZnO NPs. The aim of this study is to determine the dose enhancement factor of ZnO NPs by use of the radiochromic dosimeter in small radiation fields.

Methodology Initially, the water equivalent radiochromic dosimeter was fabricated. The procedure consists of mixing CCl4 and leucomalachite green (LMG). Then a polyurethane resin which was supplied in two parts (Part A and Part B) were mixed together to afford optically clear polyurethane resins that form the matrix of the radiochromic dosimeter. The solutions prepared were combined together and thoroughly mixed. Then the prepared mixture was poured into poly cuvettes and kept in a pressure pot (60 psi) to minimize out gassing. The maximum pre irradiation absorptions of cuvettes were then determined using UV-Vis spectrophotometer. The next process was calibration of dosimeters against ionization chamber (0.6 cc Farmer chamber) to deliver definite steps of absorbed dose. Dosimeters were fixed in a solid water phantom and irradiated in three small fields (1*1, 2* 2 and 3*3 cm2) to deliver the absorbed doses including 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20 Gy at centers of each dosimeter. The source to surface distance (SSD) was set 100 cm and 6MV photon beams producing by Varian Clinac 2100 C linear accelerator was also applied for the irradiation. At the next section, 40nm ZnO NPs were synthesized and various concentrations of ZnO NPs (500, 1000, 3000μgml-1) were incorporated into the composition of the radiochromic dosimeter and the irradiation processes were repeated in the mentioned three small fields. Ultimately, by comparing the results at presence and lack of NPs, dose enhancement factor was determined.

Results The DEF, as defined above, was then acquired for different compositions of radiochromic dosimeter in the small studied fields (Table1). Table1. DEF measured by radiochromic dosimeter.

Field Size (cm2)	Concentration of NPs	DEF		DEF		DEF
1*1	500μg/ml	1.36	1000μg/ml	1.39	3000μg/ml	1.44
2*2	500μg/ml	1.39	1000μg/ml	1.41	3000μg/ml	1.46
3*3	500μg/ml	1.40	1000μg/ml	1.45	3000μg/ml	1.50

Since in small radiation fields, lateral electronic equilibrium does not exist, higher numbers of monitor unit (MU) are needed to deliver a certain amount of absorbed dose. Higher amounts of MU lead to excessive time of treatment and consequently the probability of random errors and patient movements during treatment will rise. Therefore, finding a solution to overcome such a problem is essential. The results of this study showed that, a good value of DEF can be derived by incorporating ZnO NPs. Dose enhancement grows by increasing the concentration of NPs. In fact, by increasing the concentration of NPs, the number of NPs in a certain volume of the dosimeter would be increased and therefore the probability of photon interaction with NPs would increase and hence the DEF would grow and consequently the needed MU to deliver each step of absorbed dose would reduce. As Tables 1 illustrates, DEF increases by increasing field size. It means that by decreasing the size of radiation field, lateral scatter disequilibrium becomes more which causes less output factor for such fields compared to bigger ones. Although DEF is usually attributed by Orthovoltage photon beams, where photoelectric effect is dominant, the results of this study showed that DEF can be achieved by megavoltage photon beams, as well. In this situation, DEF may be the results of low energy photons in

the continuous X-ray spectrum, attenuated photons, probably the pair production effect and even Compton scattering. By incorporating ZnO NPs into the structure of the dosimeter, the electrical density of the irradiated volume would increase and therefore the cross section of Compton scattering and probability of producing secondary electrons or free radicals which have significant effect on DEF would increase. 3.

Conclusion The results of this study showed that ZnO NPs could be used as dose enhancing substances in megavoltage irradiation condition.

Standardisation of treatment planning in frameless stereotactic radiosurgery and radiotherapy using volumetric modulated arc therapy (VMAT) beams

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Aim: To standardise stereotactic treatment planning for new cases through compiling and categorization of a large number of treatment plans for a variety of clinical scenarios and automating plan selection from this plan library based on patient specific parameters.

Materials and methods: One hundred and seventeen patients who were treated by stereotactic radiosurgery (SRS) or stereotactic radiotherapy (SRT) in our clinic for their intracranial lesions between March 2013 and December 2015 were included in this study. In all, 120 VMAT-based stereotactic plans (SRS/SRT) were generated for these patients and were pooled together to create a library of plans. All the plans were done in MONACO (v 5.00.04) treatment planning system (TPS) using the Monte Carlo dose calculation engine. These plans were categorized on the basis of eight different parameters: (i) Number of PTVs (ii) Prescription dose (iii) laterality (left /right) (iv) tumour volume (v) Whether PTV dose coverage was challenged by presence of organ at risk (OAR) or not, (vi) shortest distance between OAR and PTV (vii) centre to centre distance between OARs and PTV and (viii) lateral dimension of external contour (brain).

Subsequently, for every new patient, the most appropriate plan was chosen from this library of plans on the basis of above categorisation using an ensemble mapping auto-select technique. The programming was done with a macro-enabled Excel worksheet. The auto-selected treatment plan (ATP) from the library of plans was 'copied' to the new patient keeping all beam and optimization parameters unchanged and placing the isocenter at the center of the new patient's PTV. Optimization and dose calculation was carried out in the MONACO TPS with no or very minimal changes in the optimization constraints and arc lengths. In addition to this ATP, another individualized treatment plan (ITP) was generated by an experienced medical physicist independently without taking into consideration the library plan. The two sets of plans were compared. The ATP and the IP were evaluated for PTV receiving 98% prescription dose (V98%), Paddick conformity index (PCI) , dose spillage in terms of volumes receiving 50% and 20% of prescription dose (V50%, V20%) and OAR doses.

Results: For 43.3% (52 out of 120) patients it was observed that dose coverage to PTV was not challenged by the presence of any OAR. Validation results for ensemble mapping technique showed that the Excel program could select an appropriate plan from the plan library for the new patient in question.

Although the program could select the appropriate plan and ATP could be generated for the new patients, the independent plans were marginally better than the auto-select plans in PTV coverage and dose conformity. The mean PTV volume receiving 98% prescription dose (V98%) was 98.7 1.1% and 97.5 ±1.3% for the IP and auto-select plans respectively. Similarly the mean value for PTV's conformity index was slightly better in ITP (0.712) as compared to that for auto-selected plans (0.693). However both PTV V98% and PCI were not statistically different between two sets.

For the largest prescription dose group (12 Gy in 1#, 64 patients) brainstem 0.5 cc volume exhibited mean doses of 873.1 134.2 cGy and 854.5 122.4 cGy for ITP and ATP respectively. Mean 0.2 cc optic chiasm dose were 690.1 78.3 cGy and 734.0 67.8 cGy for ITP and ATP respectively. MU difference was very nominal with ITP showing a mean excess MU of 67.3 (3.7%) over ATP. ITP required on average 3.5 optimizations/dose calculation which ranged from 3.5 to 5 hrs, where as ATP required not more than 1.5 to 2 hrs.

Conclusion: ATP validation results indicated multidimensional ensemble mapping mechanism can pick up the appropriate plan from the library of plans accurately for new cases. ATP plans, even though marginally inferior in plan quality to the ITP, can fulfil all the required clinical conditions and dose constraints. ATP plans save considerable planning time and is not dependent on the treatment planner's skills and expertise.

Session 8 - Education and training **/** 125

Addressing global radiation medicine human resource gaps through educational innovation

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Background: With the rapidly growing number of cancer patients globally, addressing gaps in cancer care services is now an acute need. Radiotherapy is critical to the management of cancer patients. However, the majority of patients in low-income countries do not have access to radiotherapy. The gap in radiotherapy access around the world is huge and there is a need for >200,000 new health professionals by 2035 to meet the demand for radiotherapy services (Lancet Oncol, Sept 2015). We considered the challenges and gaps in health professional training using current training models and the opportunities to address this health human resource shortfall through innovative educational methods, models and technology.

Methods: To address the current and growing gaps in available health professionals we have an obligation to explore innovations in all aspects of education and re-imagine curricula from the current "industrial model" into a "systems-based" (Frenk, Lancet, 2010) approach using a competency-based foundation. Traditional professional boundaries and scopes of practice must be challenged and new scopes of practice defined. New training models should leverage local skills and leadership while promoting global credentialing and practice standards. These models will promote local talent retention and expansion.

Results: The authors propose to explore and pilot new educational models to address three main areas for innovation: 1) professional scopes of practice and task shifting; 2) a systems-based competency model for curriculum development and 3) maximized use of educational technology in a blended curriculum. Professional scopes of practice are evolving in multiple jurisdictions; e.g.; introduction of a Clinical Specialist Radiation Therapist (CSRT) program in Ontario, Canada, the incorporation of Physician Assistants into cancer in the United States, and the development and integration of automation technologies. The scope of practice for radiation medicine professionals must be reviewed in each local/regional context and task shifting or re-distribution of roles and responsibilities accomplished to maximize the use of scarce resources. Efficiency models may be used to simulate the optimal distribution of tasks among professionals and automated technologies. The principles of such new models should be to maximize high quality and safe radiotherapy delivery while maximizing resources and access to treatment. A systems-based core curricula grounded in competency-based principles should be developed to address the all aspects of the radiation treatment process for the new professional scopes of practice. This new curriculum should articulate the new professional roles in a care environment which is capitalizing on the use of automation technologies. This curricula should encompass global standards for cancer care while allowing for local and regional contextualization, customization and challenging the status quo. Innovative curricular models must be leveraged through excellent clinical teachers and rigorously tested and evaluated through educational research. The merits of global certifications, facilitating a portable radiation medicine workforce, in the local context should be explored. A train-the-trainer knowledge translation plan should be simultaneously developed with the curriculum to promote rapid expansion of human resources for cancer care by leveraging local expertise. Blended learning approaches are likely to maximize learning and the sharing of educational resources as global public goods. Blended learning is the combination of on-line or digital learning with face-to-face learning. To facilitate this a review of potential barriers to end-users of on-line/digital content in local environments is needed as well as proposed strategies to mitigate these barriers. The on-line/digital content requires a sustainability strategy and should be developed as global public goods without cost for use.

Conclusions: The educational innovations outlined in this paper require local feasibility assessment and a systematic resource development plan to address expanding global shortages in health professionals and to address training disparities around the globe.

Thursday morning - Poster Presentations - Screen1 **/** 126

Quality control procedure forlinear accelerator multileaf collimators in radiotherapy

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Introduction: The introduction of Multileaf collimator (MLC) systems into clinical Linear Accelerators (Linacs) facilitated computer-control and verification of complex treatment, and resulted in an increase in patient set up speed. A MLC system thus requires a re-evaluation of the quality assurance requirements for beam collimation. To this end a combined procedure was developed and executed based on several Linear Accelerator Multileaf Collimator Quality Control Methodologies in Radiotherapy.
Materials and Methods: The performance of MLCs for an Elekta Linac at the Livingstone Hospital (LH) in Port Elizabeth and a Siemens Linac at the Charlotte Maxeke Johannesburg Academic Hospital (CMJAH) were examined. The standard quality control procedures executed are leaf matching, leaf position accuracy, inter-leaf leakage and transmission through abutting leaves. A single exposure procedure was developed to execute all procedures on one image as shown below.
Radiographic film was used at CMJAH and radiographic film and an Electronic Portal Imaging Device (EPID) were used at LH. Record and verify data management systems were used to set up and execute the procedure. The calibration of all the imaging devices was also performed.
Results: The individual and combined procedures were successfully carried out and analysed using the two different detectors on the two Linac systems over a period of 6 months. The data allowed for the characterisation of MLC performance over a period of time including MLC re-calibration. The analysis of the data obtained showed consistency across procedures, devices and reproducibility in the results with time.
Conclusion: Monitoring the performance of an MLC over time improves understanding of how the MLC varies with clinical usage and predicts when recalibration is necessary. The combined procedure facilitates early detection of system failure and is a resource-sparing methodology.
Keywords: Multileaf Collimator, Quality Control, Assurance

Present status of medical physics education in Bangladesh

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Title-Present Status of Medical Physics Education in Bangladesh
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The population of Bangladesh is estimated about 160 million living on an area of 143,998 km^2, the number of cancer patients equals 2000 out of 1,000,000 inhabitants per year. According to WHO, we need total 160 Centers, 320 LINACS, 640 Medical Physicists and even more considering diagnostic radiology and nuclear medicine centers. Medical physics study in Bangladesh is gaining importance day by day as cancer treatment is entering a new era from conventional to conformal therapy technique. In Bangladesh, all Nuclear Medicine Centers are under Bangladesh Atomic Energy Commission (BAEC), so they recruit physicists in the position of scientific officer and undergone training in these fields under IAEA. In this way medical physicists in the nuclear medicine area are developed but medical physics in radiotherapy and x-ray diagnosis is poorly developed.
Germany play the pioneer role in the development of medical physics in Bangladesh. The commencement of Medical Physics education in Bangladesh has started mid 90s by Bangladeshi German professor through different seminars, workshops organized by “Medical Physics in the Developing Countries” of the German Society for Medical Physics (DGMP).
As a consequence, medical physics study established in 2000 in the department of Medical Physics and Biomedical Engineering (MPBME), Gono Bishwabidyalay (GB) with collaboration of Heidelberg University, Germany. The purpose of this study is to produce medical physicists and biomedical engineers especially for the radiotherapy hospitals, diagnostics center, universities. Later, two more universities started this study at MSc level in 2014.
The syllabus of MPBME have been prepared based on the documents of DGMP, AAPM and IAEA. The M.Sc syllabus is adapted toward IAEA handbook of Radiation Oncology, Nuclear Medicine and Diagnostic Radiology. The main obstacle of the department is to find the faculty member in this field. So, from the beginning this department had a fruitful cooperation through teacher student exchange program with Heidelberg University and German Cancer Research Center, Heidelberg, Germany for 2003-2006 and this collaboration is extended further for 2014-2017 with the financial help of German Academic Exchange Service (DAAD). MPBME has a long standing collaboration with different institutions nationally and internationally. MPBME had a fruitful cooperation India, China other than Germany. Department has own laboratories for physics, IT, electronics, medical physics and biomedical engineering. Practical classes are held in different government, private hospitals and nuclear medicine centers. B.Sc and M.Sc students are placed for 3-6 months in different areas of medical physics in different hospitals of Bangladesh, India and china for internship, training and practical part of project/thesis. In 2008, University of Dhaka established Department of Biomedical Physics and Technology but M.Sc program in Biomedical Physics and Technology started from 2014. Khwaja Yunus Ali University also started M.Sc program from 2014. A total number of 76 and 24 students have been successfully completed their B.Sc and M.Sc program from MPBME in Medical Physics respectively. Under the collaboration from 2003 to 2006, 19 manpower has been developed and 40 manpower are in developing phase through the collaboration from 2014 to 2017. From 2011 to till now, 18 B.Sc students visited in Saroj Gupta Cancer Center and Research Institute, Thakurpukur, Kolkata and North Bengal Oncology Center, Siliguri, India for internship. 10 students completed their M.Sc from the Department of Biomedical Physics and Technology, University of Dhaka. Khwaja Yunus Ali University is no more in continuation of medical physics education. After having B.Sc and M.Sc degree medical physicists are working in almost all public and private hospitals. MPBME has taken a

significant step to produce 200 medical physicists by 2021 in Bangladesh and to start qualified medical physicist training/ residency program (from 2017 for existing MPs) through national & international collaboration in all area of medical physics according to International Medical Physics Certification Board (IMPCB). Government, private hospitals and institutes should take necessary initiatives for the development of medical physics. In present situation, the other universities should follow the example to build up more man power.

Keywords: Medical physics, education, collaboration, training, position, certification, accredita- tion, manpower development

Normal tissue complication probability calculation in normal and hypo-fractionated radiotherapy of head & neck tumors

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Although radiobiological modeling has a lot of promise in clinical applications it is still an investigational tool. The linear-quadratic (LQ) formalism is the tool most commonly used for quantitative predictions of dose/fractionation. Hypo-fractionation requires consistent iso-effect dose calculations and the LQ formalism is appropriate for treatments with this dosing scheme. Nevertheless various Normal Tissue Complication Probability (NTCP) models have been used the most commonly applied models is the Lyman, Kutcher, Burman (LKB) model. Others like Källman relative seriality model have been also used. Dose magnitudes with "biological sense" like Equivalent Uniform Dose (either physical EUD or biologically effective EUBED) will improve the predictions made with these response models. Other authors have recommended some corrections to alpha/beta values (*effective* alpha/beta) which take into account both the dose heterogeneity and the volume effect for the late-responding normal-tissue. Nowadays it is running in our center the HYPNO project granted by IAEA which is directed to establish an optimal radiotherapy hypo-fractionation schedule for head and neck cancer (HNC) treatment that permit to take a better advantage of own equipment availability by means of an enhanced quality assurance program for 3D-CRT and IMRT modalities. The goal of the present work is to evaluate the differences in the estimation of NTCP using the LKB and Källman models for hypo-fractionated treatment in radiotherapy of HNC and the comparison with the normo-fractionation schedule. Different sources of variations: radiobiological parameters variability and heterogeneity of spatial dose distributions as well as the evaluation of adequate choice of dose magnitudes (EUD, uniform UBED or mean BED) were considered.

The dose data used in this work were obtained from the IMRT plans of patients bearing H&N tumors those included in the IAEA - HYPNO study at INOR. The data belong to two branches: Branch A: normo-fractionated schedule: 66Gy in 33 fractions 1.6Gy/fraction both given in 5 fractions per week and Branch B: hypo-fractionated schedule: 55Gy (higher dose) in 20 fractions giving 2.75Gy per fraction in 5 fractions per week. The DICOM RT files were exported from the TPS as anonymous and the DVHs for the spinal cord, brainstem, right and left parotids, pharynx and esophagus was built.

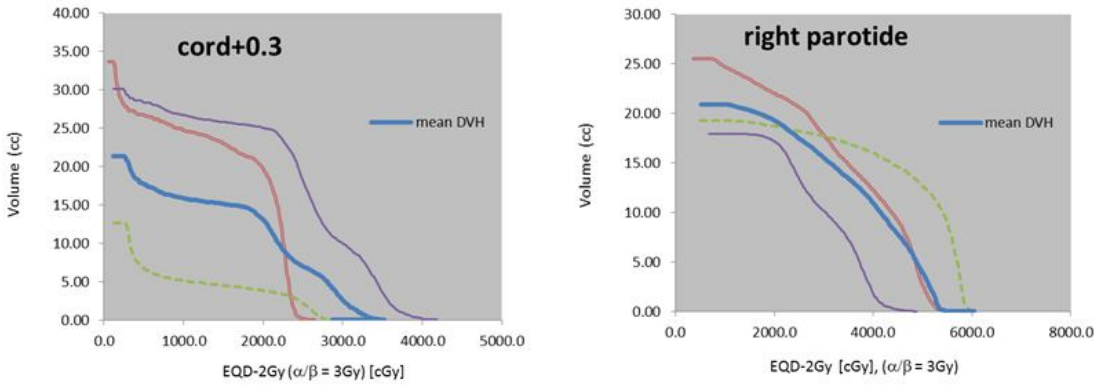

Figure 1. Mean DVH expressed as EQD_{2Gy}. Only representative DVHs are presented in both figures

The mean BED, EUD (Nimierko generalized model) were calculated from the DVHs. The dose delivered for a particular treatment scheme was expressed in terms of the Equivalent Dose at 2Gy fractions (EQD2Gy) using either mean BED or UBED. The NTCP was calculated for both branches using the LKB and Källman models adapting its formulation by inclusion of LQ model parameters

through the estimation of EQD2Gy calculated from mean BED or UBED. The maximum likelihood method was used to fit the NTCP models to the data. An average dose-volume histogram was estimated by averaging the volume fractions which receives EQD2Gy in the same dose interval for a given OAR. The NTCPs values for both models were also estimated using this average EQD2Gy-volume histogram. The feasibility of this approach was compared with the results using the individual information of each patient.
The ranking of the models was based on Akaike's information criterion (AIC). The effect of alpha/beta variability on NTCP was studied generating normal-distributed sequences in the interval like mean value +/- standard deviation. A sequence (2000-3000) of alpha/beta values was generated and the NTCP for each one was calculated. The set of alpha/beta was generated using the Box-Müller polar method. The mean NTCP for the OAR was then calculated by averaging overall NTCP values.
Conclusion The variability of alpha/beta in the calculation of NTCP produces curves less steep than those when a fixed alpha/bta value is used. The effect increases as alpha/beta is diminished and it was also observed for both branches. Similar effects have been described for tumor control curves which must be included in the algorithm for biological evaluation of radiotherapy plans. There was no significant difference between the calculations done with the NTCP models used considering the AIC calculation. The mean BED produced a similar description than those made with EUD or UBED even considering the differences in the consideration of volume effects. Nevertheless the *effective* alpha/beta correction will be useful for the biological evaluation of treatment plan that includes the tumor DVH.

Radiobiological modeling and treatment planning for sequential and concurrent combination of internal and exter- nal radiotherapy modalities

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The use of therapeutic schemes combining external beams radiotherapy (ERT) with internal radiotherapy (IRT) using radiopharmaceuticals could be a promising alternative for patients with multiple lesions or those where treatment planning maybe difficult to fulfill the organ(s)-at-risk (OARs) dose constraints. Since the temporal and spatial patterns and levels of dose delivering are different, these issues should be regarded for any formulation developed with the goal of biological evaluation or ranking in the treatment effectiveness. It has been further recommended the use of dose-response magnitude like Tumor Control Probability (TCP) and Normal Tissue Complication Probability (NTCP) for biological treatment planning or for evaluation of pre- scriptions. In this work is evaluated an extension of LQ model for radiobiological evaluation of CIERT treatments through the calculation of TCP and NTCP. On the other hand, it was studied how this formulation could be used to determine the CIERT conditions: administered activity, number of administrations for IRT as well as the dose per session and number of session for ERT that produce an iso-effective response. The results of calculations for several simulated clinical situations are also shown. The synergistic effects of combined irradiation were studied through the calculation of the Biologically Effective Dose (BED) adapting the LQ model for CIERT schemes. For IRT the dose rate was considered as multi-exponentially variable in time. For external radiotherapy was considered the standard fractioning of 2Gy per session with complete repair between fractions. Two conditions were regarded: (a) *sequential CIERT* (sCIERT): each irradiation is carried out one after the other one regardless the order and both separated by an interval t and (b) *concurrent CIERT* (cCIERT): both irradiations will be given at the same time. It was considered that external irradiation is delivered in the course of a single administration of radiopharmaceutical. The calculation considered the probability of lethal damage produced due to cross-interaction of sub-lethal damages produced by IRT and ERT.

Dose spatial distributions in tumor (PTV) and OARs with different heterogeneity degree were considered. For three-dimensional dose distributions the calculations must be done for each voxel in the Volume of Interest (VoI). For IRT was considered that all voxels, either PTVs or OARs have the same rate constants (uptake and elimination). The biological effect of the heterogeneity in the dose distribution into the VoI was evaluated by the calculation of the Uniform Dose Equivalent Biologically Effective (EUBED). The formulation was extended to the case of IRT with multiple administrations of the therapeutic radiopharmaceutical considering the interval between two successive administrations is such that accumulation is not observed. However, it should be noted that in case of cCIERT the combination must happen in the course of a single administration like it was previously supposed in the BED calculations. It was supposed that the same administered activity in each IRT session and no further changes will occurs in the radiopharmaceutical biodistribution (the uptake fractions will remained almost constant).

Iso-effective figures were calculated for the different conditions tested like comparing the feasibility of therapy schemes with IRT or ERT alone and CIERT (sequential or concurrent). The input variables are: administered activity per session and number of administrations for IRT and dose per session and number of sessions for external radiotherapy.

The TCP(D) (Poisson) and NTCP(D) (LKB) profiles were built considering the effects due to the heterogeneity in dose distribution, the radiosensitivity in the tumor irradiated volume and the OAR´s volume irradiation fraction.

The synergetic effects of CIERT schemes were more observable in normal tissue (alpha/beta=3Gy) than tumors (alpha/beta =10Gy). It was also dependent of radiobiological parameters and its heterogeneity degree. This could be important if hypo-fractionated ERT is planned to be used as part of combination. The radiopharmaceutical biokinetics was also relevant. Special care should be taken if high uptake of radiopharmaceutical is observed in critical tissues near to the irradiated target. This situation must be carefully evaluated for those cases where the CIERT schemes might be a feasible alternative when the tolerance level constraints in all OARs involved are not fulfilled during the treatment planning using ERT alone.

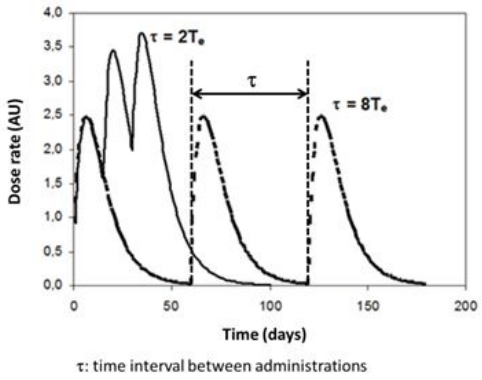

Figure 1. Internal dose rate profile for internal radiotherapy with multiple administrations

Conclusions The formulation developed could be used for the validation of treatment prescription in case of CIERT for sequential and concurrent scenarios. The inclusion of variability of LQ parameters in the calculation of TCP and NTCP must be taken into account because the curves will changes. It must be noted that in the case of cCIERT, the time interval between administrations should be chosen so that the combination of treatments occurs only in one IRT session what is dependent of biokinetics parameters of radiopharmaceutical. The formulation will allows also the planning and may be useful for optimization when conformal boosting using targeted molecular radiotherapy with radiopharmaceuticals might be a good alternative.

Neutron-gamma mixed field dosimetry on a child phantom under therapeutic proton irradiation using TL dosimeters

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Introduction: During proton therapy energetic proton beams deliver a highly conformal dose to the primary tumor mass; thereby, reducing unwanted radiation exposure to the neighboring healthy tissue. These unique characteristics provide significant therapeutic advantages in comparison to the well-established photon-therapy. However, a significant number of secondary particles, predominantly fast neutrons and gamma-rays, are produced by the interaction of the main proton beam with the beam shaping and modifying devices located inside the beam delivery nozzle as well as from the irradiated volume itself. This results in an unwanted increase in radiation exposure of sensitive organs located outside of the treated volume, thereby increasing the risk of second cancer incidence. Children are more vulnerable to 2nd cancer risk than adults due to longer life expectancy, shorter distance between organ at risk and primary radiation source and higher cell differentiation rate of organ tissues of interest. This paper presents the application of twin-TLD (TLD-500 and TLD-700) dosimetry technique developed at WPE for in-situ estimation of the out-of-field neutron and gamma dose equivalents. The TLD pairs were placed on selected organ locations of an anthropomorphic phantom while a simulated 125 cm3 skull based tumor was irradiated with protons in uniform scanning (US) mode. A prescribed dose of 2 Gy in a single fraction was delivered in three fields. The results and dosimetry protocol from this benchmark experiment could be used to estimate the neutron and gamma dose equivalents during proton irradiation of a child phantom, emulating a pediatric cancer patient.

Methods: Commonly used TLD-700 (7LiF:Ti,Mg) dosimeters are highly sensitive to gamma rays. On the other hand, the high-temperature region (HTP) of the TL-glow curve of TLD-700 is also responsive to fast neutrons, however, contaminated with gamma background. Hence, a method to eliminate the gamma background of the HTP region using primarily gamma sensitive TLD-500 (Al2O3:C) dosimeters has been developed. A polystyrene plate phantom (20 cm x 20 cm x 30 cm) was bombarded with 170 MeV protons to produce high-energy neutrons of similar energy distribution like neutrons generated during proton treatment of tumors. A Wide Energy Neutron Detection Instrument WENDI 2 (capable for dose equivalent estimation of neutrons from thermal to 5 GeV energies) was used to cross calibrate the TLD chips. The TLD chips were evaluated using a hospital based TLD reader and annealed thereafter. The annealed pairs of TLD-500 and TLD-700 chips were attached to the location of Left/Right Eye, Thyroid, Left/Right Lungs, Stomach and Gonad of the child phantom. A simulated skull-base tumor (125 cmˆ3) was irradiated with a single fraction 2 Gy proton dose.

Results: The gamma background correction factor (kG), gamma (fG) and neutron (fN) dose equivalent conversion factors are given as:

kG = TLD700AHTP /TLD500AMP (1)

fG (mSv/nC) = calibHG/TLD700AMP (2)

fN (mSv/nC) = calibHN/(TLD700AHTP-kG xTLD500AMP) (3)

Where, TLD700AHTP and TLD500AMP are the high-temperature peak of TLD-700 and main peak of TLD-500 chips respectively. Furthermore, calibHG and calibHN are the calibration gamma and neutron doses delivered to TLD-500 and TLD-700 chips respectively.

By substituting the numerical values in equations 1, 2 and 3 the gamma (FG) and neutron (fN) dose equivalent calibration factors were evaluated to be 1.68 x 10ˆ-5 and 1.22 x 10ˆ-4 mSv/nC respectively.

The organ specific out-of-field gamma (OrganHG/DP) and neutron (OrganHN/DP) dose equivalent per delivered proton dose (DP) were calculated as follows:

OrganHG/DP (mSv/Gy) = fG x TLD700AMP (4)

OrganHN/DP (mSv/Gy) = fN x (TLD700AHTP-kGxTLD500AMP) (5)

Using the TLD readings the organ specific gamma and neutron dose equivalents were estimated explicitly and the results are depicted in Figure 1.

Conclusion: During proton therapy predominantly high-energy neutrons with energies up to excess of 100 MeV prevail outside the treatment volume. These high-energy neutrons essentially contribute to risk of second cancer at out-of-field organs. The risk is higher in child patients due their smaller

physical size and longer life expectancy. The twin-TLD method for explicit estimation of out of field gamma and neutron dose equivalents requires a common hospital/clinic based TLD reader and an annealing oven. Technicians can conveniently sterilize the tiny dosimeter holders sealed in pouches prior to routine clinical applications. The technique is ideally suited for dosimetry procedures where high spatial resolution (i.e. small detector size) and direction-independence of detector response are required, in particular for pediatric proton therapy cases. At West German Proton Therapy Center Essen (WPE) the results of these benchmark measurements have already been implemented to study the second cancer risk of pediatric patients of various cancer indications, ages and genders.

Patterns of practice of radiation therapy and/or chemotherapy in Africa for gastrointestinal cancers - An audit

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Purpose: To provide data on the pattern of practice of radiation chemotherapy for GIT cancers in African continent

Methods and materials: A questionnaire was distributed to participants in the Regional training course on Gastro-intestinal cancers of International Atomic Energy Agency under the project RAF6045. This course was held from 20-24th October 2014 at International atomic energy agency headquarters at Vienna, Austria and attended by 13 countries and 25 oncologists with 1-5 oncologists from each country. The course included lectures on management of various GIT cancers including interactive discussion sessions. Requested information included both infrastructure and human

resource available and pattern of treatment (radiation therapy chemotherapy) in gastrointestinal cancers.

Results: The population catered by different centres varied from 1.5 – 8 million and the number of staff inclusive of radiation oncologists, radiation therapists as well as medical physicists ranged from 2- 52. Seventeen (71%) of 24 oncologists attending the course practised chemotherapy and radiation for management of their cases with 8 having a separate medical oncology department. Thirteen centres had between 1-10 surgical oncologists or gastrointestinal surgeons. Twenty –three centres have between 1-7 machines with 10 centres having linear accelerators alone, 3 cobalt and linear accelerators and 10 cobalt alone. Eleven centres have conventional simulators and 14 CT simulators. Treatment planning systems are available at 19 departments with capability for 3D treatments in 14 centers.The number of GIT cancers seen ranged from 10-1000/ year in different centres. Gastrointestinal cancers seen at various departments included, oesophagus 5-67/year; stomach 5-26/year; rectum 10- 60/year; colon 5-50/year and anal canal 4-27/year. In, 21 centres, >60 % cancers presented at a late stage. Seventeen/departments of the 24 institutions have multidisciplinary meetings and discussion for management of cancers. Chemo-radiation is used by 12 centres for management in 15-100% patients. Nineteen (79%) departments use treatment guidelines either developed locally or recommended internationally for treatment. The median waiting period for patients to start treatment is 60 days (14-240 days). The radiological investigations done at each centre include ultrasound in 12/24(50%); CT scan in 11/24(46%), MRI 5/24(21%).The follow up clinics are active in 20/24(83%) departments and rehabilitation services are present in 10/24 (42%) departments.

Conclusion: Majority of patients with GIT cancers present in late stages in African countries. Combination of Radiation therapy and chemotherapy is used in most of the centres for management of these cancers.

Session 8 - Education and training **/** 140

ICTP, Trieste University, italian and croatian medical physics: a training opportunity for young physicists from developing countries

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Introduction The Abdus Salam International Centre for Theoretical Physics (ICTP) and the Trieste University have initiated in 2014 a Master of Advanced Studies in Medical Physics a two-years training programme in Medical Physics. The programme is designated to provide young promising graduates in physics, mainly from developing countries, with a post-graduated theoretical and clinical training suitable to be recognised as Clinical Medical Physicist in their countries. Presently, the 3 cycles of the programme have seen 49 participants from 33 Countries: Africa (19), Asia (11), Central and South America (14), and Europe (5), selected from more than 400 applicants per year. Scholarships are awarded to candidates from developing countries with support of the IAEA, TWAS (Third World Academy of Sciences), KFAS (Kuwait Foundation for the Advancement of Sciences), ACS (American Cancer Society), IOMP, EFOMP and ICTP.

Material and methods The programme is developed following the recommendations of IOMP and IAEA for education and clinical training. In the first year 332 lectures and 228 hours of exercises are devoted to all main fields of medical physics: Anatomy and physiology as applied to medical physics, Radiobiology, Radiation physics, Radiation dosimetry, Statistics, Monte Carlo simulation, Physics of nuclear medicine, Medical physics imaging fundamentals, Physics of diagnostic and interventional

radiology (X rays, US, MRI, Hybrid systems), Physics of radiation oncology, Radiation protection, Information technology in medical physics. Each course has a final written or oral exam. The second year is spent in one of the 19 Medical physics department of the hospitals' network for the clinical training in: radiation oncology or diagnostic and nuclear medicine, on a programme developed adapting the IAEA (TCS 37, TCS 47 and TCS 50) and the AFRA guidelines. The clinical training is developed following a pre-defined Portfolio of activities, adapted for each Resident according to their previous experience in the field. The recommended time devoted to each sub-topic of Radiation Oncology is reported in the table 1.

Conclusions IOMP, EFOMP and IAEA are seeing this initiative, a unique experience at the world level, as an answer to the growing demand of Medical Physicists in developing Countries. The programme has been recently received an international accreditation by IOMP and represents an important contribution of the European medical physics community to the development of medical physics in the developing world.

Friday morning - Poster Presentations - Screen3 **/** 141

Impact of international networking on advancing radiation oncology training in a war-torn country – experience from Iraq

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Background: A radiation oncology training program is a critical element for capacity building of human resources in radiotherapy service worldwide. In spite of the great challenges facing Iraq, a war-torn country since early 1980s, the 1st high level of specialized training program in radiation oncology (4 year post-graduate board study program) was successfully established in mid-2013 under the aegis of the regional Ministry of Health and Ministry of Higher Education and Scientific Research. However, due to some gaps in some of the local expertise, a global outreach to institutes and individuals was approached and networking had been achieved to invite some of the internationally qualified experts to visit the training center and supplement locally available expertise. The authors here are trying to elaborate these efforts in advancing the level of radiation oncology training program in Iraq. It is hoped that this is of interest to the global radiotherapy community. Methods: Description of the efforts and expertise that joined the radiation oncology training program in Iraq. Results: After getting the approval to establish the 1st board program in radiation oncology in Iraq in late 2012, based in Zhianawa Cancer Center (ZCC) **/** Sulaymaniyah city, under the auspices of the Kurdistan Board for Medical Specialties (KBMS) and the real start of this program in July 2013 by accepting four trainees, networking was started by signing up some memoranda of understanding “MoU” with some training institutes

/ cancer foundations abroad and by approaching some of international experts to physically visit the training center on voluntary base for some period of time, to further support the local training program. As a result, four “MoU”s were signed with institutes **/** foundations in the USA, Canada, India and Turkey and seven colleagues accepted the invitation and joined the training program in Iraq for some periods of time, ranged from three days to two weeks. Together, this provided a comprehensive cover for the training requirements at that stage. The educational visits were achieved by the visits of experts in tumor pathology (from USA), in medical physics (from KSA and USA), in radiation oncology (from Jordan and Canada) and in clinical oncology (from UK). For the outcomes, we have achieved the following: 1. Launch of the Multi-Disciplinary Oncology Course (MDOC) Iraq series in its 1st copy for 5 days about general oncology in February 2015 and in its 2nd copy for 2 days about gynecology oncology in September 2016.

The 1st Best of ASTRO (BOA) Iraq meeting in December 2015, officially licensed by the American SocieTy for Radiation Oncology (ASTRO), where 90 top abstracts from the 2015 Annual ASTRO meeting have been presented in Iraq.

Launch of the 1st modern, high dose rate, 3D brachytherapy service in August 2016. This has established ZCC as a tertiary referral center for Iraq. 4. Receiving some trainees and staff from ZCC to get on-site attachment abroad (in the USA, India, Italy, Jordan and UK). 5. Covering the required 45 teaching hours in medical physics syllabus. 6. Sharing as external examiners in the Objective Structured Clinical Examination (OSCE) and the final exit practical exams and evaluations in ZCC and KBMS.

7. On-site patients’ consultation, remote consultation in addition to many clinical teaching sessions.

Conclusions: International networking has helped shape and advance the 1st radiation oncology

training board program in Iraq. Within a carefully structured program, focused educational sessions / visits in addition to on-site / remote consultations were achievable and practical. Beside the education of the residents, the impact of these professional visits was extended to other oncology practitioners and to medical physicists and ultimately to our patients, through the increased quality of services provided. Given the difficult circumstances Iraq is going through over the last few years, this is considered a major progress. This knowledge sharing model can be transferred to other communities with similar challenges of limited budget and expertise.

Session 8 - Education and training **/** 142

Accreditation of education and professional standards of medical physicists

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Introduction Medical physicists practicing in clinical environment, as defined by IOMP and in IAEA International Basic Safety Standards 2014, are health professionals with education and specialist training in the concepts and techniques of applying physics in medicine, competent to practice independently in one or more of the subfields of medical physics. The need for medical physicists and their important roles and responsibilities in radiation oncology are well defined by IOMP and in IAEA Human Health Series No. 25. Medical physicists practicing in radiotherapy are key members of an interdisciplinary team in the radiation oncology department dedicated to providing safe and effective treatment of cancer. Their ability and performance has a direct impact on the quality and safety of the radiotherapy services. Hence, they should be well qualified with professional knowledge and competence and be able to apply appropriately and effectively the principles of radiation physics in the clinics and to make major contribution to radiotherapy service. IOMP advocates the need for medical physicists practicing in medical institutions be qualified by going through an appropriate system of education, professional training and professional accreditation in a similar manner as other health professionals. IOMP also advocates the need for all medical physicists in different parts of the world to be qualified in a similar manner and practicing with the same standard of professional competency. The work of the IOMP pertaining to maintaining a high standard of practice by the medical physicists across the world is described in this presentation.

Methodology A global uniformity in standard of practice of the medical physicists is important in the battle against cancers as this ensures that all patients can receive safe and effective treatments. To achieve this objective, there is a need to apply and maintain equivalent standard of education, training and professional development for medical physicists in different countries. Unfortunately, as reported by IAEA Human Health Series No. 25, there is a large variation in the requirement and format of education and training for medical physicists from different countries. Although, guidance on education and professional training of medical physicists has been issued by IAEA and IOMP, formal education and clinical training of medical physicists are yet to be established in many countries. IOMP in collaboration with a number of its member organizations established an international system of professional certification, the International Medical Physics Certification Board (IMPCB). Medical physicists certified by the IMPCB for instance in radiation oncology physics are considered qualified to practice independently in this sub-fields of medical physics. IOMP considers it more appropriate for medical physicists to be certified by their own national certification board as this could incorporate in the certification examinations country specific requirements and characteristics, such as local regulatory requirements, country specific clinical practice, and national language. Instead of certifying the individual medical physicists, IMPCB conduct accreditation on national certification boards. Only in situations where formation of national certification board is impractical, e.g. due to small number of practicing medical physicists, that IMPCB may consider certifying individual medical physicists. In addition, IOMP recommends that medical physics education and training programmes be subject to independent accreditation or audit. Such activities exist in a number of developed countries, but do not exist on international level. The Organization has established an Accreditation Board for accreditation of medical physics education programme. The Board has completed a pilot accreditation on established programmes. Full implementation of the accreditation programme will soon be launched, what will greatly help maintaining the medical physics educational standards in many small countries. IOMP is also considering to set up in future an Accreditation Board for audit of medical physics clinical training programmes. As stated in its Policy Statement No. 2, IOMP considers continuing professional development (CPD) an essential part of the professional credential of the medical physicists. The quality of the CPD programme on offer to medical physicists by a national organization is evaluated during accreditation of national certification board.

Conclusion In an attempt aiming to improve the standard of practice of the medical physicists to better support radiation therapy service and other medical physics activities on a global basis, an international system of quality audit on standard of education, training and professional practice of medical physicists is being implemented by IOMP. The audit system consists of three parts, namely, (1) professional

certification of medical physicist and this has already been implemented by IOMP in collaboration with IMPCB; (2) accreditation of medical physics education programmes and a pilot run of this has been completed by IOMP; and (3) accreditation of medical physics clinical training programmes, a future task of the IOMP. These audit programmes will likely have significant positive impact on standard of practice of the medical physicists and quality of radiation therapy service across the world.

Chemoradiation in hiv positive patients with FIGO stage IIIB cancer of the uterine cervix

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Background and Purpose: Invasive cancer of the uterine cervix is the most common cancer and the leading cause of cancer-related mortality among Zimbabwean black female population. A high HIV prevalence of 43.5% has been reported among our cervical cancer patients in an unpublished retrospective study. HIV positive population tends to present with cancers at a younger age with more advanced disease and have tendency to poor tolerance to treatment and poor treatment outcome. Various randomized controlled trials conducted in the developed world confirmed chemoradiation as the gold standard treatment for locally advanced cervical cancer. There is however paucity of data on how these patients fare on treatment in a resource limited environment with a background of high HIV prevalence. The purpose of this study was to document the treatment tolerability and outcomes for HIV positive patients within the FIGO IIIB cervical cancer group.

Material and Methods: A retrospective study of a cohort of HIV positive patients with histologically confirmed invasive cancer of the uterine cervix FIGO IIIB referred to Parirenyatwa Central Hospital Radiotherapy and Oncology Centre (PGHRTC) from 1 January 2013 to 31 December 2014 was carried out. Study subjects' records were reviewed and data collected with regards to patient's and disease characteristics, mode and dose of radiotherapy given, number of chemotherapy cycles received, adverse events reported during treatment, number of unplanned hospital admissions and breaks during treatment, whether treatment was completed or not and response to treatment at 3 months post treatment review. Epi-info version 3.5.1 and Stata version 12.1 statistical packages were used to analyse the data.

Results: 128 patients with FIGO IIIB cervical cancer received chemoradiation during the study period. The patients' ages were normally distributed, with a mean age of 50.8 $\pm$ 10.3sd years. HIV status was documented in 124 patients. 65/124(51%) patients were HIV positive and 64/65(98.5%) patients on were on HAART. Younger patients dominated the HIV positive group with a mean age of 45.4 $\pm$ 8.5sd years. 59/65 (91%) of HIV positive patients had documented baseline CD4 counts with a mean **of** 526 $\pm$ 233(sd) cells/mm^3, a median of 534 cells/mm^3 and a range of 155-1099 cells/mm^3. 27/65 (45.8%) patients had a CD4 count < 500 cells/mm^3. 64/65 (98.5%) were on HAART. HIV positive patients had slightly bigger tumours even though there was marked overlap. All patients received chemoradiation with curative intent. Only 37/128 (29%) of patients received 4cycles of chemotherapy during treatment, 28 of these were HIV positive. A higher proportion of the HIV positive patients (43%) received 4cycles of chemotherapy compared to the HIV negative ones. None of the patients was able to complete 6 cycles, the most cited reasons being financial(44.44%), neutropenia(20.20%) and renal impairment(13.79%).Treatment side effects contributed only 3.4% to the reasons for unscheduled treatment breaks. Overally treatment was tolerated very well regardless of HIV status or disease extent. 183/1035 (18%) recorded toxicities were grade3-4, 50% of these were recorded in HIV positive patients. 10/14 (71.4%) patients who had grade 3-4 haematological tocities were HIV positive. 127/128 patients completed chemoradiation. All the 65 HIV positive patients completed treatment. Higher proportion of patients achieving complete tumor response at 3 months were noted in the those with following characteristics: age 45years, pretreatment Hb 10g/dl, HIV negative, HIV positive with CD4+ 500 cells/mm^3, Tumor size <7cm in greatest dimension, No hydronephrosis, no lower third vaginal involvement, squamous cell carcinoma histological type, poorly differentiated histology, received ≥ 4cycles of chemotherapy and no treatment breaks during chemoradiation

Conclusion: The study revealed that chemoradiation is well tolerated in HIV positive patients receiving chemoradiation fo FIGO stage IIIB cancer of the uterine cervix though with a high risk for grade3-4 haematological toxicities. Good HIV control , using CD4 as a surrogate, was associated with better tumor response. Response to treatment, however, vary among these patients depending on various factors which include patient characteristics, disease characteristics and treatment factors. A follow-up prospective study on chemoradiation in this group of patients is recommended.

Session 10b - Small field dosimetry **/** 144

Initial experiences in testing: the IAEA/AAPM code of practice on small field dosimetry

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Purpose: The International Atomic Energy Agency (IAEA) has established a coordinated research project focusing on clinical testing of the procedures described in the upcoming IAEA/AAPM code of practice on small field dosimetry. The initial task was the determination of beam quality based on square fields with different sizes using a standard MLC shaped 6 MV photon beams. Additionally, field output factors ($W^{f_{clin},f_{ref}}_{Q_{clin},Q}$) were determined for field sizes ranging from 10 x 10 cm^2 down to 0.5 x 0.5 cm^2.

Materials and Methods: Thirteen participants from different countries were asked to experimentally determine the $TPR_{20,10}(S)$ or \%dd(10,S){X}in4x4cm^2(S=4)and6x6cm^2(S=6)6MV flattenedphotonfield.The4x4cm^{2}and6x6cm determined in the 10 x 10 cm^2 field. Furthermore, the centers were asked to determine field output factors according to the IAEA/AAPM code of practice on small field dosimetry for field sizes ranging from 0.5 x 0.5 cm^2 to 10 x 10 cm in a 6 MV flattened photon beam using at least three different detectors. For each center, the standard deviation with respect to the mean value of the field output factors measured with these three different detectors was calculated for each field as a measure for the agreement amongst the determined field output factors.

Results: So far, the data of eight machines using $TPR_{20,10}$ and seven machines using \%dd(10){X}werecollected.TheTPR{20,10 For the relative dosimetry task, the data of eight centers was been received so far. As depicted in Figure 1, for the majority of centers the standard deviations of field output factors was below 1% over a wide range of field widths. An increase of the standard deviation with decreasing field width over the 1 % threshold was observed for five centers at a field

width of 1 x 1 cm^2. For two of these centers the standard deviation dropped below 1 % at the 0.5 x 0.5 cm^2 field. In total, five centers submitted a sufficient number of field output factors for the 0.5 x 0.5 cm^2 field. The standard deviations of these field output factors was below 1%.
Conclusion: The formalism proposed in the IAEA/AAPM code of practice on small field dosimetry for determination of beam quality in a 10 x 10 cm^2 based on experimental data in machine specific reference fields can be applied with a sufficient degree of accuracy. The slightly larger differences between the calculated and experimentally determined beam quality specifiers observed for $\%dd(10, 10)_X$ might be related to uncertainties associated with automated scanning phantoms.
The increasing variation of field output factors with decreasing field size might be attributed to positioning uncertainties of the detectors and uncertainties of the applied correction factors.
Further investigation regarding this topic is necessary. {X}valuesrangedbetween66.4
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Survival and prognostic factors in non metastatic breast cancer

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Issue: Breast cancer is the most common cancer of women in Tunisia and in the world. It represents a serious public health problem. Several studies have identified its standardized incidence, including two medical doctoral theses supervised by the radiotherapy department of the Salah Azaiz Institute of Tunis. Data about the prognosis and the evolutivity of this disease are not current. The study of survival and prognostic factors is essential to improve the prognosis of this disease.
Purpose: The aim of this study was to describe the clinical and therapeutic features of non-metastatic breast cancer, to calculate the overall survival at 5 years and 10 years, to investigate the prognostic factors of overall survival and disease-free survival, and to compare our results to those of a similar Tunisian study performed in 1994.
Materials and methods: This is a retrospective study of 474 patients with non-metastatic breast cancer diagnosed between January 1, 2004 and December 31, 2004, treated and followed at the Salah Azaiz Institute. Clinical, histological, therapeutic data have been collected. The patients have been divided into Groups according to T stage (Group 1: T0, T1, T2 and T3, Group 2: T4a, and T4b T4c, Group 3: T4d tumors) in accordance to the grouping method used in 1994. Our series of patients were also classified into Stages according to the classification of the AJCC 2010. Overall survival factors were studied for groups 1 and 2 and the disease-free survival factors were studied for the group 1, in order to compare our results with those of 1994. Similarly, overall survival factors were studied in the different stages in order to compare our results to the literature data. Univariate statistical analysis has been done by the Kaplan-Meier method and multivariate analysis by Cox regression method.
Results: Our study concerned 474 patients, including 12 (2.5%) men. The mean age was 51.8 years. The average clinical size was 39 mm. Stage II was the most common (55.9% of cases). Stage III accounted for 26.8% of the patients and inflammatory tumors 4.4% of the population. The median follow-up was 93 months. Distant failure was the most frequent way of relapse since 28.9% of patients developed metastasis during 10 years of follow up. Overall survival was 74.4% at 5 years and 54% at 10 years for all stages with an average survival of 95.8 months. There was a statistically significant difference between the different stages in terms of overall survival and disease-free survival ($p < 0.05$). Independent factors of overall survival in stage II were tumor size, hormonal status, surgical limits and metastatic relapse. In stage III, we have retained the hormonal status and metastatic relapse as independent factors for overall survival. After univariate analysis, younger age and high grade SBR were the significant factors of local recurrence after conservative surgery ($p \leq 0.05$). Yet, extracapsular extension in involved lymph nodes, was the only significant factor for local recurrence after mastectomy ($p \leq 0.05$). Young age, tumor size, an in situ component, extracapsular extension, hormonal status and local recurrence were significant factors for lymph node recurrence in the group of localized tumors ($p \leq 0.05$). Prognostic factors for metastatic recurrence-free survival were searched in stages I and II. univariate analysis, we have retained tumor size, lymph node status, number of involved lymph nodes, hormonal status, local recurrence and regional recurrence as significant factors for distant relapse in stage II. In stage III, age, time between surgery and radiotherapy and nodal status have emerged as significant factors for metastasis free survival. A comparative study between our results and those of the 1994 cohort has found a gain of 20% in terms of overall survival as the overall survival rate at 5 years was 53.2% in 1994. The difference in survival between two periods was statistically significant and was also observed at the specific survival. This survival benefit would be due to a decrease in tumor size at diagnosis (52 mm in 1994 vs 39 mm en 2004) and consequently a decrease in the rate of stage III tumors and especially the rate of inflammatory breast cancer (10% in 1994 vs 4 4% in 2004). It would also be due to a decrease in the rate of lymph node invasion (76.8% in 1994 vs. 59% in 2004) and to a greater use of conservative surgery, chemotherapy, and endocrine therapy for the series of 2004 compared to the year1994. Conclusion: The prognosis of our patients was particularly related to the stage of the disease and the quality of care reflecting some shortcomings of the health system. The improvement of prognosis between 1994 and 2004 was encouraging and impels to multiply efforts to establish early diagnosis and better health care.

Workload patterns in the department of radiotherapy in Salah Azaiez Institute : year 2012

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Background : Regular assessments in radiation therapy facilities are mandatory to meet demands and much safety standards. There is no comprehensive statistical analysis in the radiation therapy department of Saleh Azeiez Institute (SAI). The aim of this study was to assess the workload of the SAI's radiotherapy department with a description of technical features in treatments and epidemiologic characteristics of treated patients.
Methods : We performed a retrospective survey in patients recorded in SAI since January the 1st 2012 to December 31th 2012 who received radiotherapy in SAI during 2012 and after until June the 1st 2014. We analyzed pathologies, age, gender, treatment intent, dose, attendances, fractions, treatment machines and treatment techniques.
Results : There were 1548 patients treated. The total number of treatment courses was 1675 with 1451(88%) courses of external beam radiation therapy (EBRT) and 206 (12%) courses of brachytherapy. There were 1364 (88%) patients treated with EBRT among them the reirradiation rate was (6,3%). A total number of 27801 attendances was delivered. Total Fractions number was 30232. The mean of each megavoltage machine throughput was 445 patients, 475 treatment and 9745 fractions. The most frequent pathologies were breast cancer (36%), head and neck cancer (17%) and lung cancer (10,9%). The mean age of patients was 53 years. Females proportion was 57% and male proportion was 43%. Treatment intent was curative in 74% of cases and palliative in 26% of cases. The EBRT technique was 2D in 91% of cases and 3D in 9% (technique started in 2011).
Conclusion : Practices in SAI's radiation therapy department met international standards with regard to workload with an ongoing process of implementing new techniques.

Cost of radiotherapeutic management of patients with cancer in regional cancer center in India

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Introduction: With around 10,00,000 new patients with cancer annually, India accounts for more than half of burden of cancer patients in developing countries. Multi-modality management of cancer, technologic and skill intensive diagnosis and therapy causes significant strain on already burdened health-care system of developing countries. Grant-in-aid is provided by government, various national and international organizations to facilitate prevention and management of cancer in resource-poor countries like India. However optimal utilization of these resources requires computation of cost of cancer management of individual cancer by site / system and histology. Political pressure has become drivers in reducing waiting time and provision of any radiotherapy to patients presenting to oncology centers. In such milieu, we need to compute the cost of radiotherapy in developing countries to plan for future budget outlay and investment. Methods: Data regarding technology/technique required to start any radiotherapy for patients with cancer was obtained from radiotherapy planning register. Data of patients with cancer treated by single radiation oncologist in Department of Radiation Oncology, Kidwai Memorial Institute of Oncology, Bangalore from August 2012 to October 2016 was collected. Results: Cost of 3D conformal radiotherapy management of 12 pediatric tumor, 50 brain tumors, 70 head and neck cancer, 20 thoracic malignancies, 6 breast cancer and 5 gynecologic malignancies were INR 2,40,000, 32,10,000, 53,40,000, 15,00,000, 4,10,000 and 3,40,000 respectively. Cost for radiotherapy management of around 480 patients is 8400000, 1080000, 1176000 and 192000 for Co-60 teletherapy, HDR brachytherapy, LDR brachytherapy and x-ray simulation respectively. Conclusion: 3D conformal radiotherapy for nearly 160 patients costed INR 1,10,40,000 and treatment by Co-60 teletherapy for management of 480 patients costed INR 8400000 over the period of four years. Treatment by 3D conformal radiotherapy is 3 to 4.5 times more expensive that that by Co-60 teletherapy equipment. However, malignancies of brain, lung, nasal cavity, nasopharynx, stomach, pancreas, gall bladder, prostate, pediatric tumors are best managed by 3D CRT or IMRT.

Analysis of setup incertanties generated in 6D ExacTrac X- Ray system for patients in hypofractionated treatments of intracranial radiosurgery

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Introduction With the growing technology in radiotherapy, the complexity of treatment planning has been increasing and higher doses have been delivered to tumor, so it is necessary to assess the accuracy of patient setup in order to guarantee better compliance of tumor with greater protection of healthy tissues. To achieve this goal, image guided radiotherapy (IGRT) is mandatory role, especially for hipofrationated treatments, such as cranial radiosurgery. The ExacTrac X-Ray 6D BrainLAB is an IGRT system that uses an infrared (IR) system for pre-positioning, robotic table with six degrees of freedom and two orthogonal X-rays tubes for imaging. Using IGRT it is possible to reduce PTV margin to minimize dose delivered to normal tissue, but it is necessary to reduce setup uncertainties. These uncertainties can be separated into random and systematic errors. A systematic error may be understood as an average variation occurred during the treatment. A random error on the other hand, can be defined as the dispersion of systematic errors over time of treatment. The purpose of this study is to evaluate setup uncertainties for patients treated with radiosurgery intracranial hypofractionated using IGRT with ExacTrac.
Materials and Methods *Exactrac System* Treatments localization based on the ExacTrac X-Ray 6D system includes two steps: a pre- positioning using IR and X-ray verification images. The IR component has two emissors of IR waves and two cameras installed on the ceiling to read the signal that is reflected by reflective beads distributed on the surface of the patient or on a localization box. Using this information an automatic setup can be easily determined by moving the table to coincide with the positioning marks determined by the CT image. The X-ray component consists of two orthogonal X-ray tubes installed on the floor and two panels on the ceiling. Two orthogonal X-rays images are obtained and compared with reference bone anatomy using automatic fusion to DRR images generated by exactrac software. The result of comparison gives the setup uncertainty in six degrees of freedom: three translational and three rotational.
Treatment: We evaluated 36 patients treated with intracranial hypofractionated radiosurgery from August 2015 to October 2016 in a Varian linear accelerator 6EX. The dose prescribed was 25-30 Gy in 5 fractions for 30 patients and 12-18 Gy single fraction for 6 patients. Immobilization of the patient was taken with BrainLab masks. This mask is comprised of three reinforcement strips of thermoplastic material arranged in the forehead, nose and chin. The treatment isocenter were pre-localized using the localization box and correct the positioning after taken X-Ray images. The first image deviations were not considered in the analysis. During the treatment, in each angle of table it was taken images and the variations calculated were corrected if it was outside limits acceptable range (0,7 mm for translation and 1^{o} for rotation). The corrections were recorded for future analyses. Deviations generated in the translational coordinates (vertical, lateral and longitudinal) and rotational (roll, pitch and yaw) were analyzed and expressed in terms of mean values and their standard deviations. The random error distribution (RMS(si)),variation in systematic error (S(mi)) and overall distribution of setup corrections (Soverall) were determined as presented by Infusino, Erminia et al.
Results We had a total of 656 X-Ray images. All these measurements were used to calculate the errors presented on Table 1. The systematic error in the lateral, longitudinal and vertical was very small, 0.14, 0.26 and 0.15 mm respectively. Random component was a little larger, ranging from 0.3 to 0.6 mm, probably because small internal movements of the brain, fixation power of the mask, inaccuracy of the fusion algorithm of the Exactrac, inclusion or exclusion of certain anatomic features, inter-observer variation in the interpretation of daily images. The maximum overall error was 0.6mm. Additionally, the rotational correction were relatively small, ranging from 0.1 to 0.6^{o}. The 3D vector could be calculated for the translational components, the value found was 0.9 mm.
Conclusions The magnitude of the random, systematic and overall errors was quantified. The random component was larger than systematic one, opposite to that expected by the literature, showing as the Exactrac system is able to reduce the magnitude of systematic errors, so that the random error demands a little more attention, even because this kind of error is naturally difficult to minimize. But,

even with larger random errors, the value of the 3D vector was sub millimeter (0.9 mm). This study emphasizes the importance of daily IGRT and the importance of monitoring setup error for treatments with high dose per fraction.

Evaluation of tumor motion interplay effect on dose distribution in stereotactic radiotherapy

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Introduction of the Study: Intrafraction organ motion is a major concern for lung stereotactic ablative radiotherapy (SABR) during the delivery of treatment. It may cause substantial differences between actually delivered dose distribution and the planned one, due to the effect of tumor movement and multileaf collimator leaf motion. Motion management techniques allows to decrease the planning target volume which effects lower dose on healthy tissues and reduces the toxicity. In the work presented here, it was investigated the dose delivery accuracy for not gated treatment of moving target to evaluate dosimetric deviations that is induced by respiration.

Methodology: The investigation in this study was carried out by using a linear accelerator and a helical tomotherapy (HT) on moving phantom. The first group of measurements was done with 10 MV flattening filter-free (FFF) volumetric-modulated arc therapy (VMAT) on a TrueBeam linac (Varian Medical Systems, Palo Alto, CA). By default, for VMAT plan, it was with two arcs instead of one for reducing the dose deviations. Treatment plans were generated using the Eclipse treatment planning system (Varian Medical Systems). The plans delivered on CT-scanned Quasar (Modus Medical Devices Inc., ON, Canada) phantom. The Quasar respiratory phantom containing a plastic spheres as a target, is a motorized phantom that can reproduce the motion. The phantom's wooden cylinder can move in the inferior–superior direction according to the input breathing trace, as well as the capability of performing more complex nonlinear motion. The tumor volume was delineated on a four-dimensional CT image of phantom to take into account the tumor movement. The irradiation was delivered on normal free breathing pattern that it was simulated in an oscillation mode of phantom motion program. The second group of investigation was a treatment technique that is delivered from a 6 MV fan beam in HT at the same operating parameters. Gafchromic EBT2 film (Ashland, Covington, KY) was placed inside the lung inset of phantom. The measurements were acquired while the phantom moved under the described breathing pattern, as well as in a different stationary tumor position. The phantom was adjusted to have residual target in a range of -15, -10, 0, 10, 15 mm on static pattern. It was used to simulate the clinical situation of starting the therapy at random starting respiratory phase in the patient breathing cycle. A calibration curve was created to a known dose with a 10x10 cm2 field to correlate the measured film's optical density with the delivered dose. The films were scanned using a Vidar Dosimetry PRO film digitizer. Films were scanned with the 48 bit and a spatial resolution of 72 dpi. Data were saved in a tagged image file. Due to different light scattering films were maintained in the same orientation. FilmQA Pro software (Ashland) was used for comparison of the films with the treatment planning system.

Results: It was maintained the same time difference between the film irradiation and scanning for both experimental and calibration to expel the effect of color growth. Quantitative analysis of gamma function distributions and dose profile comparisons were analyzed. Therefore, measured and planned does were compared using gamma analysis (3%, 3 mm) for each breathing phase. AAPM Report No. 91 recommends that respiratory motion should be considered when tumor respiratory movement exceeds 5 mm. On the contrary, a superior–inferior tumor movement over 2 cm is relatively unusual. The results for moving and static dose delivery indicated the very poor agreement between the calculated plan and measured 2D dose distribution, as shown in figure 1. In all film measurements the tumor dose was underestimated in the lung SABR.

Conclusion: The phantom study showed dose variation in different phases of tumor motion, the normal breathing mode that CT scan was done and different phases of breathing. Breathing changes can be happened in some patients cause of some health problems or coughing during the treatment. The findings increase the need of using in vivo dosimetry during the radiation therapy for small tumor volumes with smaller margins and especially for delivering of very high dose per fraction. It is crucial that high dosimetric and geometric accuracy is maintained at each step of the treatment process. Clearly, it was easy to see on irradiated films the tumor volume is different than the irradiated targeted volume because of the tumor motion. The findings were completely independent of the treatment planning system or radiation therapy unit. In small tumor volumes to reduce the impact of the interplay effect it is recommend to use a smaller slice thickness for imaging and should be given sufficient tumor margins.

Session 24b - Brachytherapy / 154

The use of phantom simulation for brachytherapy training and education

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Introduction: Brachytherapy is a form of radiotherapy involving the precise positioning of radioactive sources near the tissue to be treated. It is often an invasive technique requiring a sterile surgical environment and a multi-disciplinary team of professionals working together to perform the complex procedure. Education and training, however, often does not take the required precision or complexity and team-oriented aspects of the technique into account. Typical training for a new site implementing a technique is limited and often includes a site visit for some members of the commissioning team to observe the procedure. For a brachytherapy team, many aspects of the technique are only performed during their first patient. Furthermore, there has been a demonstrated learning curve for brachytherapy techniques where published data has shown implant quality is improved with the experience of the treatment team. Simulation has been shown to be an effective training method and recent technological development has allowed simulation to become practical for many medical procedures. It allows the entire treatment team to perform end to end testing with local equipment in the relevant environment. It also provides the opportunity to quantitatively assess procedure outcomes in ways that may not even be possible for patients and demonstrate the capability of the team to deliver a safe and effective treatment before the first patient. We have developed anthropomorphic gelatin phantoms incorporating treatment volumes visible on appropriate medical imaging for brachytherapy simulation. These have been applied to LDR and HDR prostate treatments, HDR gynecological and LDR breast treatments. The most comprehensive simulations were for the commissioning of the LDR breast partial breast seed implant (PBSI) technique. Phantoms were used to deliver mock implants as a process improvement initiative, resulting in a number of changes in technique as well as equipment development and implant results were quantitatively assessed.

Methodology: Multi-material anthropomorphic phantoms were made from ballistic gels with imbedded target volumes. The phantom materials were chosen to demonstrate contrast on ultrasound and CT images for treatment planning and image guidance during the procedures. The speed of sound in the gels was verified to result in appropriate distance measurements on the ultrasound images. The gels were formed using molds generated from CT contours for patient specific simulations or from simple shapes and generic representative anatomy for training or commissioning phantoms. 11 breast phantoms were constructed for PBSI commissioning and simulation. These were used for a variety of purposes including full end to end testing. End to end testing followed the clinical procedure from acquisition of the planning images, development of the treatment plan, markup on the phantom and full delivery simulation with the entire treatment team. Post-implant CT images were acquired following the mock implant and registered to the planning image in order to assess delivery accuracy in reference to the treatment plan.

Results: Phantom simulation was effectively used for commissioning measurements and to validate end to end testing in variety of brachytherapy developments including HDR and LDR prostate, interstitial gynecological and LDR breast techniques. Process improvement recommendations during mock PBSI implants resulted in multiple procedure modifications. This included the introduction of a markup procedure to place surface marks on the patient using 1-1 scale treatment plan printouts to fabricate anatomical plastic cutouts. This method enhanced the ease, accuracy and speed of defining the insertion point of the fiducial needle on the implant plane. An initial systematic error of 5mm was identified when the plastic plug holding the stylet at the proper location in the needle was removed due to a retraction as it was removed. Once recognized, this error was compensated for by advancing the stylet until the seed train was felt again before delivering. Delivering in this manner no longer showed the systematic error in depth. Fiducial entry point positioning improved from 5mm to 2mm and fiducial angle error decreased by 6.4 degrees from the initial simulation to the last. Seed placement errors occurred in anterior-posterior, depth and lateral displacements and improved consecutively as simulations were done. Observations in translucent phantoms indicated needle angulations and translations which appeared to be related to bevel position during insertion. When re-insertion was done accounting for this error, accuracy improved.

Conclusion: Phantom simulation is an effective tool for commissioning a new brachytherapy technique. It can be used for training and education of the entire treatment team in the clinical

environment and serves as an end to end test of the technique when post-implant analysis of the implant accuracy is performed. PBSI simulations showed systematic seed delivery errors which were shown to be corrected with procedural changes in successive simulations. Phantom simulation improved practitioner comfort as well as improved the speed and accuracy of the implant procedure.

Comparative study of two techniques for spinalcord irradiation with 3D conformational planning

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Comparative Study of two techniques for Spinalcord irradiation with 3D conforma- tional planning

Introduction of the study Craniospinal irradiation (CSI) remains technically challenging because clinical target volume coverage is not a simple matter, that includes whole brain and whole length of the spinal axis and covering meninges. The traditional position of delivering CSI has been with the patient in the prone position, using lateral opposed fields covering the whole brain and upper cervical spine matched to posterior direct fields covering the caudal extent of the spine. Conventional treatment of adult spine usually exceeds the maximum field size available in standard linear accelerators and requires two matched spinal fields, typically accomplished with a skin gap between them. However, the gap or overlap between the fields can yield unacceptable dose heterogeneity and potentially be responsible for compromising the optimum tumor control. At our centre, we compare the conventional CSI technique using gaps and a modified 4-field technique, which employs column fields with table rotation angle and gantry angle in order to eliminate the divergence between them and allow a closer matching.

Methodology Our CSI patients were planned using computed tomography (CT) simulation, with the patient in the prone position lying on a Styrofoam plate in order to maintain the head position in the same level of whole spine, minimizing the curvature of the cervical spine and eliminating potential skin folds. The arms are placed down to the body side and the head is supported on a standard headrest besides thermoplastic mask immobilization. CSI treatment planning is performed using Eclipse treatment planning system (Varian, Palo Alto, CA). Two separate treatment plans were generated for each patient, with the aim of comparing the traditional technique and the 4-field modified technique (see Fig.1). For both techniques, the 2 opposed cranium field isocenter was positioned toward the patient feet as possible, i.e. using asymmetric collimator jaws with cranial superior border in the maximum size available. The inferior border was set limited by shoulder, including in the cranium fields as much as possible of the cervical spine and avoiding irradiating the mandible, oral cavity and larynx by the exit of spinal field. Efforts were made to spare the lenses using gantry rotation. We also employed couch rotation to eliminate the divergence in the direction of column fields. In the traditional technique (Fig. 1(a)), cranium field collimator angle is set zero, once the upper part of column is treated by a half-beam blocked field with isocenter localized in the cranium-spinal junction. Treatment of bottom part of the column is delivered by a direct field and the amount of overlap caused by the divergence of the upper and lower column fields is eliminated by the imposition of a skin gap so that both fields match in treatment depth. The cranial fields in the modified technique (Fig. 1(b)), in turn, employs also angle collimator in addition to the gantry and table angle. The purpose is to follow the direction of the superior upper column edge field, whose divergence is in the cephalic direction. In this technique, upper column field isocenter is located 20cm shifted longitudinally in relation to the edge of the cranial field, so that the blocked half of the half-beam field eliminates the divergence in the direction of bottom column field. Finally, the bottom column field is treated with 90^{o} couch rotation, eliminating divergence of bottom field and providing a perfect match without gaps in whole column.

Results We made qualitative dose distribution evaluation in the axial, coronal and sagittal planes for both techniques. For adult patients, whose extension column exceeds the maximum size available field on the accelerator, the dose distribution in the modified technique was qualitatively higher by the absence of underdose (before normalization depth) and overdose regions (after normalization depth) in the mediastinum of the patient. DVH evaluation also indicated a better and more homogeneous coverage of clinical target volume. Quantitative evaluation through indicators such as cold and hot spots, and homogeneity index (following the description of ICRU83) revealed that both techniques are comparable.

Conclusion In contrast to traditional technique used in spinalcord irradiation, the modified technique previously described has the ability to eliminate the use of undesirable gaps between the fields, so that the whole clinical target can receive more homogeneous dose without compromising tumor control. The major difference between them is that the modified 4-field technique requires couch rotation to treat column fields, and it is simple to plan and easy to incorporate into the workload of radiotherapy department.

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Medical physics audit of radiotherapy centres in Ghana

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Ghana has three functional radiotherapy centres serving a population of approximately 28 million. At present more than 7,000 new and follow-up patients suffering from a variety of cancerous and other degenerative diseases report to the three radiotherapy centres annually. Studies indicate that quality audits in radiotherapy helps to improve the quality of patient care and safety. In many developed countries, auditing in radiotherapy is well established, however in Africa, the reverse case is observed. There is evidence to suggest that diagnosis and treatment delivery improves not only for patients enrolled in a clinical trial with quality assurance (QA) programmes, but also for patients treated off-trial. Since development of a QA network programme is prone to require substantial human and financial resources, such activity is challenging especially for most medical institutions from less developed countries.

Ghana has implemented a National QA Audit programme for coordinated and sustainable audits of radiotherapy centres in the country. A team of medical physics auditors constituted locally were assembled and formed into groups to audit the three radiotherapy centres. The three centres are the Korle-Bu teaching Hospital, the Komfo Anokye Teaching Hospital and the Sweden Ghana Medical Centre. The IAEA loaned Ghana a CIRS Thorax Phantom for performance of end-to-end testing as part management system in the country.

Thursday afternoon - Poster Presentations - Screen3 **/** 157

The correction factors estimated for small field's dosimetry by using 6 and 18MV energies of a linear accelerator using on radiation oncology unit

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Background and purpose: Small field sizes are increasingly used in radiotherapy to deliver higher dose gradient to patients. Estimating dosimetric parameters for such fields in non-reference conditions based on the conventional protocols used at large fields, as used in the reference condition, lead to significant errors. The primary aim of this study was to determine and compare small fields correction factors (KNR and KNCSF) measured with different types of active detectors using on radiation oncology unit. Materials and Methods: Small field sizes were defined by circular cones down to 30 and 5mm diameters. Then, the KNR and KNCSF correction factors proposed recently for small field dosimetry formalism (TG155 protocol) were determined for different active detectors in a homogeneous as well as a non-homogeneous phantom. The non-homogeneous phantom was designed and made by using Perspex as the soft tissue and appropriate lung and bone tissue equivalent materials. Dosimetric measurements were made by using high resolution diodes (made by Scanditronix), and ionizing chambers (made by PTW). The 6 and 18MV beams were produced by a 2100C/D Varian Clinic linear accelerator system with the circular collimators fixed at its head. The linac output had an output rate of 100 MU/min. Variation of the central axis dose in the 5 and 30 mm small fields, in the inhomogeneous phantom constructed of different inhomogeneous layers (composed of cork and PTFE) for the 6 and 18MV energies was also investigated. Results: The KNR correction factors for the circle field of 30mm estimated for the Pinpoint ionizing chambers, EDP-20 and EDP-10 diodes were 0.993, 1.020 and 1.054 at 6 MV; and 0.992, 1.054 and 1.005 at 18 MV respectively. The KNCSF correction factor for the circle field of 5mm estimated for the Pinpoint ionizing chambers, EDP-20 and EDP-10 diodes were 0.994, 1.023 and 1.040 at 6MV; and 1.000, 1.014 and 1.022 at 18MV respectively. The maximum variation in the percentage depth dose in the non-homogeneous phantom relative to the homogeneous phantom in the 5 and 30 mm field sizes due to the presence of 30mm cork heterogeneity were 23.5 % and the 62.1%, respectively, while the PTFE heterogeneity caused a maximum variation of 8.17%, 7.15% for the 5 and 30 mm field size respectively. Conclusion: Implementing the correction factors based on the new dosimetry protocol proposed for the small fields increases the dosimetric precision and accuracy of small field's radiotherapy procedures of such small fields using radiation oncology unit. In addition, the dosimetric measurements with the diodes and ionizing chamber indicated that the perturbations of doses at the central axis in the small fields increases due to the presence of heterogeneities within the non-homogeneous region and thereafter. Therefore, considering the perturbations happened between the boundaries of non-homogeneous area could increase the accuracy of the dosimetry procedures in such occasions.

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Comparison of the equivalent uniform dose (EUD) in prostate cancer for target and organ at risk (OARs) between 3D+IMRT and IMRT treatment techniques

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In radiation therapy (RT) of localized prostate cancer, the main organs at risk (OAR) are bladder and rectum. In this study, rectum and bladder doses for 19 patients were analyzed. The treatment plans were generated with the Intensity Modulation Radiation Therapy (IMRT) and 3-Dimensional Conformal RT (3DCRT) + IMRT techniques. CT simulation was performed with full bladder and empty rectum. Radiation therapy oncology group (RTOG) guidelines were used to contour the pelvic and periprostatic nodes. Total prescribed dose was 76 Gy in 38 fractions. Prescribed dose was administrated in two phases. In phase-I, treatment plans were generated with 46 Gy to planning target volume (PTV1) (pelvic nodes, seminal vesicles and prostate) with IMRT and 3DCRT. In phase-II, remaining 30 Gy was prescribed to PTV2 (seminal vesicles and prostate) with IMRT technique only. 7 treatment fields were used to generate the IMRT treatment plans with sliding window technique in both the groups. Mean volumes of rectum and bladder for 19 patients were 32 cm3 and 151 cm3 respectively. Doses for rectum and bladder were compared for two tolerance levels at D<15% and D<50% following the RTOG dose volume histograms (DVH) constraints for prostate RT. The rectal and bladder doses were briefly calculated and compared for the IMRT and 3D+IMRT treatment plans. In 3DCRT+IMRT treatment plans, 15 % more doses were found in rectum and bladder for D15% as compared to IMRT treatment plan alone. Likewise 25% difference was measured in rectum and bladder doses when compared for D50% in 3DCRT+IMRT verses IMRT treatment plans. Rectum and bladder gets more doses when treated with 3DCRT as part of radiotherapy for prostate carcinoma patients when compared with IMRT alone. IMRT is better modality in terms of reducing the OARs doses prostate carcinoma and also help to escalate the dose without compromising the OAR doses.

Photon boost after lumpectomy in breast cancer and acute toxicities in NwGH & RC

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Introduction: One of the common methods in radiation therapy of Breast cancer is whole breast irradiation followed by tumor cavity boost (TCB) with electron therapy. The tumor cavity boost following Whole Breast Irradiation (WBI) is well-defined and there are numerous delivery methods of radiation therapy. In our institution we don't have the facility of electron, so our study comprised of experiencing the TCB with photons. Although photon boosts have been discouraged because of excess normal tissue toxicity. In our study we have analyzed acute skin reactions and lung doses for the level at 2Gy. Methods: Patients (n=19) of post-lumpectomy breast cancer for both left and right sided node negative were scanned for this study. Mean age for the patients was 47 year .All women were planned for 50 Gy for the whole breast irradiation via tangents followed by TCB irradiation of 10 Gy with standard fractionation. Contouring of breast, cavity, lungs and heart were done in all the cases. Mean volume of breast and cavity were 1000 cm3 and 60 cm3 respectively. These patients were observed for skin toxicity during radiotherapy as per RTOG skin toxicity criteria. Results: The mean lung volume receiving 2 Gy was 27cm3 and V20 for lung is 10% volume for 60 Gy plan. Out of total 19 patients, 75% patients had grade-II skin reaction at treatment completion and 25 % patients had grade-I skin reaction. Mean heart dose for 60 Gy plans were 100 cGy. While dosimetric analysis it has been found that conformality, dose homogeneity index (DHI) and Tumor cavity coverage was significantly covering up to 95%. Conclusion: Although electrons can be used for TCB but in our centre electron beam therapy is not available and TCB is done with photon beam following the tangential beams. In the adjuvant treatment of breast cancer therapy, whole breast radiation followed by conformal photon boost seems to be acceptable in focus of the skin toxicity, TCB dose distribution and OAR less excessive doses.

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Stereotactic body radiation therapy in a public oncologic hospital in Brazil: a five years experience

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Introduction: The challenge of implementing a new technology in a developing country is huge in many aspects. Personnel training and updating are cornerstones in this process. Brazil has an incidence of about 596,000 new cases of cancer per year. In May 2008, the Instituto do Câncer do Estado de São Paulo (ICESP) Octavio Frias de Oliveira, a public institution linked to University of São Paulo, was established. The radiation oncology department started its' activities in 2010. With 6 linear accelerators, 1 high dose-rate brachytherapy equipment and 1 computed tomography (CT) simulator, about 300 patients are treated per day using different techniques (conventional, 3D-conformal, intensity modulated radiation therapy, volumetric modulated arc therapy – VMAT, conventional and 3D image-guided brachytherapy). In 2011 the first case of stereotatic body radiation therapy (SBRT) was performed. The technique has potential benefits, as improvement of the quality of life of patients (by reducing the numbers of visits to the hospital and promoting better tumor control), and the possibility of treating a larger number of patients in busy departments likes ours (due to the potential more vacancy in the machines). On the other hand, requires high radiotherapy technology and appropriate personnel training. The clinical protocol, for such treatment, includes a CT scan with appropriate immobilization (eg thermoplastic mask, body fix), image fusion when indicated, delineation according to international protocols.
Treatment planning is performed with Monaco® software, followed by quality assurance using an ionization chamber (0.125 cc) and a matrix detector (PTW 729®). Irradiation is delivered with Elekta Axesse® linear accelerator and daily cone beam CT. The purpose of this study is to analyze the evolution of the use of SBRT in the institution after the implementation of the technology and personnel training. Methodology: treatment records of the institution were reviewed and all SBRT treatments were selected. The numbers of procedures, the treated sites and respective treatment techniques were verified. Results: From September 2011 to September 2016, 106 treatments in 94 patients were performed (Figure1). The mean age of the patients was 68 years. Treatment sites were lung (60) followed by liver (22), bone metastases (15), pancreas (5), soft tissue sarcomas (2), and isolated lymphatic relapse (2). There are two clinical studies being developed: one for hepatocellular carcinoma and another one for soft tissue sarcoma. VMAT was used to treat 79 % of the cases, the number of fractions ranged from 1 to 8. The most used dose/fraction was 7.5 Gy (range: 5 – 20 Gy) with total doses ranging from 18 to 60 Gy. The number of procedures performed in the last two years (66) is higher than the sum of all other years (40). In 2016, a mean of at least 3 procedures/month was performed. This runs in parallel with the end of personnel training (2014) as well. Conclusions: after implementation of SBRT, the number of procedures increased exponentially during the observed period. The personnel training and learning curve may be related to these findings. There is still potential to grow in the field. This is a landmark for our institution that is offering and delivering high quality ablative treatments in the public context.

On the way to paperless – a multi-professional project in radiation therapy

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The installation of Mosaiq 2.62 (Elekta) in the Radiotherapy Department at IPOCFG, E.P.E. was preceded by a rigorous process of planning and configuration. A multi-professional working group was appointed to work out the complete workflow of a radiation treatment, trying to meet the usual followed procedures with an optimized sequence. Receptionists, secretaries, nurses, radiation oncologists, dosimetrists, medical physicists and radiation technologists have worked together for around three months prior to any software installation. The complete workflow of the patient through the treatment process in external radiation therapy (ERT) was discussed and structured, including all the forms and documents usually kept in paper support, for records. The process was led by a medical physicist. The purpose of this work is to present the result of this process which aimed at installing an Oncology Information System (OIS) that could regulate, control and register all the steps followed by the patient since his/her entrance in the RT Dept. towards his/her hospital discharge, including medical and nursing appointments, image acquisition procedures with positioning and immobilization requirements, structures delineation, treatment planning and optimization, treatment verifications and treatment delivery sessions, image review, nursing care procedures, medication prescription and clinical assessment of treatment outcome. The major ambition of this project was to make it paperless. RT Dept. staff includes 12 radiation oncologists, 3 residents, 25 RTTs, 10 clinical secretaries, 5 receptionists and more than 30 nurses. Six medical physicists and 5 dosimetrists, belonging to an independent Medical Physics Dept. give permanent support to the RT Dept. The major equipment integrates 2 Siemens Oncor linear accelerators, 1 Tomotherapy HD unit, 1 Simulix Evolution (Elekta) conventional simulator and 1 CT-simulator Siemens Sensation Open. A MR unit belonging to the Radiology Dept. is connected via PACS. The brachytherapy (BT) sector has one Flexitron (Elekta) afterloader for breast, gynae and prostate HDR implants. Also LDR prostate seed implants are performed with Prolink Bard system. Overall around 1500 patients are treated per year. The previous use of Lantis R&V system has facilitated the first approach to Mosaiq. The database conversion from Lantis to Mosaiq was done with no major problems. Mosaiq 2.62 installation required the upgrade of Syngo RT Therapist platforms of the Oncor linacs. The tools available in Mosaiq 2.62 made it possible to structure and configure the external radiotherapy (ERT) sequence for the first implementation phase of the Mosaiq project. IQ Scripts engine enables the use of logical building blocks to define patient pathways and clinical protocols according to the department clinical practice and the structured workflow. For ERT, the patient pathway included 76 Quality Check Lists (QCL) which correspond to the same number of task descriptions – e.g. booking of a clinical appointment, perform some nursing assessments, delineate structures, etc. Through IQ scripts these 76 tasks have been grouped by automation in 14 building blocks where one initial task triggers off for the intended staff or location a sequential list of tasks including the automated generation of the needed documents like dose prescription form or positioning and immobilization form. The sequential completion of each task drives the following steps of the process. At the end, the RT patient chart contains all the relevant information and approved documentation concerning his/her complete pathway through the RT Dept. Patient related documents can be either imported (like treatment planning documents, independent MU calculation or other patient specific QA documentation) or automatically generated and presented to the user for filling in (like dose prescription form, immobilization and positioning form, or the technical reception form through which the RTT welcomes the patient and registers some preference for daily treatment hours, for instance). The first type of documents is eScan whereas the second is eScribe. The latter requires Word configuration and may include merging fields to be automatically filled in upon, for instance, completing assessments in earlier steps in the workflow. ERT workflow configuration and testing in Mosaiq required one month full time of a dedicated medical physicist supported by Elekta applications specialist. An intensive training program was also organized for all professionals. Staff was divided in multi-professional groups and the configured ERT workflow was simulated with test patients. Connectivity to the general Hospital Information System (HIS) and the hospital electronic patient chart was assured by dedicated solutions that prevent task and registry duplication. This integration is a dynamic process

that can evolve with the natural HIS development. The GoLive of paperless Mosaiq project took place on October 10, 2016. With less than one month of practice, it still requires a close daily monitoring. A daily 30 minutes briefing including a multi-professional team is a fundamental pillar of the successful implementation of such an ambitious project. Brachytherapy and Radiosurgery patient pathways have already been configured and will soon be tested and implemented.

Treatment plan stability to geometric uncertainties. PTV and CTV related dose-volume statistics comparison for 3D CRT, IMRT and VMAT irradiation of the «average» prostate patient in N.N. Alexandrov National Cancer Centre of Belarus.

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Aim or Objective: To quantify the impact of geometrical uncertainties in patient position during prostate cancer irradiation on the PTV and CTV related dose-volume statistics and to analyze the results obtained for the 3D CRT, IMRT and VMAT techniques.

Methodology: For our study, we analyzed 220 treatment plans of the prostate cancer patients that were treated in the N.N. Alexandrov National Cancer Centre of Belarus last year. We have identified anatomical parameters influencing the dose distribution and identified representative («average») patient with these parameters, the most appropriate medium to their values in the sample: BODY height- 237,8 mm; BODY width - 364,5 mm; CTV - 338,2 cm3; prostate volume - 123,6 m3; rectum volume - 75,7 m3. The experienced medical physicist created and calculated clinically acceptable 3D CRT, IMRT and VMAT treatment plans for this «average» patient using the Eclipse TPS version 13.7 and photon dose calculation algorithm AAA. The following parameters were used in the planning process: total dose - 78Gy, fraction dose 2Gy, PTV=CTV+0,5cm margin; 3D CRT - 4 fields 18MV, simple box technique; IMRT - 9 fields 6MV (0, 40, 80, 120, 160, 200, 240, 280 and 320 deg. gantry rotation); VMAT - 2 arcs 6MV (360 deg. rotation CW and CCW). These plans have been artificially introduced geometrical uncertainties 5 and 10 mm on each axis x - lateral, y - vertical, z - longitudinal). For every of the treatment plans with the presented geometrical uncertainties PTV and CTV related dose-volume statistics were analyzed.

Results: For treatment plan stability to geometric uncertainties determination following dose- volume parameters were analyzed: for PTV: PTVmin, % - minimal percentage absorbed dose; D2%, Gy – near-max absorbed dose; D98%, Gy – near-max absorbed dose; D50%, Gy – meadian absorbed dose, HI – homogeneity index; CTV - CTVmin, % - CTV minimal percentage absorbed dose; CTVD98%, Gy – CTV near-max absorbed dose. Table 1 shows the results for 3D CRT, IMRT and VMAT treatment plans both reference and with introduced geometric uncertainties. Table 1. PTV and CTV related dose-volume statistics.

Conclusion: Geometric uncertainties on the longitudinal axis z had the most significant impact on the PTV and CTV related dose-volume characteristics, than for other axes for every considered radiotherapy techniques. Significant changes in the heterogeneity index of the treatment plan were observed if any geometric uncertainties are introduced. This situation seems typical for all considered radiotherapy techniques. In the cases where geometric uncertainties about 10 mm can not be taken into account during patient irradiation, IMRT and VMAT techniques is not appropriate due to significant deviations in the delivered absorbed dose. In general, the stability of 3D CRT treatment plans to geometric uncertainties in patient positioning is higher than that of IMRT and VMAT (approximately the same for these techniques) for prostate cancer treatments. It is mandatory to perform patient position control during IMRT and VMAT prostate cancer treatments. An additional research are required to evaluate the effect of geometric uncertainties on the bladder and rectum related dose-volume statistics.

Improving of the training programs for medical physicists and engineers in N.N. Alexandrov National Cancer Centre of Belarus

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Background: Due to economic and other circumstances in the countries of the former Soviet Union, there is a significant engineering and physics staff turnover rate in the radiotherapy departments (the average age of employees of the radiotherapy engineering and medical physics department, N.N. Alexandrov National Cancer Centre of Belarus is about 30 years). To maintain the high quality of radiotherapy services for oncological patients it is necessary to develop and implement a program of training of medical physicists and engineers, which will allow for rapid integration of new employees in the work of department and enhance the possibilities in the field of continuous professional education.
Methodology: In order to ensure standardization of the main technical procedures in external radiotherapy and brachytherapy relevant instructions and standard operating procedures in Russian have been developed and introduced into N.N. Alexandrov National Cancer Centre of Belarus clinical practice by the experienced engineers and medical physicists of the radiotherapy engineering and medical physics department. The documents describing in detail physics and engineering staff actions were introduced for the following radiotherapy procedures: [U+F02D] patient positioning verification using and 3D CBCT images; [U+F02D] RT chart physics ac- tions; [U+F02D] wall-mounted lasers position calibration; [U+F02D] IBU images based treatment planning; [U+F02D] 3D adaptive treatment planning for intracavitary brachytherapy with MRI control; [U+F02D] patient irradiation using Flexitron brachytherapy unit; [U+F02D] treatment planning using SWIFT TPS; [U+F02D] patient irradiation using MicroSelectron brachytherapy unit; [U+F02D] treatment planning using Oncentra prostate TPS; [U+F02D] linear accelerator monitor unit calibration; [U+F02D] producing of the shielding and aperture blocks; [U+F02D] linear accelerator mechanical parameters calibration; [U+F02D] MLC initialization; [U+F02D] linear accelerator and OBI reboot and shut down procedures; [U+F02D] linear accelerator mechan- ical and dosimetrical parameters daily checks and QA; [U+F02D] linear accelerator weekly QA procedures; [U+F02D] 2D image acquisition using EPID and OBI; [U+F02D] linear accelerator service mode operation; [U+F02D] treatment delivery using linear accelerator; [U+F02D] CT and PET images registration procedure; [U+F02D] analysis of the treatment planning statistics; [U+F02D] import of the patient data to the Eclipse TPS; [U+F02D] patient data transfer from CT to the dedicated data server; [U+F02D] CT and MRI images registration procedure; [U+F02D] 3D treatment planning using MasterPlan TPS; [U+F02D] 3D treatment planning using Eclipse TPS; [U+F02D] IMRT and VMAT verification using EPID; [U+F02D] IMRT and VMAT veri- fication using Octavius 4D; [U+F02D] EPID calibrations; [U+F02D] IMRT treatment planning using Eclipse TPS; [U+F02D] VMAT treatment planning using Eclipse TPS; [U+F02D] treatment delivery QA.
Results: A training for all employees of the radiotherapy engineering and medical physics department according to their job descriptions using the developed instructions were performed. Since 2016, each new medical physicist employee goes a step up training and allowed the implementation of complex planning procedures or clinical cases only after checking their knowledge on the basis of the criteria set out in the relevant instructions. Senior medical physicists check all the results of his work. For engineers in the department we apply the same approach except that all the work that he or she was trained with use of the developed instructions he does in the presence of a senior engineer who carries out the constant control over his actions.
Conclusion: The introduction of the developed instructions into N.N. Alexandrov National Cancer Centre of Belarus clinical practice helped streamline the process of training young employees of the radiotherapy engineering and medical physics department and more intelligently approach to the assessment of the knowledge they have received. This training system allows maintaining a high level of motivation of the personnel and its commitment to continuous professional education through additional financial stimulation of the education results. Standardization of the treatment planning and radiation

therapy procedures has a positive effect on the quality of medical services for cancer patients.

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The results from the ultrasound and IBU-guided brachytherapy planning in locally advanced cervical carcinoma.

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Objective: To preform dose-volume statistics comparison ofthe ultrasound and IBU-guided brachytherapy treatment plans in locally advanced cervical carcinoma using 3D CT and/or MR imaging.

Material and methods: From April to September 2016, 14 patients with locally advanced cervix carcinoma were treated in N.N. Alexandrov National Cancer Centre of Belarus. All patients underwent EBRT 50Gy/25 fractions to the entire pelvis region (3D CT-based treatment planning). After that, all patients received 5Gy/fraction intracavitary brachytherapy (5 fractions in 3 weeks). All applications were performed under theultrasound control. The bladder was filled with 100 ml saline to ensure good visualization and to avoid the bulb. IU-channel for the ring applicator was selected according to the size of the uterus (obtained using ultrasound imaging). US-guided treatment planning enables visualization of the cervix and uterus and allows sparing ofthe normal tissues. This planning is aimed to cover a whole cervix volume with 100% of theprescribed dose. X-ray imaging was performed using IBU-Digital. 5Gy isodose was normalized to Manchester points A. According to GEC-ESTRO recommendations CTV High Risk (CTV HR) was identified using the CT and MRI fusedimage. The bladder, rectum and sigmoid were outlined as OARs. US and IBU-based calculated treatment plans were transferred to the 3D CT or MRI scans to define D2cc OARs and D90 CTV HR. The total accumulated dose value for EBRT and brachytherapy boost were evaluated in terms of equivalent dose in 2 Gy per fraction (EQD2), using a/b = 3 Gy for OARs and a/b = 10 Gy for CTV HR.

Results: Figure 1 shows the relationships between the D90 of CTV HR and OARs. No clear relationships between D90 of CTV HR and OARs D2cc dose were observed. The OARs D2cc mean dose value in IBU-based treatment plans was higher than in US-based plans. Furthermore, themean total dose value was higher on US-based plans. Figure 1. Dose-volume statistics for the US and IBU-guided brachytherapy treatment plans

Conclusion: Using ultrasound in gynaecologic brachytherapy to guide the applicator placement allows to avoid perforation and optimize the applicator position within the uterine canal, and thus to improve thequality of implants. Ultrasound-guided brachytherapy planning in locally advanced cervical carcinoma in comparison with IBU-based planning has increased target coverage and reduced overall dose to the OARs.

Multiple brain metastases treatment, dosimetric comparison of IMRT vs VMAT, is there any gain?

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INTRODUCTION: Volumetric Arc Therapy (VMAT) and Intensity Modulated Radiation Therapy (IMRT) have been used in brain radiosurgery in terms of non coplanar rotational arc beams with the aid of circular cones to provide beam collimation. The goal of this study is to evaluate two treatment techniques VMAT and IMRT in the treatment of intracranial metastases and to compare results between them. The issues discussed in this study with regard to not only the beam characteristics but also the dosimetry features. Both the pros and cons of both techniques are presented. 37 Lesions in 10 patients treated with VMAT were re-calculated in IMRT, for its comparison in parameters of dosimetric homogeneity, target conformation, organs at risk (OAR) protection, monitor units used, treatment time per fraction used in the 2 described techniques, PTV volumes >14 cc and target dose 40 Gy in 10 Fractions.

MATERIALS AND METHODS: We evaluate the mean dose to normal brain tissue, maximum dose to OARs. Patients were simulated in Computed tomography (CT) simulation General Electric (GE) Optima model, slides acquisition 1.25 mm; Magnetic Resonance was also done in a Siemens de 1.5T with 1 mm slices in contrast enhanced T1 MPR, T2 Flair, T2 Ciss, Diffusion, Perfusion, DTI Tractography; image fusion for PTV and OAR contouring; calculation were done in Monaco® planning system version 5.10.02 with Monte Carlo algorithms; treatment delivery were make in a LINAC Elekta Infinity™ with Agility™ head with 160 interdigitating leaves with cm width at isocenter; positioning verification XVI versión 4.5.1 b141. Dosimetric analysis were made in regard to conformity Index RTOG (CI-RTOG), homogeneity index (HI-RTOG), Paddick inverse conformity Index (PCI), Dmean. OARs were analyzed in terms of Dmax and Dmean.

RESULTS: Treatments were assessed regarding to the on beam time. Dosimetric conformity, homogeneity and OAR were comparable between IMRT and VMAT single Arc, Treatment Delivery time 16 +/- 1.30 minutes for IMRT and 2 +/- 0.20 minutes for VMAT 1 arc. Mean MU were 1130 and 903 for IMRT, and VMAT 1 arc plans, respectively.

CONCLUSIONS: Data found in this study suggest that VMAT and IMRT plans are clinically comparable in terms of CI, HI, and OAR restrictions. However there is a substantial difference on beam time and fewer MU for VMAT compared to IMRT. This MU reduction is important due to limits in the exposition time to the resultant leakage radiation even though it is minimum due to Agility™ head used for the treatment. Fewer on beam time limits the inter-fraction potential uncertainties due to OAR and PTV movements, what could lead considerable dosimetric variations. This important clinical advantage makes VMAT a safe and efficient treatment technique for multiple brain metastases more than 14 cc volume with controlled extracranial disease.

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Analysis of dose deposition in lung lesions: a modified PTV for a more robust optimization.

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Introduction: In lung cancer, SBRT is often used to deliver high doses to a small dense lesion (GTV) moving into a low density tissue (the margin generating the PTV). In order to reach an acceptable degree of accuracy, type B or MC-based algorithms should be adopted. If a modulated technique (IMRT or VMAT) is used to treat such inhomogeneous PTV, an apparently homogeneous dose distribution is delivered, but high photon fluence is generated inside a 3D shell (PTV-GTV) due to its low electron density (ED). This situation gives the paradox that the dose distribution is apparently uniform, but the GTV, which will move into the PTV, will receive a dose that depends on its position. This work was designed to evaluate this phenomenon and to suggest a more robust dose optimization.
Methodology: A TPS Monaco 5.11 (Elekta, SWE) with a MC algorithm was used to simulate a SBRT treatment in a dummy patient (55 Gy in 5 fractions). In a first step, in order to evaluate the dose discrepancy on the target when the motion of the high ED GTV is considered, the photon fluence was optimized for the original PTV ED (EDo) and then used to calculate the dose on a "forced" PTV ED (EDf) in which the ED of the PTV was forced to the mean ED of the GTV. In a second step, the photon fluence was optimized for PTV EDf and then used for the dose calculation on PTV EDo in order to evaluate the dose variation on the lower ED region of the PTV. In both steps, the recalculation was done employing the same beam arrangement, and parameters as used in the original plans so that the segmentation and photon fluence were identical with the same number of MU. Dosimetric comparisons between the original and recalculated dose distribution were made in each step in terms of: dose profiles through PTV, and Dmean, D98% and D2% for PTV-GTV, the maximum difference between 3D dose distributions was also evaluated.
Results: Using Monaco MC algorithm, In step 1 dose profiles, calculated on EDo and EDf, differ up to 6.6%, 3.4% and 3.8% on longitudinal, sagittal and transversal axes along the plan isocenter (center of GTV). Dose increments of 1.6% for D98%, 2.5% for Dmean and 5% for D2% were obtained for PTV-GTV (see figure). A maximum dose difference of 9% of the prescribed dose was obtained between the 3D dose distributions. In step 2 the maximum difference between dose profiles was -3% for all three axes along the plan isocenter. A reductions of -1.5% for D98%, Dmean and D2% were achieved for PTV-GTV. The maximum difference between the 3D dose distributions was 6% of the prescribed dose.
Conclusions: A static GTV should receive an homogeneous and unvaried dose, but step 1 shows that the dose delivered to GTV, when it moves, reaching a position inside the PTV where the photon fluence is optimized for low electron densities, is higher than what estimated on the original EDo map. The GTV is thus irradiated in a more homogeneous way in step 2 in which the fluence is optimized for its mean ED everywhere in the PTV. We propose that, in lung small lesions, the PTV is modified in terms of electron density thus considering the GTV mobility. Optimizing the photon fluence for the "forced" mean electron density appears an effective way to evaluate the dose actually delivered to the GTV.

Proposal of a simplified procedure for the commissioning of AAA and Acuros photons calculations algorithms for Varian accelerators.

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Introduction : Two important steps are dedicated to the modeling of calculation algorithms like AAA and Acuros: Measurement of the different data (pdd's, profiles, output factors. . .) required by the algorithm then modeling from these data. Commissioning of the algorithm in accordance with different protocols like TRS-430, NCS-15, IPEM Report 94. . . . The purpose of this work is to propose a simplified methodology for the commissioning and this specially in the case of limited duration missions in emerging countries. Only the aspects related to the calculations are involved in this proposal (scales, data transfer. . .) For some algorithms, the measured data are send to the manufacturer who will perform the modeling and send back the data ready to be used for the calculations on the TPS. In this case a more complete commissioning has to be realized. For Varian algorithms it is not the same situation and the user will have a full local control on the different steps between the data measurements and the modeling. AAA and Acuros algorithms are both based on Monte Carlo based pre modeling of the head of the accelerator and the different measurements are used to adjust a few parameters related to the local machine. If the different measurements are performed with the correct detector (spatial resolution, energy dependence. . .) and in a correct way, the results between measured and calculated data will be very good. In case of differences, there is no way or no parameters (except maybe the second source size) to modify the algorithm and generally the problems are linked to the quality of the measurements. The results of the modeling for AAA for 13 clinacs and 3 TrueBeam machines have showed that the dosimetric data of all these different machines are the same for each photon energy. From this ascertainment, we have developed a methodology to simplify the commissioning of the algorithm after the modeling for a specific energy. This procedure is based on the following points :

Comparison of the measured data (Pdd's, profiles and ouput factors with the reference ones. If they are identical, continue with the procedure.

After the modelisation, use of the "Beam data analysis" Varian module to verify the adequation of the measured and calculated Pdd's and Profiles. Verification of the output factors.

Use of a home created set of plans based on recommendations from IAEA TRS 430 and NCS-15 protocol. These different plans are covering the following points : Complex fields Rectangular fields MLC and collimator Half fields and Asymmetric fields Off axis measurements Missing tissues Modified SSD Obliquities Fields with wedges All these plans have been calculated on our system with AAA and Acuros algorithms. The results of the calculations have been compared with measurements performed in water or PMMA phantoms. For the wedges comparisons are based on measurements with the PTW 2DARRAY 729 detector. All these data have been validated for each energy. For the new equivalent machine (Clinac or TrueBeam) commissioning, the set of plans and phantoms are imported in Eclipse and the results of the calculations obtained with the new algorithm are compared with the reference ones

Measurement in the water phantom of a limited number of calculated data to validate the procedure.

Use of 5 different plans calculated for different localisations (prostate, breast, lung, Head&Neck and brain). Plans and CT's are imported and after recalculation, the results are compared via the 3D doses matrix comparisons module of PTW Verisoft.

Establishment of Radiotherapy Calibration Facility at the SSDL of KFSH&RC

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The Secondary Standard Dosimetry Laboratory (SSDL) of KFSH&RC is the 1st, and so far the only SSDL in the region having a full range of calibration capabilities covering radiation protection, diagnostic radiology, and radiotherapy.

The SSDL of KFSH&RC is a full member of the International Atomic Energy Agency / World Health Organization SSDLs network. Its standard instruments were calibrated at the IAEA's Reference Dosimetry Laboratory and hence all the measurements are traceable to the Primary Standard Dosimetry Laboratories (PTB) and the BIPM through the IAEA.

The radiotherapy calibration facility at the SSDL of KFSH&RC was established in 2014. The full commissioning of this facility is presented in this paper. This commissioning mainly revolves around three parameters; verification of the radiation safety aspects, testing of various physical and dosimetry parameters (timer error, verification of the source positioning, beam profile free in air and water, output and depth dose measurements,…) and the establishment of the reference absorbed dose to water.

Last but not least, the SSDL participated in an external audit program managed by the IAEA to confirm that the established reference absorbed dose rate is within the acceptable limits. The results of this audit, which are presented here, were satisfactory.

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Evaluation of BEBIG HDR+ dose optimization methods: A case study of HDR brachytherapy cervical plans

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Introduction: High dose rate brachytherapy (HDR) has taken an important place in the treatment of cervical cancer. Treatment planning system is required to calculate dwell time and position. Many methods are used to optimize those parameters such as manual method and automatic method. The aim of this work is to compare graphical (GRO) and inverse planning by simulated annealing (IPSA) optimization methods offered by BEBIG HDR+ considering dosimetry and planning time.
for cervical plans

Methodology: Ten retrospective cervical brachytherapy patients were chosen for this study. Manual GRO and IPSA plans were generated for each patient. Plans were compared using dose-volume histograms (DVH) and dose coverage metrics including; conformal index (COIN), and homogeneity index (HI). Approximate planning time was also recorded.

Results: There was significant difference between GRO and IPSA in terms of mean COIN of and 1.18 (p=0.04) and no significant difference in terms of mean HI of 0.32 and 0.44 (p=0.09) respectively. Mean GRO planning times were greater than 20 min while average IPSA planning times were less than 10 min.

Conclusion: For the same dosimetrical plan, IPSA offers a reduced planning time compared to GRO.

Quality control, dosimetric measurement and clinical experience with intraoperative radiation therapy (IORT) - Intrabeam device

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INTRODUCTION: On February 2016 our department started to use an Intraoperative Radiation Therapy System (IORT) Intrabeam PRS 500 con XRS4. Carl Zeiss, with delivery energy of 50 Kv; as the same as other radiation therapy treatment requires position and safety during the treatment. In our service we developed a radio-protection manual and quality control program required by regulatory entities in Peru, independent measures were done with conventional techniques as ionizing chambers and radiocromic fields in solid water getting the absolute dose and isotropy for all applicators use in clinical practice. The INTRABEAM device 50 kV of X Rays have different kind of applicators as spherical shape, surface, flat and needle with different sizes from 1 to 6 cm, what allows us many different kind of medical uses as treatment in breast, skin, brain, pancreatic, liver, vertebral metastases. It is described key dosimetric parameters as relative and absolute dose and isotropy for each applicator, also the dose rate in different key points 1 and 2 meters from the applicator, to estimate the biological dose in Sv presents during treatment time and then established the radio protection plan. In Our Experience we have treated 22 cases where 68% were breast, every treatment it is done the intrinsic control specified by the manufacturer what allow us measure the equipment stability.
MATERIALS AND METHODS: All treatments were carried out with a IORT Device from the manufacturer Carl Zeiss Meditec AG, INTRABEAM model, with 50kV energy, measurements were made using ionization chambers PTW TN23342A, Electrometer PTW Unidos E model and dosimetric sheets EDR2, recommended manufacturer test are:
[U+25CF] Probe Centering: Tolerance 1mm
[U+25CF] Dynamic Deviation: Tolerance -0.5mm/0.5mm(1mm) [U+25CF] PDA Control: IRM ±15.0\%
[U+25CF] Output Control: ±10.0\%
Alternative procedures carried out in addition to those recommended by the manufacturer were:
[U+25CF]Isotropy (For circular devices). [U+25CF] Dose in a reference point.
[U+25CF] Dose to 1mm of surface.
This test were carried out using dosimetric sheets EDR2, ionization chambers mentioned. Solid water chamber RW3 phantom. Sheet Scanner ScanMarker 9800XL Plus Microtech. Regarding to quality guarantee we established a procedure program for radioprotection optimization such as where to place the leaded glass, sterile field X-Drape® D-110 use for getting rid of disperse radiation in 98%, and patient identification and also dose prescription. We evaluate beam stability that not exceed 1% been 10 times below established by the manufacturer. (Table N° 1) and values in the time of mean IMR are 1.2% (Table N° 2) at maximum 1.2% (Table N° 2) at maximum that in comparison with the manufacturer gives is 12 times below of the tolerance.
With regard to the clinical experience up to now so far we are treated 29 patients with good clinical results in slide A, B and C a magnetic resonance, Tumoral Bed post resection, and Intrabeam Spherical applicator that fits the cavity.
CONCLUSIONS:
We confirmed that the use of sterile field attenuates in great percentage disperse dose.
Alternative Tests confirmed that the dose given to patients and prescription are within acceptance tolerance gaps.
As the correct the applicator is placed in contact to the surface to treat, the better the treatment will be, because 1mm of air or minimal inclination, the dose can vary up to 20%.

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Frameless volumetric intracraneal stereotactic radiosurgery with non coplanar arcs: clinical experience, accuracy and dosimetric evaluation

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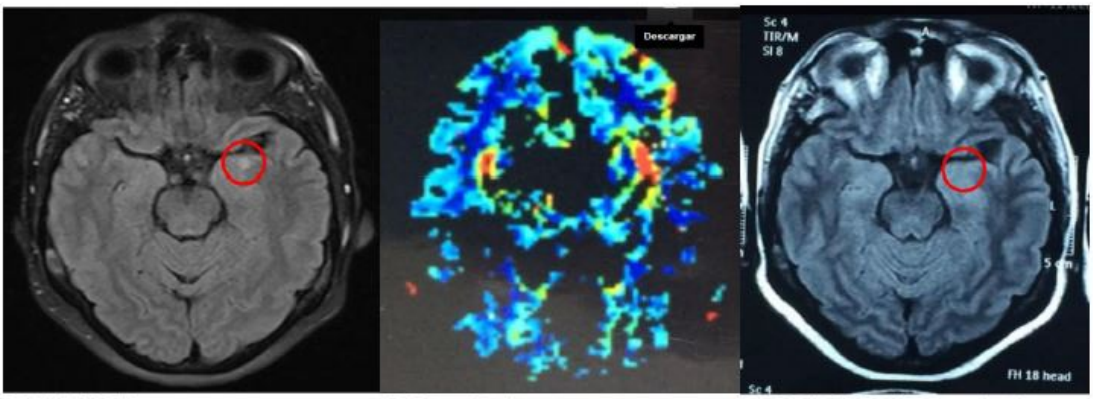
INTRODUCTION: In the last decades technological advances are increasing with the development of new treatment techniques and ways to deliver cranial radiosurgery (SRS), that is based into precision and accuracy, Volumetric Arc Therapy (VMAT) have been used in brain radio surgery in terms of non coplanar rotational arc beams with the aid of multi-leaf (MLC) to provide beam collimation. Using the traditional Leksell Stereotactic System, the time to do a treatment in average was around 6 hours; however the workflow using a frameless system decreases the mean treatment time in less than an hour, turning out to be a resources optimization for its realization, all this with the help of all accessories, quality assurance that should be made before deliver a proper treatment. The goal of this study is to show our clinical experience doing frameless SRS, with VMAT technique in the treatment of Arteriovenous Malformations (AVMs), Brain Metastases (BM), Meningiomas, among others. The issues discussed in this study with regard to not only the clinical features, but also beam characteristics, and dosimetric features.



RM (T1WC) pre treatment RM perfusion post treatment RM(T1WC) 6 weeks Post tto

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Testing the IAEA/AAPM code of practice on small field dosimetry at KFSHRC: preliminary results

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Purpose: An International code of practice for reference and relative dosimetry of small static used in external beam radiotherapy is being jointly published by the IAEA and AAPM. This dosimetry protocol is intended to fill the gap left by the universally adopted codes of practices such as TRS398 and TG51 when dealing with small field sizes. At the Department of Biomedical Physics belonging to King Faisal Specialist Hospital and Research Centre, we have undertaken to test the procedures described in the upcoming code of practice using a 6 MV flattened photon beam from a Varian True Beam machine. Measurement were performed in a full circle 3D scanner (San Nuclear Co.) using a farmer like ionization chamber and three small volume detectors (Semiflex, Pinpoint and Edge). The field sizes were ranging from 0.5 cm x 0.5 cm to 10 cm x 10 cm.

Materials and Methods: The beam profiles and depth dose data, for all the fields, were measured in a 6 MV fron a Varian True Beam, using two small volume ionization chambers and an Edge diode. The depth dose data were consistent when applying a 0.5r to the PDDs obtained with the central axis of the chamber, showing that this shift is still valid for small fields. The %dd(10,S) were deduced from these PDDS and the TPR20,10(S) values were experimentally determined with the Edge detector and the pinpoint chamber applying the standard procedure. The quality indexes TPR20,10(10) and %dd(10,10), were calculated from these values using the analytical expressions of Palmans, given in the Code of practice. In addition, the output factors for a

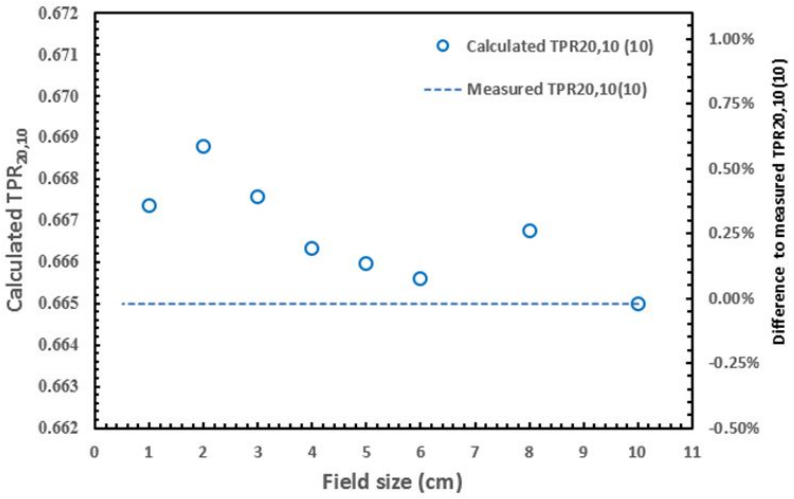

Fig. 1. Difference between measured $TPR_{20,10}(10)$ and calculated values from measured $TPR_{20,10}(S)$

field sizes lying from 10 cm x 10 cm to 0.5 cm x 0.5 cm were measured using the same detectors. The field output factors were calculated using the output correction factors given in the COP. The values obtained with the three detectors were compared.

Results: For field sizes lying between 10 cm x 10 cm and 1 cm x 1 cm, the values of TPR20,10(10) calculated from the measured TPR20,10(S), ranged between 0.665 and 0.669. The values of %dd(10), calculated from the measured %dd(S) ranged from 65.04% and 66.29%. This gives maximum deviations of 0.57% and -1.9% respectively observed for 2 cm x 2 cm field size. Higher deviations were obtained for 0.5 cm x 0.5 cm (-8.68% and -5.7% respectively) stressing that the Palmans expressions are valid down to 1 cm x 1 cm. Regarding the output factors, it is shown that the

consistency between the calculated field output factors obtained with the three detectors was within maximum 1.5%.

Conclusion: Using the formalism of the IAEA/AAPM code of practice on small field dosimetry, the quality indexes TPR20,10 and %dd for a field size 10 x 10 cm^2 can be determined with sufficient accuracy using the experimental data of TPR20,10(S) and %dd(S) in machine specific reference fields. Better compliance between the calculated and experimentally determined beam quality specifiers are observed for TPR20,10 and larger discrepancies are observed for 0.5 cm x 0.5 cm coming probably from the alignment of the detectors with the central beam axis and from the accuracy of the scanning systems. Regarding the field output factors, it is shown that the difference between the corrected and uncorrected output factors can be as large as 8 % for smaller field sizes stressing that the previous procedure of output factor determination was not appropriate for small field sizes.

Biological dose estimation for different photon beam quali- ties used in radiation oncology

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Introduction Although the effect of ionizing radiation in biological systems depends not only on the applied dose, but also on the used energy, dose rate and filters, these parameters are often neglected during radiation therapy. Peripheral blood lymphocytes were irradiated in vitro with a Varian TrueBeam linear accelerator and chromosomal aberrations were analysed in this biological dosimetry study using the linear-quadratic model. Samples were irradiated either with different energy levels or with different dose rates, then dose-reponse curves were compared. The differences in dose-response effects between gamma photons and kV photons were also studied. Our goal was to identify the potential, substantial variations between different therapeutical scenarios and to explore the limits of the linear-quadratic model. Materials and Methods Venous blood sample was obtained by venipuncture from 22 healthy volunteers into Li-heparinized vacutainers. Blood samples in 2 ml cryotubes were positioned in a water filled plastic phantom in order to achieve homogenous doses. Samples were positioned in the isocenter. Irradiation was conducted with different dose rates as follows: 80, 300, 600 MU/min with 6, 10, 18 MV photon beams and 400,1600, 2400 MU/min at doses between 0.5 and 8 Gy at room temperature. Flattening Filter free (FFF) mode was also studied at 6 and 10 MV. Metaphases from lymphocyte cultures were prepared by standard cytogenetic techniques: 0.8 ml blood was added to 9 ml RPMI-1640 cell culture medium containing 15 % bovine serum albumin and penicillin/streptomycin (0.5 ml/L). Lymphocyte proliferation was induced with phytohaemagglutinin M (0.2%). Incubation time was 50-52 hours at 37 ° C. Cell proliferation was inhibited with 0.1 mg/ml colcemid (Gibco) in the last 2 hours of culturing. Cell cultures were then centrifuged and hypotonized with 0.075 M KCl for 15 minutes at 37 ° C, then cells were fixed with cold methanol-acetic acid 3:1 mixture. The cells were dropped on glass slide, and stained with 3% Giemsa. Chromosome analysis was performed in the first cell division, and a minimum of 100 metaphases were scored. All aberration types were recorded: aneuploidy, chromatid and chromosome fragments, exchanges, dicentrics, rings and translocations. Alpha (a) and beta (b) values were calculated for all dose-response curves. Results At lower doses (1-2 Gy) acentrics (not to be confused with the dicentrics or rings coupled fragment) exceeded the number of dicentrics, however, at higher doses this tendency reversed and dicentrics predominated. However, as photon energy increased (at the same dose rate) aberration frequency tended to decrease, i.e. lower energy caused more aberrations. The a coefficient of dose-response curves was negligibly small, the b quadratic values dominated. The effect of conventional irradiation technique with Flattening filters and intensity modulated radiation therapy mode (FFF) on chromosomal aberrations were also compared. The highest values were as follows: 533 aberrations/100 cells (318 dicentric + ring chromosomes) at 8 Gy, 6 FFF, 400 MU/min. Two Gy dose fractions induced 14 0.9 dicentrics and 29 1.6 all aberrations in 100 cells. Conclusion The effect of 2 Gy dose fractions on chromosomal structure was almost identical at different energy levels and dose rates. However, higher aberration rates were found between the applied modalities when larger fraction doses were used. These results might be important in the case of hypofractionated radiotherapy and radiation incidents.

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Feasibility of prompt gamma imaging for passive-scatter proton radiotherapy treatments

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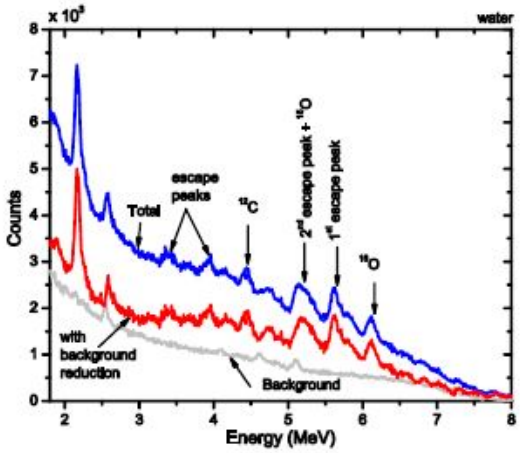
During proton beam radiotherapy, an ideal treatment plan has all the primary protons stopping at the edge of the tumour volume. Due to the sharp fall-off at the end of the Bragg peak, an in-vivo verification of the delivered dose has become a priority to ensure minimal radiation damage to the normal tissue surrounding the tumour and to ensure uniform dose deposition within the tumour. However, there are no primary particles exiting the patient to be used to develop an imaging device for in-vivo treatment verification. An alternate option is to use secondary radiation, like the prompt gammas produced by proton-nuclei inelastic collisions. Several detector designs have been proposed that use prompt gammas produced within the patient. These prompt gamma emissions mainly depend on the clinical proton energy and the atomic composition of the tissue, producing a wide energy range of possible gammas. For passive-scatter proton therapy, there is the additional challenge of extensive background radiation from the passive-scatter beam. The primary aim of this work is to investigate the feasibility of prompt gamma imaging in the passive-scattering proton therapy context, specifically for high-dose, low-fraction treatments, using a Monte Carlo simulation method with the Geant4 (v9.6.04) radiation transport code.

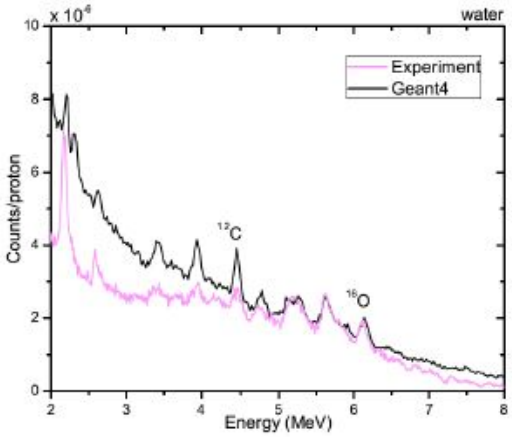
The initial experiment measurements for this work were carried out at the proton therapy facility at iThemba LABS in Cape Town, South Africa. Detection of the prompt gammas produced by a 200 MeV passively scattered proton beam was performed with a LaBr3 detector surrounded by lead shielding. The detected prompt gamma energy spectra emitted from the water target is shown in Figure 1(a). This measurement looked at the discrete prompt gammas emitted from the dominant element ^{16}O found in water. The 6.13 MeV gamma-ray emission line with its first and second escape peaks is clearly visible as well as the emission line at 4.44 MeV due to the $^{16}O(p, \alpha)^{12}C^*$ reaction.

A Monte Carlo model for iThemba passive-scatter proton treatment nozzle was built for com- parison to the above-mentioned prompt gamma measurements. The model was validated using experimental depth and lateral dose data for clinical dose delivery. The Precompound model was selected for proton inelastic nuclear reaction and optimised against available experimental cross section data[1]. The water target, the $LaBr_3$ detector and the lead shielding was added to the Geant4 beamline simulation to replicate the experimental results, shown in Figure 1(b). While the Monte Carlo model under-estimates the background radiation, the relevant prompt gamma peaks are clearly visible and provide a good validation for the Geant4 simulation.

This prompt gamma Geant4 model was then used to evaluate the prompt gamma production from a typical brain arteriovenous malformation (BVM) treatment. A typical BVM treatment at iThemba LABS delivers 54.5 Gy over 3 fractions to a 5 x 4 cm cylindrical volume using a 10-cm water equivalent proton beam. Unfortunately, ethical clearance has not yet been granted to use patient data, so a simple model of bone, water, and tissue was used to mimic a patient. The prompt gamma production from several single-material targets (bone, water, tissue, lung, fat) was also simulated. These results will be discussed as well as the feasibility and the challenges of PGI for a passive-scatter proton therapy treatment.



(a)



(b)

Figure 1: (a) Detected prompt gamma energy spectra (b) Comparison between measured and simulated energy spectra emitted from water target for proton energy corresponding to a 24-cm range in water.

The implementation of CREX in the department of radio-therapy

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Objectives: Risk management is an important issue in the activity of a radiation oncology department. CREX (in French: comité de retour d'expérience) were inspired from the French experience in civil aviation to ensure quality and security of treatment delivery. We aimed to report our experience in the feedback committee.

Methods: In the department of radiation oncology (Habib BOURGUIBA hospital, Sfax- TUNISIA), CREX staffs were started since December 2014. We planned monthly meetings with the participation of all the team: doctors, medical physicians, manipulators. Its aim is to collect and expose errors or misses in the medical care. The different points and difficulties are declared. It enables each active member in the department to listen to every event, to select the event that will be selected for analysis (ORION method) and choose the most important correcting actions. A report is written after each meeting.

Results: In our experience of about 2 years, we detected 3 major events (dose prescription, fields) which were analyzed. Correcting actions were discussed and chosen. We verified the application of those actions. The minor events were also noticed and attention was required.

Conclusion: Risk management is an important issue requiring the involvement of all the staff, a clear communication, structured steps and the verification of applying correcting actions. Such experience should be generalized in all radiotherapy departments.

Validation of a novel dosimetry application for measuring the calibration curve of Gafchromic Films

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Introduction The optical properties of the Radiochromic film, expressed for its optical density (OD), change as the absorbed energy varies. The film to use should be defined in terms of its capability of modification in OD for different dose adsorbed levels, besides of the spatial response and linearity. For this study, we use the GafChormic XR-RV2 film, in a dose range from 0 Gy to 10 Gy, cut in small pieces and irradiated with 100 kVp and 150 kVp energies. The samples will be measured with a spectrophotometer and compared with the result obtained with commercial scanner. The aim of this work is focused on obtaining calibration curves for the same samples of films, using a spectrophotometer comparing the results of measurements with a graphic scanner.

Materials and Methodology A kilovoltage x-ray beam (50 kVp to 150kVp) from an Xstrahl 150 X-ray therapy Unit used for superficial treatment, was employed in this study. It was calibrated following the protocol described in Report-76 by TG-61 of the AAPM.

The film XR-RV2, is composed in its interior by a block of three layers; the adhesive sensitive (12.0 mm thick), surface (3.0 mm) and active (17.0 mm), and is coated on both sides by layers of polyester one of yellow color and another one of white color, both of 97.0 mm thick. The dose was delivered to the center of the Gafchromic XR-RV2 films by a circular field cone with diameter of

5.0 cm, positioned on a 30.0 x 30.0 x 5.0 [U+3016]cm[U+3017]ˆ3 solid water phantom with the film at surface. The films, were cut into small samples (4x4 cm2) from the same sheet, and each sample was irradiated with one of two beam qualities (100 kVp or 150 kVp), considering doses from 0 to 10 Gy in steps of 100 cGy calculated at the surface, where the sample with 0 cGy will be measured for background reference.

With at least 24 hours after exposure, the films were scanned by two different methods. First, a graphic scanner Epson-Expression-11000XL, used in day to day film evaluation was employed; this scanner works with a Fluorescent Xenon Lamp and has a resolution of 2400 x 4800 dpi. Afterwards, it is applied for comparison a spectrophotometer LAMBDA 1050, taking into consideration that the white polyester layer in the film does not permit the pass of light, it should be used in reflection mode, which is based on the collection of light reflected by the films, through an integrating sphere that is able to measure a wide range of reflected light from a material as a function of wavelength. This device was chosen for this work, due to its high sensitivity of the absolute reflectance measurements, which improves on traditional methods of testing, by automatically and reproducibly changing the angle of the sample, and it is capable to set the resolution to different levels (down to 0.2 nm).

The spectrophotometer has a double beam, the first one is focused on the non-irradiated film that is placed in position of the standard sample (reference). In the second beam position, irradiated sample films were placed and measured; this reflectance measurement was performed at a wavelength range of 650 nm and 620 nm, where the highest reflectance was obtained. The program allows to measure optical density by reflection, defined as: OD=log[U+2061](1[U+2044]R) Where OD is the optical density and R the reflectance. The doses were defined at the same position of reference points in a square patterns of 1x1 cm2 around the center of the film, defined as a dot matrix, which is evaluated in the scanner as well as the spectrophotometer. This method was applied for establishing the calibration curve for the beam by both devices.

Results The Gafchromic XR-RV2 film calibration curves were found to be weak dependent of beam energy (approximately lower than 8% difference of the pixel values between 100 kVp and 150 kVp). The Total reflectance has shown in the primary data obtained, to decrease with increasing irradiation doses. This behavior is mainly due to diffuse reflectance, since the specular reflectance is essentially constant with wavelength and slightly dependent on the irradiation dose.

Conclusions Some of the data obtained in this pilot project, support the hypothesis that the sensitive layer reacts to irradiation more linearly than data measured using standard commercial devices.

The Gafchromic XR-RV2 film can provide acceptable accuracy of dose measurements for kilovoltage x-ray irradiation using small field irradiation, by determination of a its calibration curve. The combination of Gafchromic XR-RV2 film with flat-bed scanner represents a low-cost and viable dosimetry tool for in vivo Dosimetry in irradiation procedures with superficial radiotherapy.

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Status of Radiotherapy and results of TLD postal dose qual- ity audit in Ukraine

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Radiation therapy (RT) is one of the main treatment modalities for cancer patients. The effectiveness of radiation therapy depends on highly specialized equipment, the accuracy of delivery of absorbed dose to target tumor and staff qualification. The population of Ukraine is approximately 43 million. According to Ukrainian Cancer Registry statistics (Bulletin 17, 2016) there were 125 424 new cancer cases registered in 2015. Crude incidence rate was 345.9 per 100 000 of population (356.8/100 000 males and 336.5/100 000 females). Currently, there are 53 Oncology enters in Ukraine with radiotherapy equipment including four private Oncology clinics. The information about status of radiotherapy in Ukraine has been collected by the IAEA's annual survey DIRAC for all Ukrainian radiotherapy departments through National Coordinator – Grigorev Institute for Medical Radiology (IMR). The summarized data on radiotherapy equipment is presented. There are 103 teletherapy units in radiotherapy departments, including 80 Cobalt units (Co-60 radiation source) and 23 linear accelerators. Currently 45 Cobalt units (56.3 %) are in use for about 20 years or more and only 23 units (28.8 %) – less than 10 years. More than 50% of Cobalt radiotherapy units have the radiation sources Co-60 with the lifetime more than 10 years. There are also 42 brachytherapy units (6 units with Ir-192 source and 36 units with Co-60 sources) in Ukraine. Nine of them are not operational due to the absence of radiation sources. There are 36 CT and 5 conventional (X-ray) simulators in use. In total 18 radiotherapy departments are operation without simulators. There are 60 treatment planning systems (TPS) in radiotherapy in 35 Oncology centers (66 % of total). In the remaining 34 % oncology centers the dose calculation for patient irradiation is still performed manually. One of the ways to detect possible errors of the delivered dose in radiotherapy is to conduct independent external audits of the dose calibration quality for radiation beams. Ukraine participates in IAEA/WHO TLD postal audit of dose calibration quality for radiotherapy beams since 1998 (IMR – National Coordinator). During the period 1998-2015 the 48 Oncology enters took part in IAEA/WHO TLD -audit. A total number of checked radiation beams were 356 (15-25 beams per year). The results of the audit showed that about 25-30% of teletherapy units exceeded the 5% acceptance error limit. According to the national survey of radiotherapy departments the clinical dosimetry carried out not in all departments due to absence of modern dosimetric equipment, irregularly maintenance of teletherapy machines and low qualification of staff. In the framework of National TC-Project UKR/6/010 "Developing and Implementing a National Quality Control System by Strengthening the Knowledge and Capacity of Medical Physics at Radiotherapy Departments" (2012-2013) there were three training workshops organized for medical physicists of Oncology enters: the two workshops on topic - Radiotherapy Practice at the Oncology (Clinical dosimetry) and one on topic - Commissioning and QA of Treatment Planning Systems. Also 25 complete sets of the equipment for clinical dosimetry were provided for radiotherapy departments of Regional and Municipal Oncology Hospitals of Ukraine under this IAEA TC-project. After IAEA technical support (training of medical physicists, implementation of International Code of Practice TRS 398, and the use of modern clinical dosimetry sets) the results of TLD-audit in 2014 demonstrated the positive impact on improvement of the quality of clinical dosimetry in RT departments. The limit of acceptance error 5% was exceeded only for two teletherapy units (about 6% of total number audited units). The annual DIRAC survey of radiotherapy departments gives a possibility to monitor and assess the situation regarding equipment and staff in RT departments of Ukraine. Unfortunately at present the level of radiotherapy facilities is not sufficient for quality treatment for patients requiring radiotherapy. The main priority needs of radiotherapy departments in Ukraine identified through DIRAC survey and TLD-audit include are: replacement of radiation sources for Cobalt radiotherapy units; modernization of equipment using for radiotherapy – CT simulators and treatment planning systems; creation and implementation of a National Protocol to determine the absorbed dose in the external beam radiotherapy and permanent training of medical staff including medical physicists.

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The "CLAWS" – An applicator for whole-eye radiotherapy

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Introduction: Ophthalmic tumors are fairly rare and diverse and their diagnosis and treatment usually requires special expertise and equipment, including patient care by a multidisciplinary team. Brachytherapy is the preferred radiation treatment modality for various intraocular tumors and the most commonly used radionuclide is I-125. The "Claws" is a gold applicator that is loaded with I-125 seeds for localized whole-eye radiotherapy. It was designed at Groote Schuur Hospital. The applicator is mainly used to treat retinoblastoma, a childhood cancer of the eye.

Methods: Under general anaesthesia, a pericorneal ring is attached to the four extra-ocular muscles, and four appendages, each loaded with I-125 seeds, are inserted beneath the conjunctiva in-between each pair of muscles and attached anteriorly to the ring. The applicator has an inside diameter of 22 mm. Current dose calculations approximate each I-125 seed as a point source, and a project is underway to improve the dose calculations, and particularly the dose to critical structures in and around the eye, based on Monte Carlo calculations.

Spectra of the OncoSeed IMC6711 seed at different angles were measured in air using a silicon drift detector. Seed measurements in specially designed phantoms were done using thermoluminescent dosimeters and gafchromic film. A CAD model of the "Claws" was designed and used to manufacture a PVC model in a milling machine, which was then micro-CT scanned at a 20 μm resolution. The CAD model was also cut into 20 μm slices; these will be edited and used as input for Monte Carlo simulations.

Results: The applicator irradiates the eye with minimal dose to the surrounding bony orbit, extraocular optic nerve, eyelids and lacrimal gland. Certain seeds may be omitted to reduce the dose to the unaffected parts of the eye. A typical treatment prescription is 40 Gy given over four days to the centre of the eye. General anaesthesia is also required for the removal of the applicator.

Conclusion: The applicators are cost-effective because they can be re-used. The I-125 seeds are regularly used for other eye plaques and implants. The eye does not need fixation during treatment and cosmesis is excellent. The Monte Carlo simulations will take into account the gold shielding of the applicator and the anisotropic dose distribution around the I-125 seeds, which will give a better estimation of the dose to the organs at risk.

Film2Dose: an research intended tool to access the com- bined standard uncertainty on radiochromic film dosimetry using multi-channel optimization.

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Introduction: Modern state-of-the-art techniques in radiotherapy, such as volumetric modulated arc therapy (VMAT), have constantly increased the complexity of treatment delivery and increased the demand for quality assurance (QA) and better small field dosimetry. Dosimetry using radiochromic EBT3 films is a tool sometimes selected to verify the correspondence between planned and measured doses. A film dosimetry methodology was developed using absorbed dose to water standard and the combined standard uncertainty were also estimated using Scientific Python packages on the software Film2Dose. Figure 1.
Film2Dose software can import many Therapy Planning System formats.
Methodology: Scanned images were measured using calibration films with known doses delivered. The optical density measures were done defining areas of interest of approximately 0.5 x 0.5 cm2 at the centres of the exposed areas. Data was obtained for the red, green, and blue color channels at a resolution of 16 bits/channel and 72 dpi.
$OD = log_{10}(65535/M(x))$
Where M(x) is pixel value from channel x (Red, Green and Blue) The methodology implemented is optical density based using scanned film images to perform dose measurements. Calibration curves were obtained for each channel using the least squares polynomial fitting. The uncertainty parameterization for each calibration curve was implemented based on literature for type A uncertainty. A methodology to perform multichannel weighted average dose was implemented to estimate Type B uncertainty.
Dose Calculation: The optical density dx is obtained using a color flatbed scanner for image digitization on red (R), green (G) and blue (B) bands of the visible spectrum. The scanned optical density is defined as:
$dX = log_{10}(X)$
Where X [0, 1] stands for the normalized color channel stipulated by the output of the scanner by analog-digital conversion in 16 bits. The color channel value X also depends on scanner coordinates (i,j), i.e., spatial pixel position.

In accordance with the Beer–Lambert Law, the triple-channel approach can separate numerically the dose-dependent part of a scanned optical density signal from any disturbance by the equation 3:

$$D^{x} = \bar{d}^{-1}_{x}(d - \Delta d)$$

Where the factor $\Delta d = \frac{I}{I}$ is the disturbance value and $\bar{d}^{-1}_{x}$ is the inverse calibration function. This parameter could be interpreted as film relative thickness, artifacts or noise that modifies optical density values measured by scanner. \

Some functional forms for the sensitometric curve have been proposed on literature. Three different empirical curve types were chosen to map doses from optical density:

$$d^{(n)}_{1}(D) = 3n = 1\ a_n D^{(n-1)}$$

$$d^{(n)}_{2}(D) = 3n = 1\ a_n ln(\frac{D}{100} + 1)^{(n-1)}$$

$$d^{(n)}_{3}(D) = 3n = 1\ a_n arctan(\frac{D}{500})^{(n-1)}$$

Multi-channel dosimetry: Since the dose cannot depend on the color channel X selected for evaluation of Eq. the Multi-channel approach uses the information of a sequence of multiple

channels $\{X_k\}^{k}_{k\ 1}$ in a least squares error function of differences between three channels. A new robust objective function

known that one outlier may cause a large error in a least squares estimator. In film dosimetry some artifacts might occur more frequently than it was expected in a normal. This work contribution is the implementation of that robust smoothed objective function in the Gafchromic dosimetry optimization. Then, the robust objective function:

$ \Omega (\mathit{\Delta d})=\frac 1 k\left(\overset k{\underset{i\neq j}{\sum }}\sqrt{(D_{{\text{Xi}}}-D_{{\text{Xj}}})^2+\delta ^2}\right)\rightarrow \underset{\mathit{\Delta d}}{\text{min}}
$

Results: Calibration curves from all channels were obtained using a least squares polynomial fitting and their results were evaluated using uncertainty estimation. The standard uncertainty on average dose per region of interest area with approximately 0.5 x 0.5 cm2 was evaluated on recommended dose range (0 - 1000 cGy). Both relative Type A, Type B and combined standard uncertainty values for 1 standard deviation (k=1) behaved asymptotically as function of absorbed dose to water. Combined uncertainty values were around 20% to 10% on 40-100 cGy dose range, and having an asymptote around 2.5% on doses higher than 350 cGy.

Conclusion: This work shows that an accessible radiochromic film dosimetry platform can be created using solely open source technologies with statistical confidence and traceability to primary dose to water standards. The uncertainty analysis showed that EBT3 film can access optimum results on doses higher than 350 cGy.

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Evaluation of radiation doses to organs at risk and comparison the toxicity with application of modern techniques radiotherapy of treatment patients for prostate cancer

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Keywords: Hypofractionated radiotherapy, IMRT, prostate cancer, toxicity. Background: Cancer of the prostate is one of the most important medical problems facing the male population. Radiotherapy (RT) is one of the major methods of treatment for prostate cancer. Purpose. The aim of this study was to compare doses for the bladder and the rectum and to estimate manifestations of acute genitourinary toxicity (GU) and gastrointestinal toxicity (GI) with application three-dimensional conformal RT (3D-CRT) and intensity modulated RT (IMRT) with using the classic mode of fractionation and hypofractionation regime. Material and Methods: 102 patients with intermediate-risk prostate cancer were treated 5 days per week: using 3D-CRT 74 Gy in 37 fractions (n=33), using IMRT with classic mode 76 Gy in 38 fractions (n=32) and using IMRT with hypofractionation regime 67.5 Gy in 27 fractions (n=35). Compare the medium doses for the bladder and the rectum was performed using dose-volume histogram. Acute local toxicity was assessed with the scale RTOG/EORTC. Acute toxicity scores were recorded weekly during treatment and 3 months after radiotherapy. Results: Median dose for the bladder was: 3D-CRT 55.10 8,65 Gy, IMRT with using the classic mode of fractionation 44.84 9.10 Gy, with using hypofractionation regime 44.31 4.36 Gy . Median dose for the rectum was: 3D-CRT 52.39 6.88 Gy, IMRT with using the classic mode of fractionation 44.19 8.49 Gy, with using hypofractionation regime 42.29 8.83 Gy. GU toxicity grade 1 was 3D-CRT for 21 evaluated patients (65.6.9 %), IMRT with using the classic mode of fractionation – 18 (56.3 %), IMRT with using hypofractionation regime – 19 (51.4 %). Also grade 2 was 3D-CRT – 7 (21.9 %), IMRT with using the classic mode of fractionation – 6 (18.6 %), IMRT with using hypofractionation regime – 7 (20.0 %). And grade 3 was 3D-CRT – 2 (6.25 %). GI toxicity grade 1 was 3D-CRT for 22 (66.8 %) patiens, IMRT with using the classic mode of fractionation – 20 (62.5 %), IMRT with using hypofractionation regime – 20 (57.1 %)/ Also grade 2 was 3D-CRT – 8 (24.2 %), IMRT with using the classic mode of fractionation – 5 (15.6%), IMRT with using hypofractionation regime – 6 (17.1 %). And grade 3 was 3D-CRT – 3 (9.0 %). The median follow-up was 22 0 months (IQR 14 4–38 2). **Conclusions:** According to the survey, with 3D-CRT dose to organs of risk more than an average of 11.0 Gy to the bladder (U-test, $p<0.05$) and 9.0 Gy - to the rectum (U-test, $p<0.05$). Analysis dose to organs of risk proves that using IMRT with using hypofractionation regime the values of radiation dose comparable to IMRT with using the classic mode of fractionation. Only in the group 3D-CRT we observed acute toxicity grade 3.

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Carbon Ion Radiotherapy for Prostate Cancer; a nationwide survey of the Japan Carbon-ion Radiation Oncology Study Group (J-CROS 1501)

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Introduction of the study; Multi-institutional analysis of the patients with prostate cancer who have received carbon ion radiotherapy (CIRT) as the prospective study in each institute of the Japan Carbon-ion Radiation Oncology Study Group (J-CROS) was carried out. **Methodology;** Data of patients enrolled in prospective clinical trials performed at National institute of radiological science, Gunma university heavy ion medical center and Ion beam therapy center, SAGA-HIMAT foundation were retrospectively analyzed. CIRT dose and fractionations were 66-63Gy(RBE)in 20 fractions, 57.6Gy(RBE) in 16 fractions or 51.6Gy(RBE) in 12fractions.All patient risks were reclassified according to the D'Amico risk classification. A short-term (6 months) androgen deprivation therapy (ADT) and a long-term (24 months) ADT were combined with CIRT for the intermediate-risk group and the high-risk group, respectively. ADT was not combined in low-risk group. The biochemical failure was defined as a rise of >2.0 ng/mL above PSA nadir (Phoenix definition). **Results;** Between December 2003 and December 2014, the total number of enrolled patients from all three institutions was 2157. The number of patients in low-risk, intermediate-risk, and high-risk groups were 263, 679, and 1215, respectively. A total of 1754 patients (82%) underwent ADT. The median follow-up periods of surviving patients was 29 months. The five-year biochemical relapse-free survivals (bRFS) in low-risk, intermediate-risk, and high-risk patients were 92%, 89%, and 92%, respectively. The ten-year bRFS in low-risk, intermediate-risk, and high-risk patients were 77%, 70%, and 79%, respectively. The five-year local control rates (LCR) and cause-specific survivals (CSS) in low-risk, intermediate-risk, and high-risk patients were 98%, 96%, and 99% for LCR, respectively, and 100%, 100%, and 99% for CSS, respectively. The incidence of grade (G) 2 and G3 late toxicities were 4.5% and 0% for the bladder, and 0.5% and 0% for the rectum, respectively. **Conclusion;** Analysis of the first multi-institutional data on CIRT for prostate cancer suggested that the treatment outcomes of CIRT were favorable, especially in high-risk group patients.

Challenges and solutions of establishing advanced radiation oncology services in low and middle income (LMI) countries

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Purpose: To address the challenges that face LMI countries (LMIC) and how radiation oncology service (ROS) professional; medical physicists (MPs) and radiation oncologists (ROs), from 5 different LMIC practically overcame these challenges.

Challenges and solutions: The multiple clinical and administrative challenges in our LMIC are a result of either lack of or insufficiency in the following 4 categories: 1] Number of qualified ROS professionals, 2] Academic education and clinical training, 3] National regulations including official recognition of the ROS professions, 4] Availability of modern equipment and required maintenance. The first two are most important from clinical point of view, whereas the remaining two show the level of maturity and awareness of the ROS professions in the country. To address challenges in categories#1 and #2, several LMIC presented in this study have resorted to collaborative agreements with reputed regional or international cancer institutions. Examples include the agreements between MD Anderson Cancer Center (MDACC) with each Jordan's King Hussein Cancer Center (KHCC) and Egypt's National Cancer Institute (NCI); between Zhianawa Cancer Center (ZCC) and West Virginia University and between King Hamad University Hospital (KHUH) and Turkey's Erciyes hospital. These agreements result in implementation of clinical services and treatment techniques as well as local staff training. Regional collaboration among LMI institutions is also sought after; as an example the collaboration between Jordan's KHCC with each Egypt's NCI and Iraq's ZCC in which MP and RO experts are exchanged. In addition to institutional agreements, networking with regional or international experts is also used to augment certain aspects of clinical service, such as ZCC using King Faisal Specialist Hospital and Research Center (KFSH&RC) MP experts and KFSH&RC using MP experts from McGill University. The second category poses a more difficult challenge. Currently, the Asia part of Arabic countries along with Egypt, a population of approximately 240 million, have few clinical training programs. There is a handful of RO residency programs available one in each country (Egypt, Iraq, Jordan, Lebanon and Saudi Arabia). For MPs, the situation is worse with one residency program in Saudi Arabia. Almost all physicists in our region get on-the-job-training. To mend this severe lack of training, extensive clinical workshops are continuously conducted in the region. The nature of these workshops is hands-on training and each focuses on a particular clinical aspect. Regional countries have adopted a synergistic approach in which each contributes its experts in particular field to train others. These workshops serve as a main source of knowledge transfer and training. To add another layer of challenge, national regulations and recognition of the medical physics (MP) profession is lacking, with the exception of Egypt and Saudi Arabia (SA). In the former the MPs have an official title of "specialist scientist" while in the latter the MPs are fully recognized with preferences for board certification, though itself lacks a board certification scheme/body, even while it hosts the region's only residency program. It is interesting that neither specialties, MP or RO are available among the list of specialty studies (thirty in total) in the Arab Board of Health Specializations, http://arab-board.org/specialities. Due to lack of national guidelines, large institutions in LMIC are left to develop their own QA protocols adopted from other bodies such as AAPM, IAEA and ESTRO and then pass them on to smaller institutions through training workshops and regional expert visits.

Results: The implementation of the above solutions namely agreements with regional and international institutions and reaching out to individual experts have resulted in many success stories; implementation of SBRT, SRS, VMAT and IMRT techniques in most centers, and improvement in on-going services such as pediatric oncology and brachytherapy in others. The most important impact of these outreach efforts is in regards to training and education of the staff. Graduates of the handful RO residency programs are now practicing in many local LMIC, including Bahrain, Egypt, Palestine (Gaza

Strip), Iraq, Jordan, Saudi Arabia and one in the UK. The single MP residency program has graduates working in Jordan, Oman, Saudi Arabia and Yamen.
Conclusion: There is no one-single global solution in establishing safe state-of-art treatment techniques in LMI countries. However, we found that the one successful and cost-worthy solution adopted by professionals in the 5 countries presented in this study is networking and outreach to regional and non-regional institutions and individual experts. LMI states have to adopt a synergistic solution in which each one benefit the other where expertise is lacking. Leading regional institutions should shoulder the burden of passing on the knowledge and provide for training for others. National guidelines and recognition of the ROS professions by the local authorities remain the big challenge that require efforts on the political and global scale.

Carbon-ion radiotherapy for prostate cancer with bladder invasion

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Introduction of the study; The standard treatment for prostate cancer with bladder invasion which was classified very high risk according to the NCCN clinical practice guidelines in oncology version 1.2015 has not been established. There are few reports, and one of them reported that 44.6% of patients received neither the operation nor the radiation therapy. The carbon ion radiotherapy has a superior characteristic both biologically and physically, so it is important to search the therapeutic potential of the treatment. The purpose of this study is to report the experience of carbon ion radiotherapy for prostate cancer with bladder invasion.**Methodology;** 807 prostate cancer patients were treated at Gunma University Heavy-ion Medical Center (GHMC) between March 2010 and September 2014, and 6 prostate cancer patients with bladder invasion, who underwent radical carbon-ion radiotherapy (57.6 Gy (RBE) **/** 16 fractions **/** 4 weeks) with concurrent androgen deprivation therapy were identified retrospectively. All patients were diagnosed as clinical T4N0M0, by using magnetic resonance imaging (MRI) and cystoscopy.Five patients received neoadjuvant and concurrent combined androgen blockade, followed by LH-RH agonist after carbon-ion radiotherapy. One patient received Gn-RH antagonist throughout the treatment period.**Results;** The median follow up time was 42 months (range, 22 - 65 months). The local recurrence was observed in 1 patient. The Grade 1 acute genitourinary (GU) toxicity was observed in 2 patients. Grade 2 or higher toxicity and acute gastrointestinal (GI) has not observed in this analysis.**Conclusion;** Carbon-ion radiotherapy with concurrent androgen deprivation therapy for prostate cancer with bladder invasion was effective and have no problem technically. It might be a useful treatment option for the very advanced prostate cancer.

Commissioning and validation of total skin electron therapy (TSET)

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AIM: To report the results of commissioning, validation and in-vivo dosimetry of Total Skin Electron Therapy (TSET). Methods and Materials: TSET was commissioned in linear accelerator (Varian True beam) using 6MeV electron in high dose rate total skin electron ode (HDTSe) mode

at a treatment distance of 5 m with filed size 40x40cm2 at gantry angle 270° , collimator angle 0° , using the Stanford technique based on the AAPM TG report 23. TSET patient positioning
device was made of wood with a Plexiglas beam spoiler of 2mm thickness. Dose prescription was 30.6 Gy/17fractions.
The measurements were carried out using parallel ion chamber (Roos chamber, PTW) with UNIDOS electrometer (PTW inc), gafchromic film, and TLD (LiF). Phantoms used for commis- sioning and validations were solid water phantom slabs of various thickness, 30X30 cm 2(Standard imaging Inc) and a 30cm diameter cylindrical cheese phantom (Standard imaging Inc).
Commissioning: PDDs and profiles (along X and Y axes) were measured for single dual field.PDDs and profiles for the single dual-field beam created from two scattered electron beams

directed at oblique angles (11°) were measured using Roos chamber and gafchromic film .A
gafchromic film was kept at cross-sectional plan sandwiched between two halves of a cylindrical phantoms located at the treatment plane midpoint was irradiated to determine the depth dose due to six dual-field beam geometry. The characteristics of the electron beams were evaluated by calculating most probable energy Ep,o a lower mean energy Eo and R50. The beam uniformity was checked by irradiating films pasted on the surface of the cylindrical phantom on a plane perpendicular to the beam axis at the treatment SSD. Dose output was measured for single dual beam and it was followed by the measurement of overlapping factor from dose measured by TLD. **Validation**: Validation of absolute dose was carried out using TLDs powder in sachets size 1cm x1cm which were kept on the cylindrical phantom to measure the dose and compared with the calculated dose.
In vivo dosimetry**:**
In-vivo dosimetry was carried out using TLDs (LiF).Sachets of TLDs were kept at different parts (viz. forehead, SSN, umbilicus, left intra mammary ,right axilla,right calf and left toes etc) of patient skin (during the patient treatment)
Result: From the Y-profile, uniformity the degree of scattering angulations between two oblique fields were calculated and found to be (11[U+F0B0]). The symmetry and flatness of single beam in X and Y axis were 1.02% and 3.83% on the treatment plane 4.5 % and 8.77% respectively. The measured symmetry and flatness were out of tolerance (4% for X-axes and 8% for Y-axes) as per AAPM report no 23, however was improved in single dual beam technique. It was improved further to 0.7% and 1.36% along X-axes and 1.54 % and 4.64% along Y axes. The most probable energy Ep,o and a lower mean energy Eo were calculated as 4.38MeV and 3.31MeV . R50 and Rp were found to be 1.43 cm and 2 cm. Dmax measured for single dual beam was 5mm while the Dmax measured for six dual beams was 2 mm. The overlapping factor calculated was found to be 3.1. The films exposed at the treatment plane using six dual fields were found to be uniform within 0.5%. The absolute dose validated by the TLDs kept on the phantoms; it was upto 6 % from the calculated. For patient in-vivo dosimetry, doses measured at SSN, umbilicus, left intra mammary and left toes were in the range of 5.5-9% variation from the prescribed dose but as expected doses to organs like forehead, right axilla, right calf etc shows high dose variation in the range of 20-28% from the prescribed dose. (Table 1)
Conclusion: TSET has been clinically commissioned and validated.

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Education and training activities of JASTRO

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Population of Japan is 127,767,994 and in 1981 malignant neoplasms became the first rank of mortality and the rate increasing steadily. In 2011, about 357,000 patients were died from cancer per year and 750,000 patients were suffered from cancer per year in 2008. The number of new patients treated with radiation therapy is estimated to be approximately 213,000 in 2012 and the number of total patients including new patients and re-treatment patients treated with radiation therapy is estimated to be 252,000. However, the number treated with SRT for body is 4,000 and the number of patients for IMRT now is near 6,000, which is as few as 3.3% of new patients treated by RT.

Regarding statistics of Japanese radiation oncology, there are 80 medical schools in Japan and 80000 graduates per year, and there are 700 radiotherapy facilities and as small as 500 qualified radiation oncologists. Only 40 new graduates apply for radiation oncology training program per year and in 2010 we are estimating that there are almost 1,000 full time radiation oncologists, 600 JASTRO certified radiation oncologists, 1,900 therapists, and 170 full time medical physicist in Japan. Japanese medical students study 6years in medical University and take written national board examination for Medical Doctor. Then they spend Internship of general medicine for 2 years and go to Internship of radiology for 2 years to take written board exam for Certified Radiologist. Then they take Residency program of radiation oncology for 2 years to take written and oral board exam for Certified Radiation Oncologist. Hence, at least, it takes 12 years from entering medical school to become board certified radiation oncologist in Japan.

Mission of the JASTRO educational committee is to manage educational lecture at annual JASTRO meeting and summer educational seminar and to improve the quality of education of radiation oncology at medical school for recruitment of medical students. The committee plans educational lectures at JASTRO annual meeting, we have 6-10 lectures for 400-600 participants. In addition, JASTRO conducts Summer seminar with 2 days course on radiation oncology once a year, and Seminars for medical students and residents with 1 day course twice a year consisting with lectures and RTP practice, Seminars for RO nurse twice a year with 1 day course, and Radiation biology seminar once a year, which is 1 day course, and Radiation physics seminar every two years, with 1 day course. JASTRO has formulated three kinds of Guidelines; Guidelines on TRP, Guideline of brachytherapy, and Guideline of RT planning for image guided RT.

Cancer e-learning is operated by cooperation of Japan Society of Clinical Oncology, JASTRO, and 6 other societies. It consists with a total of 148 lectures in the fields of Clinical trials and statistics, Basic oncology, Site specific clinical oncology, Palliative medicine, Medical care, Chemotherapy, Radiation oncology, Psycho-oncology. Among them there are 23 Radiation oncology items.

Regarding education collaborating with international organization, JASTRO has been making a great effort to provide many educational opportunities such as ESTRO School, JASTRO-ESTRO workshop, Japan-China-Korea trilateral symposium and Japan-Taiwan Radiation Oncology Symposium on Radiation Oncology.

JASTRO support IAEA activities mainly of RCA. JASTRO supported four projects listed here: Improving Image Based Radiation Therapy for Common Cancers in the RCA Region: Regional Training Course (RTC) on 3D CRT at Gunma Univ. 2012/3/5-9, Supporting 3D image-Guided Brachytherapy Services–RTC on 3D IGBT for uterine cancer at Saitama Medical Univ.2014/9/29-10/3, Strengthening the Application of Stereotactic Body Radiation Therapy (SBRT) to Improve Cancer Treatment–RTC on SBRT at Tokyo Metropolitan Komagome Hospital. 2014/10/20-24, and Strengthening Intensity Modulated Radiation Therapy Capability in the Region (RCA) –RTC on IMRT at Gunma Univ. 2017/3/6-10.

Session 8 - Education and training **/** 226

International Radiotherapy Plan Competition: A step to- wards better planning and global transfer of knowledge

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Purpose: The quality of any plan for a radiotherapy patient is as good as the planner. Achieving optimum plans require both knowledge in the capabilities of the treatment planning system (TPS) and the clinical expertise of the planner. The aim of this competition is to challenge planners worldwide to do their best plan and then compare their dose objectives with others using the same or another TPS. Global transfer of knowledge is then shared through webinar sessions in which top planners from each TPS category share their planning tips and techniques. The major outcome of this initiative is to distribute global knowledge and best practices among the radiotherapy planners, which will lead to better plan qualities for cancer patients. in the whole world, knowledge sharing is worldwide and so is the impact. Methods and Materials: A left sided breast case with axilla and supraclavicular lymph nodes was put for the challenge. The dose scheme is 50 Gy to PTV_TOT_EVAL delivered in 25 fractions. Around 400 participants from 50 countries have registered from different geographic regions (36% from Asia, 4% from Africa, 38% from Europe, 5% from South America, and 10% from North America). The quality metrics, generated by the Plan IQ software (Sun Nuclear Corp.) were extracted from the RTOG protocol 1304 with even tighter tumor conformity and homogeneity indicators and tighter organ at risk (OAR) sparing criteria. All participants received the same dataset package: The CT DICOM image set, DICOM structure set, set of dose quality metrics, and the general planning rules that define certain practical aspects of the plan, i.e. allowed max number of fields, field arrangements and angles, energy, dose calculation algorithm, use of advanced heterogeneity correction, and size of dose calculation grid. The participants were given two weeks to submit their plans, which were evaluated by the PlanIQ software and were given scores out of 100 points. Results: Around 220 plans generated by different commercial TPS's, Varian-Eclipse, Elekta-Monaco, Philips-Pinnacle, Accuray-Tomotherapy, RaySearch-RayStation, and others. Of which, only 180 plans were evaluated using the Plan IQ software. The plans submitted per TPS were as follows: 93 Eclipse plans (51.6%) 30 Monaco plans (16.7%), 19 Pinnacle plans (10.5%), 13
Tomotherapy plans (7.2%), 10 RayStation plans (5.6%), and 15 plans from other vendors (8.3%). The scores' statistics per TPS were as follows: Eclipse's mean score was 58.3% (STD= 13.5% with mean deviation of 11.1%); Monaco's mean score was 62.1% (STD= 13.8% with mean deviation of 10.9%); Pinnacle's mean score 73.1% (STD= 17.4% with mean deviation of 13.9%). RayStation's mean score was 89.6% (STD= 11.3% with mean deviation of 8.4%); and for Tomotherapy the mean score was 66.5% (STD= 20.1% with mean deviation of 16.7%). The highest score was 98.2/100. Following the announcement of the results, a series of webinars was arranged with the 3 top planners from each TPS category. The webinars are free of charge and were attended by planners using the same TPS as well others who wanted to learn planning tricks. Each webinar lasted for 1 hour, 20 minute per presenter, followed by questions and answers session. The feedback from the participants was overwhelmingly positive in regards to the knowledge shared that a WhatsApp group was initiated in which participants and others who came later keep on sharing their questions and solutions when it comes to clinical treatment planning. A youtube channel was also initiated to allow others to watch the webinars and other materials. Conclusions: In the 21st century knowledge transfer and learning is not confined to physical sites. We have initiated a plan competition that metamorphed into a truly global knowledge sharing and training tools. We noticed that the competition raised the awareness of TPS capabilities and participants who scored low have resubmitted plans that got high scores. Social media was used to create a community of planners to keep the momentum of learning and knowledge transfer going strong. In 2017, another case will be presented in the 2nd edition of the plan competition and this will kick start another round of educational webinars. Our aim is to hold these competitions and the subsequent educational webinars annually, each competition will feature new difficult cases or testing new features of TPSs such as the auto-planning capability. The ultimate goal is better patients' plans through increasing both clinical and TPS knowledge

Impact on dose and volume on irradiated brain on recurrence and survival of patients with glioblastoma multiformae

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Introduction: Glioblastoma multiformae is the most common and the most aggressive brain tumor. Despite the major advantages in personalization and precision of the treatment, median survival of patients is approximately 12 to 16 months. Today standard of care for patients with glioblastoma is postoperative radiotherapy with temozolomide followed by adjuvant temozolomide. Radiation is corner stone of the treatment and with highest benefit of all modalities of the treatment.

Methods: Dosimetric analysis of treatment plan data has been performed on 70 patients with glioblastoma, treated with postoperative radiochemotherapy with temozolomide, followed by adjuvant temozolomide. Patients were treated with 2 different treatment approaches, regarding definition of treatment volumes and prescription of radiation dose. First group of patients has been treated with one treatment volume receiving 60 Gy in 2 Gy daily fraction (31 patients) and second group of the patients has been treated with “cone down” technique, which encompass of two phases of treatment, first phase 46 Gy in 2 Gy fraction followed by “cone down” boost of 14 Gy in 2 Gy fraction (39 patients). Quantification of “V57Gy”, volume receiving 57 Gy and more and ratio between brain volume and “V57Gy” has been done. Average values of both parameters have been taken as a threshold value and patients have been split into 2 groups for each parameter (smaller and lager than threshold value).

Results: Mean value for Volume “V57 Gy” was 593,39 cm3 (range 166,94 to 968,60 cm3), Mean value for brain volume has been measured as 1332,86 cm3 (range 1047,00 to 1671,90 cm3) and mean value for ratio of brain and “V57Gy” has been 2,46 (range 1,42 to 7,67). Time to progression and overall survival of patients has been analyzed using Kaplan-Meir methodology. There was no significant difference between two groups for both “V57Gy” and ratio between brain volume and “V57Gy”.

Conclusion: Irradiated volume with dose more than 57Gy (“V57Gy) and ration between whole brain volume and “V57Gy” does not have any impact on recurrence and survival of patients with glioblastoma.

Planning implementation of a hybrid VMAT (H-VMAT) in radiation therapy treatments of head and neck cancer cases; a dosimetric comparison with IMRT and VMAT; should we move on?

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INTRODUCTION: For head and neck cancer (H&N) It was compared three treatment techniques as volumetric modulated arc therapy (VMAT), Intensity Modulated Radiotherapy modality sliding Windows (IMRTsw), and Hybrid treatment thechnique (H-VMAT), the latter consists in blend both techniques VMAT and IMRTsw and give different weights for each during planning. The research is to compare the dosimetric distributions, and observed gains with regard to dose distribution, treatment time and scattered radiation imparted to the patient. MATERIALS AND METHODS: For a patient with a Head and Neck Cancer diagnose we decided to compare treatments described above, patient was simulated in supine position, inmobilized by using thermoplastic mask, in all cases positioning was verified by using cone beam (XVI), patients were planned with the three treatment techniques to the case of VMAT (1 arc) and for IMRTsw (5 fields). Patients were simulated in Computed tomography (CT) simulation General Electric (GE) Optima model, slides acquisition 1.25 mm; Magnetic Resonance was also done in a Siemens de 1.5T with 1 mm slices in contrast enhanced T1 MPR, T2 Flair, T2 Ciss, Diffusion, Perfusion;
image fusion for PTV and OAR contouring; calculation were done in Monaco® planning system version 5.10.02 with Monte Carlo algorithms; treatment delivery were make in a LINAC Elekta Infinity™ with Agility™ head with 160 interdigitating leaves with 0.5 cm width at isocenter; positioning verification XVI versión 4.5.1 b141, Calculations were verified with PTW OCTAVIUS System.
VMAT treatment modality consist in use IMRT fields and VMAT Archs blended with with the new bias dose option (B) This allows us to account for doses previously planned for a patient in a new plan during the optimization proccess, and different weights deliver treatments to achieve lower dispersion and higher tumor dose conformality. When compare dose distribution shown in figure 1, it is observed that 5% (Blue) dose is less in H-VMAT; what reflects less scattered radiation, with regard to 5% scattered dose is less with H-VMAT as is with the hot points as well. Dosimetric analysis were made in regard to conformity Index RTOG (CIRTOG), homogeneity index (HIRTOG), Paddick inverse conformity Index (PCI), Dmean. OARs were analyzed in terms of Dmax and Dmean.
Ptv: volume tratement planification Conformidad index: (ICRTOG)
Homogeneity index (HIRTOG) Dmax: Maximun Dose Dmin: Minimun Dose Dmean: Mean Dose Paddick inverse conformity Index (PCI): Table N°1 It is observed for H-VMAT that CI, HI,
Paddick Index, are better than those for IMRT or VMAT alone, nor for MU that are in between of the mean values. Table N° 2 it is observed the values distribution in Gy, between PTV volume
in H-VMAT compared to IMRT 5 Field and VMAT 1 Arc, showing 2%, 50% and 95% volume isodose distribution; and it is seen that cGy given to PTV are less in H-VMAT leading to a better isodose distribution and homogeneity, having in count that the prescribed dose is 6600cGy. Table 3 Shows patient dose distribution, 5% Isodose (330cGy) for H-Vmat the % is fewer compared in volume cc, to IMRT and VMAT alone, that allow us to control more efficiently the possible colateral effects that its could lead to. Also it is observed a gain in the 50% isodose being less for H-VMAT. It is observed that the maximum dose distributed in IMRT is bigger, and mean dose is closer to the prescribed dose in H-VMAT.

In Table N° 4. Dose max is less for HMAT in comparison with VMAT and IMRT.
In conclusion the hybrid H-VMAT technique shows improvments from the treatment time compared to IMRT, dose distribution and less scattering to VMAT, making it a good option in the Radiation therapy planning for head and neck cancers.

Para-aortic lymph nodal staging and evaluation of treatment outcome by 18F-fluorodeoxyglucose positron emission tomography (FDG-PET) in advanced cancer cervix

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Purpose: Computer tomography and ultrasonography are commonly used for baseline evaluation for carcinoma of uterine cervix. Addition of functional imaging using FDG PET CT may aid in diagnosing the patients with occult para-aortic nodes and / or distant metastasis. This technique need to be validated rigorously before routine clinical use. We attempted to evaluate & validate the use of FDG PET-CT for carcinoma cervix as baseline imaging.

Material and methods: Patients diagnosed with carcinoma cervix stage IIB & IIIB were included for this study and underwent pretreatment FDG PET-CT done as per the protocol approved by an institutional ethics committee. All the patients were treated with curative intent radiotherapy (External / extended field radiation and brachytherapy). Concurrent chemotherapy was used for patients with good renal function. Patients with conventional imaging suggestive of para-aortic nodal disease but negative on PET-CT or patients with conventional imaging and PET- CT both suggestive of para-aortic nodes were treated with extended field radiation therapy encompassing the para-aortic region and pelvic nodes. The patients with conventional imaging
negative for para-aortic nodal disease but positive on PET imaging were treated with pelvic radiation therapy only.

Results: Between September 2005 to November 2008, 96 patients were enrolled in this protocol. The median age of the cohort was 49 years (Range 32-66 years). Squamous carcinoma was the commonest histology (92%). On clinical examination, 60% of patients had FIGO stage IIB, while remaining had stage IIIB. Thirteen patients (14%) were upstaged after PET CT (having Para-aortic nodes), while 5 patients were down staged of having only pelvic nodes (conventional imaging showed para-aortic nodes). The median dose of external RT was 50 Gy. Eighty eight (92%) received concurrent chemotherapy (Median number of cycles 5). At median follow of surviving patients of 74 months (Range 5-102 months), 5 year disease free survival (DFS) is 59% and 5 year overall survival (OS) is 63%. Disease free survival and OS was significantly inferior for patients having para-aortic nodes on PET CT as compared to patients without para-aortic nodes, while there was no difference in OS or DFS for patients having para-aortic nodes on conventional imaging as compared to patients without para-aortic nodes.

Conclusion: PET-CT as a baseline investigation for carcinoma of uterine cervix is feasible. Detection of para-aortic nodes on PET-CT signifies poorer outcomes as compared to detection of the same by conventional imaging.

Thursday afternoon - Poster Presentations - Screen1 / 232

Harambee: tuning african brain drain to gain in global radiation oncology using information and communication technology

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Introduction: The 2014 World Health Organization (WHO) Cancer Report highlights major global cancer disparities, with over 60% of 14 million new cases and 70% of 8.2 million deaths per year occurring in low and middle-income countries (LMIC). These major disparities in cancer deaths are in part a reflection of poignant underlying disparities in Radiation Oncology services. For example, radiotherapy, which is needed in the treatment of over 50% of cancer patient, is not available in 31 of Africa's 54 countries. These disparities are exacerbated by the devastating effects of African brain drain, the emigration of African Health Care Professionals to Europe, Asia and North America. We describe efforts about a growing movement of these African Diaspora Healthcare Professionals to turn the brain drain into gain in reducing the global disparities in Radiation Oncology care, research and education using advanced information and communication technologies (ICTs).

Method: We reviewed the growing number of global oncology publications, conferences, symposia, organizations, and global health activities lead by Africans in Diaspora (AiD) over the past 5 years to assess the outcomes and emerging consensus on how ICTs can be employed by the AiD for Global Radiation Oncology.

Results: There has been an upsurge of activity by the AiD in Global Radiation Oncology towards establishment of a virtual Harambee platform for telemedicine, online learning and e-research involving AiD in Europe and North America united against cancer. This effort is being lead in Europe by MEPHIDA (Medical Physicists in Diaspora for Africa) and in North America by the Harvard Global Health Catalyst bringing the AiD and ICTs together. With launch in April 2017, the ICT-powered Harambee platform integrates: 1) telemedicine activities: remote treatment planning and quality assurance support; second opinion; and support in the setting up of new radiotherapy facilities in Africa 2) Education and training in Global Radiation Oncology certificate programs in partnership with the African Organization for Research and Education in Cancer (AORTIC) 3) Crowdfunded research with AiD mentors on low cost technologies for radiation oncology and imaging.

Conclusion: Africans in Diaspora are coming together across countries and continents to connect the values of community belonging (Harambee) with technological advancement to create a system where every African woman, girl, man, and boy can have access to radiation oncology services. The virtual Harambee provides an unprecedented growing movement to turn brain drain to major gain, reducing the disparities in radiation oncology in Africa.

An evaluation of the portal dosimetry and arccheck systems for VMAT pre-treatment patient QA plan verification

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In external beam radiation therapy the precise patient positioning is essential with the current use of complicated treatment plans. Patient-specific pretreatment verification of volumetric- modulated arc therapy (VMAT) is strongly recommended for all patients in order to detect any potential errors in treatment planning process and machine deliverability, and is thus performed routinely in many clinics. Portal dosimetry is an effective method for this purpose because of its prompt setup, easy data acquisition, and high spatial resolution. Portal imaging is often used for pre and during treatment anatomical setup verification. Currently the most advanced and widely used amorphous silicon Electronic Portal Imaging Device (EPID) and the Varian TrueBeam linear accelerator were used here for the measurements. A Varian Portal Dosimetry system was compared to a SunNuclear ArcCheck diode array for VMAT pre-treatment patient plan Quality Assurances (QA). For further validation of the method, direct comparisons of the delivered QA beam to the treatment beam were performed using EPDI and the ArcCheck systems and show that gamma passing rates under 2%/2 mm criteria are 90,0%–100% for the all VMAT plans. The EPDI and the ArcCheck systems showed comparable dosimetric results. In this study, the results revealed both systems to be suitable for patient-specific QA measurements for VMAT. We conclude that, depending on the status of clinic, both systems can be used interchangeably for routine pretreatment QA.

Comparison of CT and PET-CT based gross tumor volume (GTV) and organs at risk (OAR) in IMRT of head and neck cancers: institutional experience

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Aim- To compare the gross tumor volume **(GTV)** and organ at risk **(OAR)** identified on CT to that obtained from fusion of PET and CT images i.e. hybrid PET-CT in IMRT planning for head and neck cancer.

Material and Methods - Twenty five patients with primary carcinoma of the oropharynx and hypopharynx were included in this study after thorough history, physical examination, laboratory, histological and imaging testing. Patient immobilization was done by four clamp thermoplastic device. Separate CT and PET-CT simulation was done. Target volume (GTV) and Organs at risk (OAR) delineation was done by the same physician on separate CT and PET-CT images. A treatment margin was added to the CT GTV and PET-CT GTV separately to create the PTV. The planning dose prescribed for the study was 66Gy/33#@ 2Gy per fraction to the PTV containing the gross tumor volume. Different PTV pertaining to the macroscopic extension and microscopic extension (low dose PTV) were drawn. Two different IMRT plans were made for PET_CT and CT. Two different plans were made, one for the CT_PTV and other PET-CT_PTV and DVHs were generated for all critical normal structures. All the plans were generated with the standard dose prescriptions and the dose constraints of all the organs at risk were respected according to QUANTEC.

Observations and Results – The following parameters were observed-

The effect of PET and CT image fusion on change in Staging,

Gross TumorVolume

Dosimetric Comparisons of Organs At Risk between the CT only and PET-CT Plans. Hybid PET/CT imaging led to a change in staging in 7 out of 25 patients i.e. 28% as compared to CT alone in our study. Out of these 7 patients, Upstaging was seen in 5 patients and the remaining 2 were downstaged. In the rest of 18 patients i.e. 72% there was no change in the staging. The mean target volume of GTV as defined by CT alone, PET alone and PET/CT combined is 28.52 15.08, 19.35 9.31 and 32.42 15.92 cc. PET-GTV was smaller than CT-GTV in 20 out of 25 cases i.e. 80% and larger than CT-GTV in 5 out of 25 cases i.e. 20%. The mean CT-PTV AND PET-CT-PTV were found to be 252.17 91.74 cc and that of pet-ct-ptv was 228.90 cc. The statistical tests between the CT-GTV & PET-CT-GTV and CT-PTV and PET-CT-PTV were found to be significant (p value 0.004 and 0.017 respectively).The mean dose received by different organs at risk as a result of CT and PET-CT based planning was calculated and found to be significantly different for spinal cord, pharyngeal muscles and both cochlea ('p' value 0.057, 0.06 and 0.02 respectively).However, that of brainstem and bilateral parotid was found to be insignificant.('p' value – 0.34 and 0.58).

CT is still considered the standard for treatment planning volumes and PET can be used for greater target delineation to avoid the geographical misses. But the larger gross tumour volumes would also put greater demands on complex planning to reduce the dose to organ at risk. Thus the added benefit of including the geographical misses can be impacted negatively by the close approximation of dose to the critical organs and this needs further prospective studies. With the advent of adaptive radiotherapy, using the fusion of PET and CT images during the course of radiotherapy is a promising approach to changing dose distributions and can be utilised for dose escalation strategies.

Conclusion- 18F-FDG in oncology is a Gold standard as non-invaive functional imaging. In head and neck cancer, it has not been recommended for primary tumour as a lone modality, but only in conjunction with CT/MRI. Fusion of PET and CT images i.e. combined PET-CT can improve the GTV delineated on CT alone, highlight the unknown areas of disease and prevent geographical misses which possibly can over a long time, reduce the local recurrences and FDG- avid nodes can also be used for dose escalation. Based on our data as well as review of literature results, the incorporation of PET information may act as an adjuvant for radiotherapy planning and allow usage of highly conformal and biologically effective treatment.

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Conformal and intensity modulated radiotherapy in head and neck cancer in South America

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Introduction: Head and neck carcinomas are a group of malignant tumors with a common location. Conformal Radiotherapy and Intensity Modulated Radiotherapy conform the dose and protect organs at risk. A descriptive study of patients with squamous cell carcinomas of the head and neck treated with these radiations techniques in South America was conducted.

Materials and methods: A retrospective observational study was realized. Cases were defined as adults with histology diagnosis of head and neck carcinoma in all stages, treated with Conformal Radiotherapy or Intensity Modulated Radiotherapy in the Instituto Nacional de Cancerología, Bogotá, D.C., between January 2005 and December 2012. Information about social, demographic, clinical variables, complications and outcomes were recorded. Kaplan-Meier test was done for overall and free-progression survival.

Results: 59 patients were included (69.5% men). 20 patients received 3DCRT and 39 patients received IMRT. The median total dose received was 66 Gy. 96.6% of patients presented acute complications during treatment. 100% of patients treated with 3DCRT and 94% of patients treated with IMRT presented any acute complication. 40% of patients treated with 3DCRT and 15.4% of patients treated with IMRT. More common toxicities were radiodermatitis and mucositis. 52.5% of patients have late complications. 50% patients in 3DCRT group and 51.3% patients in IMRT group have a complete response. Mean overall survival rate was 42.7 months (CI 95% 24.5-60.7 months) in 3DCRT patients and 46.4 months (CI 95% 37.4-55.4 months) in IMRT patients. Mean relapse free survival rate was 42.8 months (CI 95% 25.2 to 60.4 months) in 3DCRT patients and 59.9 months (CI 95% 25.2 to 60.4 months) in IMRT patients.

Conclusion: Patients with head and neck carcinomas treated in our center with 3DCRT or IMRT showed outcomes compared to others studies reported, prospective studies are still needed to proved benefit of IMRT over 3DCRT.

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A new multidisciplinary treatment strategy for advanced rectal cancer: a chemo-radiotherapy with a new radio-sensitizer infusion by endoscopic guide.

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Introduction of the study: We have experienced a new multidisciplinary treatment strategy for advanced rectal cancers: a chemo-radiotherapy with a new radio-sensitizer, which is antioxidant enzymes-targeting drug to induce hypoxic cancer cells (a cause of treatment resistance) re-oxygenation, infusion by endoscopic guide with the approval of our Ethical Review Board and evaluated the safety and the efficacy of the new treatment. Herein, we report these outcome.
Methodology: Between October 2014 and August 2015, we treated 5 advanced rectal cancer patients with the chemo-radiotherapy and the radio-sensitizer infusion by endoscopic guide. Treatment radiation dose for the primary lesion and relative lymph nodes area under prone position with a berry board was ranged from 39.6 Gy to 50.4 Gy. The chemotherapy was S-1 80-100 mg/body in three patients, and FOLFOX6 (bolus and infusion fluorouracil and leucovorin with oxaliplatin) with bevacizumab in one and without bevacizumab in one patient. Endoscopic radio-sensitizer injections into primary rectal lesions were done twice a week until the last irradiation.
Results: The Median follow-up time is 19 months. Two patients received surgical resection after the new treatment demonstrated pathological complete responses, respectively. The other three patients did not have indications for surgery; stage 4 in two, and high age, heart failure and dementia in one. In the formers, endoscopic rectal biopsies showed local pathological complete responses after the treatment for 17 and 11 months respectively, and the latter denied follow-up endoscopic examination after the treatment, but anal pain and rectal hemorrhage have disappeared for 18 months. There have been no severe adverse events in both acute and late phase, except grade 3 acute ileitis of one patient received FOLFOX6 with bevacizumab.
Conclusion: We hope this minimally invasive and safe treatment will be a new option as a curative treatment strategy for rectal cancer. A further accumulation of many cases is needed.

Commissioning and validation of Total Body Irradiation (TBI) in Varian True Beam linear accelerator (LA)

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Aim: To report the results of commissioning and validation of Total Body Irradiation (TBI) in Varian True Beam linear accelerator (LA).

Materials and Methods: TBI technique was commissioned for 6 MV (Doserate 300MU/min) beam in Varian True Beam LA following the recommendation of AAPM TG 17. Various dosimetric parameters were measured viz: output, Tissue Maximum Ratios and profiles. The treatment distance was set at 5m, with the gantry 270, and collimator 45deg. The patient positioning device was a wooden stand kept near the primary wall with a perxpex beam spoiler of 1.5 cm thickness kept at 30 cm from the stand midline facing the beam. 10 patients were treated so far using the anterior-posterior technique from March to October, 2016. The dose was prescribed at the umbilicus. According to the required conditioning regime 3 patients were prescribed 2Gy, 1 patient 7.2Gy, 3 patients 8 Gy, 2 patients 13.2 Gy and 1patient 14.4 Gy. The number of fractions differed from single fraction (3 patients), 4 fractions (4 patients) to 8 fractions (3 patients). In- vivo dosimetry was performed using thermoluminescent dosimeters with appropriate build-up, which were placed at strategic reproducible locations namely the forehead, Supra Scapular Notch (SSN), Umbilicus, Right Palm and Left Knee. The dose measured at each point were tabulated and compared with the expected dose.

Results: The output of the machine for this technique was measured as 0.0419 cGy/MU. The depth of maximum dose was 3 mm. Flatness and symmetry was measured as 1.27% and 2.09% respectively in the horizontal direction and 3.21% and 2.2% respectively in the vertical direction. The average(sd) percentage variation in the dose measured at Forehead, SSN, Umbilicus, Right Palm and left knee were 6.64 (2.9), 2.93(2.2), 8.28(2.96), 12.01 (5.14) and 3.58(7.17) respectively. The flatness and symmetry were found to be in the acceptable range. As per the institution protocol the separation at different position like the forehead, SSN, apex of lung, mid lung, lower part of lung, umbilicus, calf etc are taken and the treatment dose is prescribed to an average depth of these points. Therefore the mean (sd) variation of 8.28(2.96) was obtained between the prescribed and the measured dose. However it was within the AAPM recommendation of 10%.

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An unacceptable variation of 13.1% and 10.11% was seen in 2 patients which correspond to a difference of 4 cm between their prescription and midline depth.

Conclusion: TBI has been commissioned and validated successfully in our new Varian True beam Linear accelerator.

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Quality Assurance Team for Radiation Oncology (QUATRO) audit to the Institute of Oncology and Radiology of Serbia: example of good impact on the development of radiotherapy in the institution

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Institute of Oncology and Radiology of Serbia (IORS) is the largest oncology institution in Serbia, dealing with cancer prevention, health care and treatment of malignant disease. Also IORS serves as a teaching base for Faculty of Medicine. Due to external and internal problems in Serbia in the last decade of the twentieth century, the problems and difficulties have been accumulated in field of radiotherapy. We were partially aware of our drawbacks so we requested a QUATRO audit from the IAEA. The main goal was to get an objective evaluation of the current situation and facilities, and to get guidelines for improvement of our radiotherapy department according to IAEA/ ESTRO established standards. The QUATRO audit was approved and conducted in March 2006 (13-17th) by an IAEA audit team. Auditors had full disclosure to all documents, facilities and protocols. All our staff members were very cooperative, active and answered to all given questions and requests from the auditors. IAEA Audit team report was completely objective and according to our situation in Radiotherapy Department. It revealed a significant amount of shortcomings in our protocols, QA/ QC procedures and guidelines. Moreover, auditors had many negative comments on our equipment and the lack of some essential radiotherapy devices and staff. After the IAEA mission we made some steps forward in order to improve the technology infrastructure in IORS and to adjust the clinical practice according to the established standards and suggested policy by the IAEA. We arranged many meetings with Government authorities in the attempt to acquire more funding. That resulted in the purchase of new crucial equipment suggested in the IAEA report: a CT simulator, Ro simulator, 3 new LINACs, dosimetry, QA and mould room equipment. On our part we made new written protocols and procedures; redesigned treatment sheets; continued to create institutional RT protocols; started implementing 3DCRT in most localizations; employed more RTT, physicists and physicians; devised a quality management system; defined the new educational programme for RT technicians according to ESTRO curriculum and started a postgraduate study in radiation oncology. We also planned to start a postgraduate study for medical physicist. We requested a follow-up audit to asses our development. The follow-up audit was approved and conducted from 7-9 December 2009 by the same audit team as in the first visit. The QUATRO team observed positive developments in our department. Substantial improvement in developing the infrastructure, logistics, and equipment upgrades had been achieved. Moreover, the audit team observed outstanding performance in some treatment units and concluded that our equipment is up-to-date. The overall impression of the follow-up visit was that IORS has been able to implement the recommendations of the lst QUATRO audit for significant improvement of both in technology and practice. The audit team concluded that with similar compliance to the recommendations of the follow up audit, there is a good chance to develop the department further with the goal of achieving the level of practice that fulfils the requirements of a center of competence. We are still working hard to further improve the situation in the Radiotherapy department of IORS and still use the QUATRO report recommendations as guidelines to achieve our goals to become a highly professional and effective service of evidence-based radiotherapy which follows the IAEA, ICRU and ESTRO criteria.

First conclusions regarding the validation of an automated micronucleus counting microscope based on samples from prostate tumorous patients

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Introduction: As the part of the validation of an automated micronucleus (MN) counting microscope, we tested its performance in the range of low doses. The MN assay makes it possible to determine the quantity of DNA damage as a biomarker of the received dose. For the testing process we examined blood samples from patients with prostate tumour undergoing low dose rate brachytherapy treatment. Our study aimed to identify the factors that can influence the accuracy of the automated system.

Methods: The cytokinesis-blocked micronucleus (CBMN) test was conducted with peripheral lymphocytes sampled just before the beginning of the therapy and at regular intervals during the treatment period (1 day, 3 months, 6 months after seed insertion). In the course of the slide preparation the cells are forced to start proliferation and arrested before the division of the cytoplasm and cell membrane. As a result the objects of interest, the so-called binucleated cells are created. They contain two main daughter nuclei which can be accompanied with small nucleus-like fragment residues, named micronuclei, in case of DNA damage. All of them have a well-defined contour and circular shape thus can be identified using automatic image processing. The average frequency of the MN found in binucleated cells correlates with the received dose. Although it is a high dose that the seeds are locally delivering to the tumour, the MN assay measures the whole body equivalent dose of the irradiation received by the healthy tissue surrounding the gross tumour volume. Thus the number of identified aberrations is in the range of the low doses (<500 mGy). The automatic slide scanning and image segmentation was done by Radosys Radometer-MN Series automated microscope dedicated to this assay.

Results: Factors that can influence the accuracy of the automatically determined MN frequency were identified. Afterwards sample subgroup-pairs were formed in a way that they differ only in one of the previously identified factors of the slide preparation or scanning. We defined the accuracy of the automatic counting system as the MN-frequency difference between the totally automatic and the supervised (semi-automatic) MN-scoring method. The factors can be classified into three groups according to the degree of their effect on the accuracy.

Conclusions: There are further factors that influence the scoring during automatic procedure compared to the standard manual inspection. Only those samples can be compared based on their MN-frequencies that behave in the same manner regarding the factors labelled “significant” in Table 1. The differences in staining and geometrical properties of the cells and (micro)nuclei found to be negligible. The automatic evaluation is found to be also robust for slightly out-of-focus images. Beside the inevitable difference of the individual cell stress tolerance of the different patients and the effect of the received dose the greatest contributor to the inaccuracy is the impurity of the sample. Thus the analysis of these artefacts has an utmost importance. Their well-designed classification should imply whether they can be eliminated by further cleaning cycles. Otherwise this task is delegated to a possible improvement of the image processing algorithm.

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Broken machines or broken systems – The ugandan experience, on accessing/maintaining radiotherapy services, in low and middle-income countries

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Introduction: By 2020, about 70% of new cancer cases will occur in LMICs. According to DIRAC, 27 African countries have no radiotherapy and only 26 countries have. The expected number of new cancer cases in Africa in 2015 was 700,000. Over 50% of cancer patient's benefit from radiotherapy alone or in combination with surgery or chemotherapy, implying that over 350,000 would require radiotherapy. Common malignancies including cervical, head&neck, etc mainly presenting in advanced stages – are incurable without radiotherapy, especially in the absence of highly-specialized surgery and chemotherapy. Despite this enormous need, access to radiotherapy is inadequate for most cancer patients and machine down-time remains high. The Machines per Million Population (MMP), in LMICs range from 0.1-0.3, which is very low compared to developed countries (4.0–6.0). Case in point Currently, Uganda has no functional external beam radiotherapy services. The single Cobalt-60 machine, installed at Mulago in 1995 stopped functioning beyond repair in March 2016, a feature that attracted international attention. The number of new cancer patients worked on this machine gradually increased from 292 in 1995 to 1920 in 2015; treating a total of 25,465 patients (600,000 sessions) over the 21 year period. In comparison to a Linac, that can treat 312500 - 375000 sessions. Efforts for the expansion of radiotherapy services in Uganda started as early as 2000. It was planned to have 2 more EBRT units at Mulago and 3 centres in regional hospitals. However, due to budgetary constraints, this expansion program was postponed every year until it was dropped. Plans for the replacement of the broken Cobalt unit started in 2005, three years after a major overhaul that included source exchange. The department made several consultations and expert missions were sought from IAEA: (1) Assessment of Cobalt-60 machine and current capabilities in the Department by Jan Karl Hough December 2008 (2) Design and construction of a bunker for expansion of radiotherapy services by Frederic Johannes Lange, December, 2011 Despite all these recommendations, there were no tangible outcomes as far as expansion of radiotherapy services in the country. There were numerous administrative/managerial factors that hindered progress in radiotherapy, e.g. (1) Between 2010 and 2011, the Mulago hospital administration identified a contractor to construct a new bunker, procure and install a new Cobalt-60 machine. However, before this process was completed, there was a change in administration in April 2011 that resulted in halting the process. (2) Between 2011 and 2013 the new administration came up with a relocation plan of the department, worked on designs for the radiotherapy bunkers (2 EBRT/1 HDR and other auxiliary facilities). However, before the process was concluded, the department was transferred administratively to be under the Uganda Cancer Institute (UCI), in June 2013. This was in fulfilment of PACT recommendation, with the aim of creating an integrated cancer treatment centre. The UCI administration noted inaccuracies with the designs and the process was halted, however construction started in June 2016.

The above scenarios are characteristics of system breakdown, which in this context is a collapse of responsible authorities to perform, organise, maintain and support services following a fixed plan or set of rules. Government owned facilities are more affected than those that are privately owned. Irabor et al (2016) reported the stagnation of radiation oncology resources in Nigeria. It was reported that as of Jan 2016: only 2 of the 9 commissioned radiotherapy centres were functional, that 2 of the 5 linear accelerators installed in 2010 were not functional and that there were fewer brachytherapy (HDR +LDR) units than in 2001. The blame was put on the Nigeria economic and political climate, lack of trained servicing engineers, procurement of equipment with minimal input from end users and no servicing contracts. Johanna et al (2016) also reported on how the challenges of resourcefulness were affecting radiotherapy in the Philippines. The Kenya's main hospital has a functional Cobalt-60 unit where the source has not been replaced since its installation, over 17 years ago. The Zambia's only radiotherapy centre installed a Cobalt-60 unit in 2013 that is not yet utilised due to procurement mishaps – unfortunately the source is decaying. Conclusions: Machine breakdown, downtime and decommissioning are some of the many events in a radiotherapy department. There is need for support

for partnership and systems of care, more vigorous mechanisms to ensure that radiotherapy is part of planning for cancer care and control in LMICs. There are essential requirements that need much bigger budget, staff and mandate to ameliorate the numerous logistical complexities of acquiring and maintaining radiotherapy services. The lessons from Uganda and other LMICs emphasize the fact that it's not that machines break, but systems do.

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Quality Assurance Team for Radiation Oncology (QUATRO): The National Center for Cancer Care & Research (NCCCR) experience

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Introduction: In 2009, the National Center for Cancer Care & Research (NCCCR)-Qatar underwent major upgrade of its facility and manpower. This upgrade included the commissioning of new equipment, the implementation of new techniques and modalities as well as recruiting new staff. In order to ensure that the quality of care provided meets international standards it was essential to solicit an independent external auditor. Due to the lack of national quality audit system in Qatar it has been decided that all the activities of the radiation oncology department will be audited by the group QUATRO.

Purpose: This work describes our QUATRO experience as part of a comprehensive external audit of our radiation therapy facility.

Materials & Methods: A detailed description of the tasks performed during both the prepara- tion and execution phases is described. A team was first formed including leaders, technicians and administrative staff and a work plan that includes specific goals has been established. The first task was to familiarize our department with this type of audit and thus ensure a smooth running of the visit of the QUATRO group. This was done during one month prior to their visit through the study and the analysis of some documents sent by the group and through the completion of a questionnaire containing information about our department including the techniques used for treatment, patient information and staff specification and their qualifications. After this preparation step, the five-day visit of the team was organized and the main program of the visit was outlined. The visit started with a presentation addressed to the QUATRO group in which the history of our department, information about patients, treatment techniques and personnel was detailed. A presentation was then given by the QUATRO group underlying the goals of the audit procedure. In addition to observing the procedures applied in our department, a validation of our measurements was carried out by comparing them with those conducted by the group using their own equipment. At the end of this visit, a document was drafted by the group listing the outcome of the audit including the points on which improvements are recommended.

Results: Although the QUATRO team stressed the fact that our department is capable to provide radiation therapy of very advanced technology and in consequence complies with the criteria of the IAEA for a center of competence, the auditing report of QUATRO group highlighted few areas of improvement. Since then, some of these recommendations have been implemented. The structure of Multi-discipline Teams (MDTs) has been reorganized and expanded. The site specific relevant MDTs are now attended by radiation oncologists to support patient accrual. In addition, further guidelines have been developed for target and Organs At Risk (OAR) definition and this process is now peer-reviewed. ICD codes have also been implemented.

Discussion: The importance of this work lies in the fact that this is the first quality control audit in our department, carried out by an approved external organization. The classification of our department by the audit team as a center of competence for the next 5 years enabled us to validate the procedures practiced in our department and thus to strengthen our confidence level.

Roadmap for setting up a comprehensive state of the art radiation oncology facility at Mbingo Baptist Hospital (MBH) Cameroon

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INTRODUCTION: Radiotherapy is an essential cancer treatment which according to experts suggestions contributes to four in ten cases where cancer is cured.1 It is a relatively cheap, safe, 2 cost-effective treatment that is associated with high levels of patient satisfaction 3. Yet radiotherapy is still lacking in many African countries. Cameroon with a population of 22.3 million inhabitants has two radiotherapy units, however these services do not get the due attention they deserve compared to other cancer treatment modalities. Considering the growing global burden of non-communicable diseases, particularly cancer, which has become a leading cause of mortality and disability in low- and middle-income countries, with more people across the world developing cancer than ever before, and with over two-thirds of all cancer-related deaths occurring in developing countries, there is an urgent need to get into action to fight for a better cancer health care in underserved areas. METHOD: The first step was a comprehensive assessment of the necessity of Radiation Therapy at a selected hospital. The Mbingo Baptist Hospital (MBH) is a 300 bed hospital located in the North West province of Cameroon in Central Africa. Due to the broad spectrum of treatment modalities being offered at this hospital and the fact that patients come in from all over Cameroon, the hospital is being developed into a referral, teaching hospital. As concerns management of cancer, surgery is being offered. There is a pathology unit and also the possibility of receiving Chemotherapy on site. These and more make MBH one of the advanced centers in Cameroon where diagnosing cancer is possible and at least two treatment options can be administered. The hospital records show that close to 2000 patients have been diagnosed of cancer. The most common cancer cases seen are breast, cervical, kaposi sarcoma and now due to a specialized training program in Head and Neck Surgery many of the patients treated in this program have some form of cancer. Unfortunately, Radiotherapy, being an inevitable treatment modality in the successful treatment of advanced stages of Head and Neck cancer and cervical cancer, does not exist at this hospital. To follow up with the establishment of a comprehensive cancer care program at MBH: - Colleagues from the US and Germany in the field of Radiation Oncology (Doctors, Medical physicists and specialists in Radiation protection) first met to assess the need and feasibility of such a project on site. - Get in contact with already existing facilities in Douala and Yaounde. - Meet with the authorities of the hospital to address the need and importance of such an infrastructure. - Involve the Dean and staff of the medical school at the Capital for cooperation. - Visit the National Radiation Protection Agency in Yaounde as concerns safety regulation standards. -Make an estimate of the financial burden required to complete such a project, work on the project's blueprint and set a deadline for project completion. RESULTS: At the end of the journey, it was clear that MBH will not be able to carry the burden of such a project in totality. A roadmap created for establishing a comprehensive cancer center at Mbingo. Radiation oncology health professionals from Germany and the USA have committed to the project with plans to support in training of local staff. After brainstorming on different ways to assist the funding of the project, it was concluded that the diaspora and international partners get involved and making sure that MBH guarantees for a reliable stable source of power was outlined. It was also concluded that such a facility will need housing possibility also for the relatives of patients being treated at the center. To guarantee sustainability, long term strategies of collaboration via internet and Telemedicine with colleagues abroad would be mandatory. CONCLUSION: The project is at its initial stage but the initiators and driving forces of it have the strong will to see it successful. To our knowledge, this is the first attempt for a mission hospital to come up with a radiation oncology project in Cameroon and we believe the success of this project will be a motivation for others to follow. For the success of this project, we rely on financial assistance from persons and organizations of goodwill.

Dosimetric Influence of translational and rotational motion correction using a robotic couch in the linear accelerator based stereotactic radio surgery and radiotherapy dose delivery

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Introduction: The linear accelerator based radiosurgery is initially started with invasive frame, like Lakshell frame and BRW frame. However in recent times improvement of setup imaging and other accessories like six dimensional motion enabled couch empower the community to move towards a frameless radiosurgery. Stereotactic radiosurgery (SRS) and stereotactic radiotherapy (SRT) deserves a very high degree of accuracy in reproducibility. While treatment, after placing the patient in couch due to the weight of the head, cranial side goes down due to fulcrum affect. In an invasive frame based case the head is attached to a couch mount with a three screws governing the rotational and translational motion able to provide all six dimensional motions to bring the head back in the appropriate position. However in a frameless SRS/SRT it is not possible. Therefore the couch six-dimensional motion is used for reproducing the patient position. The advantage of stereotactic localisation using an invasive frame can be completely or partially obtained by the cone beam imaging and six dimensional couch movements. In this study we would like to evaluate the dosimetric error in absence of couch motion. Materials and Method: 30 patients of either stereotactic radiotherapy or radiosurgery with 33 PTVs were planned in Monaco or iPlan Treatment planning system (TPS) and delivered in Elekta Axesse (Elekta, Stockholm, Sweden) linear accelerator equipped with uniform 4 mm width multileaf collimator (MLC). After placing the patient in the couch a cone-beam CT (CBCT) was performed yielding a set of positional correction values (called as primary correction values). Patient positional error translational (lateral, longitudinal and vertical) and rotational corrections (roll, pitch, yaw) obtain by CBCT was performed using the robotic couch to obtain the correct isocentre as well as alignment of the patient. Further another CBCT was acquired to verify the couch enable patient positional correction. Positional correction obtained in the second CBCT (called as residual correction) and either cannot be corrected further or having no dosimetric influence. Planner fluence was verified using 729/octavious Phantom with and without applying the primary and residual shifts in the couch and matched with the TPS obtained values. Further gamma index evaluation was done with the TPS generated planner dose (without shift) and measured planner dose with primary and residual corrections. Result Dose distribution was analysed using the gamma index used as sealing function. The mean difference between the {TPS-Measured with no couch shift} –{TPS-Measured with CBCT shift} and its standard deviation for a large range of g (4.2-0.14) shows a very high variation of dose with a mean difference of 15.6% and maximum of 29.6% and minimum of 1.1%. The maximum, minimum and mean SD were 25.9% and 3.4% and 17.4% respectively. Mean 1%-1mm, 2%-2mm gamma passing when compared between TPS fluence and measurement obtained using a couch movement using primary correction values were 73.1 3.5% and 83.5 2.3% respectively. Same gamma criteria between TPS fluence and measurement obtained from applying the residual table correction yields 95.1 2.4% and
98.2 1.7% respectively.
Discussion: Brainlab Elekta has come together for first time in our centre for offering the frameless stereotactic solution. However due to the specific design that brainlab base plate can only be fixed with the Elekta couch extension but not with the main couch a significant shift in the patient position was observed. As the couch extension is not firmly adhere with the main couch its acting as a lever of first kind; while putting the patient on the couch the cranial end goes down due to fulcrum effect. Sometime the movement in more than 1 cm. This movement of the cranial end may lead to a complete geometrical miss of the tumour. This problem appear for invasive frame stereotaxy as well and corrected using the roll, pitch, yaw rotation screws attached to the frame base. These rotational corrections attributed to the patient head weight and fulcrum effect is correctable only in terms of couch rotation and movement. As result shows the gamma passing with the primary table correction is significantly high and not suitable for

therapy delivery. Nevertheless, positional error substantially decrease to an acceptable limits after

applying the rotational and translational shifts to the table. Conclusion: Conclusively it can be stated that a imaging system having capability of 6D patient position matching and a couch system having capability of correcting the 6D motion should be used for the correction in frameless stereotactic therapy. Without the six dimensional motions enable robotic couch it's not possible to correct the positional error properly and hence we strongly recommend the use of robotic couch during the frameless stereotactic radiotherapy and surgery.

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Interfraction variation in the target volume for accelerated partial breast irradiation (APBI) using intraoperative multicatheter interstitial brachytherapy and its dosimetric impact

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Introduction of the study: Multi-catheter interstitial brachytherapy (MIB) is the oldest technique with longest follow-up for Accelerated Partial Breast Irradiation. Intra operative multicatheter interstitial brachytherapy requires duration of implant in situ is generally 7-10 days which may lead to post operative changes such as seroma formation and regression. This may result in variation in the lumpectomy cavity (LC) and the planning target volume (PTV) during the course of treatment. The present work aimed to investigate the dosimetric impact of interfraction variation in the target volume during accelerated partial breast irradiation for intra-operative breast implants.

Methodology: Intraoperative placement of flexible catheters was performed on sixteen patients who underwent computed tomography (CT1) based brachytherapy planning. The lumpectomy cavity was delineated on CT1 which included seroma, radio-opaque clips, and air in the cavity. Clinical target volume (CTV) was obtained by growing a uniform margin of 1 cm around the cavity. CTV was edited by limiting the skin by 0.5 cm and up to the chest wall. For brachytherapy CTV was considered as planning target volume (PTV). Catheter reconstruction was done on CT1 and active dwell positions of each catheter were obtained by giving a margin of 0.5 cm over CTV. Graphical optimization was done to yield optimum plan PCT1 for the treatment. CT was repeated prior to the last treatment fraction (CT2). Contouring of LC, CTV and catheter reconstruction were carried out on CT2. PCT1 was manually reproduced in CT2 which yielded plan PCT2. Plans were compared using coverage index (CI), dose homogeneity index (DHI), external volume index (EI), overdose volume index (OI) and conformal index (COIN). CI is the fraction of the LC or CTV receiving a dose equal to or greater than the prescription dose. EI is the ratio of the normal tissue volume outside the CTV receiving a dose equal to or greater than the prescription dose to the CTV. DHI is the fraction of breast tissues receiving a dose between 100% and 150% of the reference dose. OI is the fraction of the CTV receiving a dose equal to or greater than two times the reference dose. The COIN takes into consideration the coverage of the CTV by the prescription dose and also the unwanted irradiation of normal tissue outside the CTV. The data was compared and statistically analyzed by T-test for paired samples using Statistical Package for Social Sciences (SPSS version 20.0, IBM, Chicago) software.

Results: The mean volume of LC and PTV was 68.02 ± 27.95 cm3 and 138.84 ± 46.93 cm3 for PCT1 while it was 74.88 ± 31.33 cm3 and 146.56 ± 55.88 cm3 for PCT2. Mean CI of LC and PTV decreased significantly by 3.74% (r=0.024) and 8.64% (r=0.001) in PCT2. 11.8% and 10% increase in the mean EI and OI was observed in PCT2. Variation in the mean DHI was small and insignificant for both plans. Significant decrease (p=0.001) in mean COIN value was observed in plan PCT2 (0.538) compared to PCT1 (0.602).

Conclusion: The interfraction variation in the LC and CTV volume was found patient specific. Interfraction variation in the CTV volume has shown the significant impact on coverage and conformity of the target volume.

In silico model of radiotherapy treatment outcome for different fractionation schemes considering dynamic biological processes

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Introduction: Observational clinical studies of radiotherapy (RT) outcome for different fraction- ation schemes are a very costly and demanding task. Therefore, the development of computational tools that simulate tumour and normal tissue response under scenarios can be enormously useful for trials design. This work presents a model for treatment outcome evaluation of different fractionation schemes considering tumour characteristics and normal tissue tolerances.

Methodology: Tumour response is simulated with a previously published *in silico* model (Tumour Response Model, TRM), which considers a representative virtual tumour created from the volumetric information of real tumours. This model can also import clinical information about tumour oxygenation and real inhomogeneous dose distributions and considers the following biological processes: tumour growth, accelerated proliferation, hypoxia-induced angiogenesis, oxygen-dependent cell killing, resorption of dead cells and shrinkage. Moreover, the response of normal tissues (NTCP) is calculated from the clinical DVH by using the empirical Lyman- Kutcher-Burman (LKB) model. As an example, two head & neck (HN) IMRT plans with a conventional fractionation scheme were chosen to show the capabilities of the model. Both virtual tumours were created with hypoxic cores, which are commonly observed in these type of tumours. For each virtual HN tumour, three fractionation schemes were simulated: conventional (2Gy/fx,
1fx/ day, 5 days/week), hyperfractionated (1.2 Gy/fx, 2 fx/day, 5 days/week) and CHART (1.5 Gy/fx, 3 fx/day, every day). The radiobiological parameters for the simulation were $\rho = 10^4$ tumour cells per mm^3, α/β =10 Gy, α =0.37 Gy^{-1} and σ_α=0.06 Gy^{-1}. Simulated tumour control
probability (TCP) curves were compared to those calculated with a DVH-based Poisson Model for the same tumour cell density. Regarding normal tissue, DVHs corresponding to the altered (i.e., non conventional) fractionation schemes were generated by re-escalation and redistribution of the original DVH, keeping constant the relative dose distribution for different fractionation schemes. NTCP curves were generated for parotid glands (endpoint xerostomia) as a function of biological effective dose (BED) considering α/β values of 3 and 10 Gy. The Uncomplicated Control Probability (UCP) was calculated from TCP and NTCP curves, considering both parotid glands. For each fractionation scheme, the optimum prescription dose was defined as the maximum dose to the tumour fulfilling the constraint that NTCP remained equal or below 10% for the less irradiated parotid gland (D_{NTCP} 10).

Results and discussion: The radiosensitivity parameters in the TCP Poisson Model leading to a match with the TRM simulated TCP curves resulted α/β =10 Gy, α =0.295 Gy^{-1} and σ_α=0.04 $Gy^{-}1$. TRM considers an intrinsic oxic α value, modified by oxygen enhancement ratios
and tumour reoxygenation, while the Poisson model does not consider hypoxia explicitly. An effective α value in the Poisson model is thus needed to match both TCP curves. The results
for the simulated TCP and the resulting value of UCP at the prescription dose D_{NTCP} 10, for each patient and fractionation scheme, are shown in Table I for the case of α/β = 3 Gy, as an
example. It can be observed that, for the same patient, the analysed fractionation schemes lead to different prescription doses (fulfilling the same NTCP constraint) and to different UCP values.

Conclusion: A tool for calculating TCP, NTCP and UCP under different fractionation schemes for

representative clinical cases has been developed. Dynamic biological processes, volumetric information and clinical dose distributions are considered for the simulation of the response of tumour and normal tissue. As an example, this tool was applied to two IMRT HN patients under three different fractionation schemes. Results shown that our simulation, with α values commonly assigned to HN tumours, properly describe a realistic clinical outcome. The proposed *in silico* model could be used for any type of tumour, OARs and clinical dose distribution. A thorough validation of the model with a large number of clinical cases is still needed to use the model as a clinical tool.

Toxicity of radical radiotherapy with or without chemotherapy in HIV positive and negative women treated for locally advanced cervical cancer

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Introduction WHO has reported 85% of cervical cancers occurring in low resource settings. It is the commonest cancer in women in many regions worst hit by the HIV/AIDS. Combined chemotherapy and radiotherapy (CRT) is the standard of care for women with cervical cancer in the developed world but the gains from CRT come at the cost of increased toxicity. Only a few data is available regarding the toxicity of radiotherapy (RT) in HIV positive (HIV+) women with cervical cancer who are treated in a low resource setting. We designed a prospective case-control study comparing the acute toxicity of CRT versus RT alone in HIV+ve and HIV negative (HIV-ve) women receiving curative treatment for cervical cancer. Material and Methods Women attending the Mulago Hospital RT department receiving radical RT for FIGO stage IIB to IVA cervical cancer using a telecobalt unit with dose of 46 – 50 Gy delivered to the pelvis followed by a single
brachytherapy (BCT) fraction using a caesium source of a single 25 – 30 Gy fraction (=), were recruited. Eligible women for chemotherapy were treated with cisplatin at 40mg / m2 once weekly during external beam RT. The primary end point was the rate of grade 3 / 4 toxicity. Chi-square test, the independent samples t-test and the Mann-Whitney U test with the Logistic regression analysis were used as appropriate. Statistical analyses were carried out using SPSS version 18. The trial was approved by the local ethics committee. Results 189 patients were recruited. 119 (63%) patients were HIV-ve, 70 (37%) patients were HIV+ve. 99% of HIV-ve women were treated
with 50 Gy/25=, 45% of HIV+ve women receiving RT only and 19% of HIV+ve women receiving CRT were prescribed 50 Gy/25=. The majority of HIV+ve women were treated with 46 Gy/23=.
BCT data were collected in 159 (84%) cases. Of these, 147 (92%) were treated with a single 25 – 30 Gy fractions. 95% of women receiving 46 Gy to the pelvis were treated with the higher BCT dose of 30 Gy. The HIV+ve group were more than ten years younger than HIV-ve participants ($p < 0.0005$) and had less advanced disease ($p = 0.003$). 44 of 70 (63%) HIV+ve women received 46 Gy/23 fractions, while HIV-ve women were almost all treated with 50 Gy/ 25 fractions ($p < 0.0005$). Grade 3 toxicity scores according to HIV status. HIV+ve patients were more likely to experience grade 3 skin toxicity ($p<0.0005$) and WBC toxicity ($p= 0.019$). More women treated with CRT experienced a break in treatment due to toxicity (though not statistically significant). Logistic regression suggests HIV+ve women were 25 times more likely to experience a grade 3 skin reaction (95% CI 2.7 – 234). Grade 3 WBC toxicity due to CRT was more evident in HIV-ve (23% vs to 4% for RT alone) compared to HIV+ve women (27% vs 21%) probably because toxicity to RT was already much higher than in the HIV-ve women. Grade 3 GIT and GUT toxicities were not common. Conclusion: In our limited resource setting, grade 3 toxicity was more common in HIV+ve women than HIV-ve women treated either with RT alone or CRT. The use of CRT in a low resource setting especially in women with HIV infection warrants careful consideration if optimal therapeutic balance is to be achieved as resources required for optimal monitoring and treatment of the CRT side effects may be lacking and as RT alone is an effective treatment offering reasonable outcomes. Optimizing RT treatment is arguably a more valuable intervention in this setting.

Need for competency-based radiation oncology education from a global health perspective

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NEED FOR COMPETENCY-BASED RADIATION ONCOLOGY EDUCATION FROM A GLOBAL HEALTH PERSPECTIVE Eduardo Rosenblatt, Gregorius Ben Prajogi, Michael Barton, Elena Fidarova, Jesper G. Eriksen, Bruce Haffty, Barbara Ann Millar, Anita Bustam, Eduardo Zubizarreta, May Abdel-Wahab. Although not a new concept in itself, competency-based education has set the trend for the globally accepted standard norm for education and training of medical professionals including postgraduate medical education in radiation oncology. Societal needs demand from radiation oncologists that they be not only competent in the knowledge and skills relevant to their specific discipline (be a medical expert), but that they also display competencies such as professionalism, scholarship, health advocacy, management/leadership, collaboration and communication. The realities of developing countries, in particular lower-middle income and low-income countries set different priorities than high income countries. A large proportion of cancer patients do not have access to adequate radiotherapy services. Resource constraints determine limitations in equipment, accessories, and dosimetry. Lower than standard staffing levels and limited quality education and training also contribute to substandard care and clinical outcomes. In this environment, the addition and assessment of competency based elements to training programmes can be challenging. On the other hand, it is precisely in these countries, where competencies such as the ones listed above are highly needed in the radiation oncology profession. Various models and best practices are already available to assist implementation of competency-based education in radiation oncology, making it unnecessary to re-invent them. However, it would be useful for radiation oncologists in charge of education and training in LMICs to review and adapt them in accordance to the daily realities faced in their countries. It is strongly recommended that this initiative be aligned with the larger picture of nation-wide changes in medical education that might already be in motion, or in the absence of such changes, to involve major stakeholders to play an active role in the process. Effective change-management strategies will need to be applied throughout the implementation process, while keeping a focus on a clearly defined goal. In order to provide these goals and milestones, prior assessment involving key stakeholders will be an indispensable first step that must be taken in order to enable informed decisions to be made during the course of implementation. Since 2009, the Division of Human Health of IAEA has adopted a pragmatic approach to planning, developing, implementing and evaluating education and training programs. This approach emphasizes that more attention should be given to actionable components of the process: mapping the curriculum, writing measurable learning outcomes, designing and planning relevant courses, selecting effective approaches to learning and assessment, and ensuring continuous development through program evaluation. Outcomes, contents, approaches in instructional methods, learning opportunities and assessment of competencies will need to be wisely chosen, developed and adapted within the context of local needs and available resources to ensure effective implementation. Fortunately, most of the workplace-based assessment methods have been made with time constraints in mind, which should make their implementation more manageable. The utilization of information technology, while requiring a certain amount of commitment and upfront investment, will assist in the management of the significant amount of assessment data that will be produced. Implementation of competency-based medical education in the education of radiation oncologists in LMICs is both a need and a challenge. The available frameworks and competencies, despite being very relevant to the realities faced by radiation oncologists in LMICs, will still need to be adapted in order to ensure effective implementation at the regional/national level. Radiation oncologists need to employ effective change-management strategies to ensure that the changes which are introduced can remain sustainable within the context of national healthcare, education and political systems.

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Enhancement of the biological effectiveness in the bragg peak: a nanodosimetric perspective

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In proton therapy, a constant relative biological effectiveness (RBE) of 1.1 is currently recommended and used in clinics. This is despite the fact that this quantity varies (for example with the depth of the proton beam) in a medium, which also causes a change in the biological beam range. Various authors have noted that it is worth considering these variations in treatment planning, especially for beams pointing towards or passing laterally adjacent to organs at risk. These variations are strongly dependent on the physical properties of the beam as well as on absorbed dose and the biological properties of the irradiated tissue.

To study the physical properties of proton tracks, we examined biological effectiveness in terms of novel nanodosimetric quantities related to track structure based on the formation of ionisation clusters in target volumes, comparable in mass per unit area, to a DNA segment. The track structure of different ionising radiations can be characterised by nanodosimetric quantities derived through measurements and numerical simulations.

In this study we present an investigation of the variation of nanodosimetric parameters with depth in the proton beam leading up to the Bragg peak region, which is an indication of the variation in biological effectiveness. Simulations are performed using the GEANT4-DNA extension toolkit that can simulate physics processes using models that can track step-by-step interactions of particles in liquid water down to the eV scale. The DNA target is modeled by a cylindrical volume of water with dimensions comparable to a DNA segment of 10 base pairs. These targets are placed at various positions in and around the track to map out the variation of nanodosimetric parameters.

The results of this investigation demonstrate an ionisation cluster size distribution that shows an enhanced biological effectiveness at track ends (Bragg peak region). The enhancement of the biological effectiveness is observed in and off track axis. This result is in contrast to the clinically accepted use of a constant RBE value of 1.1 for protons.

In vivo dosimetry for kilovoltage X-ray Radiotherapy

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Purpose: Basal and squamous cell carcinomas constitute the most frequent cancer type in Cuba. This kind of lesions can be treated by different methods, including radiotherapy with kilovotage X-rays (KVRT). Recently a new KVRT unit - donated to the INOR´s Department of Radiotherapy (DR-INOR) in the framework of a IAEA´s technical cooperation project- has been commissioned. As part of the patient-specific quality assurance program established at DR-INOR for external beam radiotherapy, it has been recommended to implement in vivo dose measurements (IVD), as they allow effectively discovering eventual errors or failures in the radiotherapy process. The purpose of this work is to characterize and implement two measurement systems for routine KVRT in vivo dosimetry. Materials and Methods: The studied KVRT unit, model Xstrahl 200, is able to treat shallow and low deep laying lesions, as it provides 8 discrete beam qualities, from 40 to 200 kV. For in vivo dosimetry measurements a radio-photoluminescence (RPL) dosimetry system, model Dose Ace, -also donated to DR-INOR by the same IAEA project- has been studied and commissioned. In a similar way, response of radiochromic EBT3 type film was investigated for purposes of IVD in KVRT, including energy response of the film. Main dosimetric parameters of those systems, such as reproducibility, linearity and filed size influence were assessed for 120kV beam quality. Both systems were calibrated in terms of entrance dose, reported at 1 cm depth, which is the most commonly used prescription depth for this beam quality. Several test cases of increasing complexity were designed, based on previous clinical experience, to evaluate the systems overall accuracy for IVD purposes. Five cases were designed in slab plastic phantom and a sixth case, type “end-to-end”, was established on and anthropomorphic phantom. Finally, both methods were applied in real patient IVD, including different anatomical localizations, as nose, ear, scalp, cheek and chest wall. As a preliminary rule, during the daily output constancy check, a glass element of the same batch to be used in patients is irradiated in the reference field (10 cm diameter cone), in order to verify the stability of the RPL measuring chain. Results: Characterization of RPL system for in vivo dosimetry: The intra-detector reproducibility, expressed in terms of coefficient of variation, was better than 0.5%, while the inter-detector reproducibility, for the used batch, was close to 1%. Linearity for dose range from 100 to 250 cGy was better than 0.999, expressed in terms of regression coefficient; this allowed using a single calibration coefficient NRPL for each quality, obtained for the reference cone (10 cm diameter, 20 cm focus-skin distance) at 1 cm depth in water, resulting in a NRPL= 2.807 10-5 cGy/reading units. The field size dependence of the response was evaluated for cones of 3, 4, 5 and 10 cm diameter; corrections were close to unity within the measurement uncertainty. Characterization of EBT3 system for in vivo dosimetry: The response of the EBT3 film system was evaluated in a similar irradiation conditions than the RPL system. Calibration curves for entrance dose at 1cm depth were obtained for 4 relevant beam qualities (40, 80, 120 and 200 kV), showing a very low energy dependence of the dose response with respect to 120 kV, reaching 4% under-response at the highest quality (200 kV). The field size correction factors for 120 kV were also close to unity. For the test cases performed in plastic phantom and anthropomorphic phantom, maximum discrepancies of 3% and 5 % were found for the dose measured with RPL and EBT3, respectively, when compared calculated dose. The most difficult region to perform the test cases was the anthropomorphic phantom’s lacrimal location due the irregular surface. In vivo verifications performed in 10 real patients resulted in an average discrepancy of 3% between RPL measured and calculated dose, with a maximum discrepancy of 6% in one patient. The IVD also allowed detecting a gross error in one patient, due to a mistaken introduction of beam quality while editing the treatment parameters in record and verify system of the KVRT unit. Conclusions: The RPL dosimetry showed an excellent linearity for the studied beam quality, and, due to its high sensibility, is more recommendable for hyper-fractionated schemes with curved and irregular patient contours, as those in lacrimal region irradiations, where positioning of RPL element is easier than EBT3 film piece. The radiochromic system involves smaller corrections with field size, but it sensibility is much lower; hence it is more adequate for hypo-fractionated treatments on smoother

patient outlines surfaces fields. IVD showed its significance also in this modality of treatment, as part of the comprehensive quality assurance program.

Potential biomarkers for personalized oncology radiation in uterine cervical cancer

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Uterine cervical cancer (UCC) is one of the most prevalent malignant neoplasms in the world. UCC develops beyond the stage in situ and is frequently treated by a combination of intracavitary radiation therapy and external beam radiation therapy; 30 to 40% of patients with similar prognosis factors not respond equally to a comparable standard treatment. Therefore, the study and identification of prognostic biomarkers, which indicate the probable course of the disease in an untreated individual, and predictive biomarkers, which allow identification of subpopulations of patients most likely to respond to a given therapy, would be extremely useful in the selection of patients for the development of innovative and effective therapies for locally advanced, metastatic and refractory uterine cervical cancer. A comparative analysis of UCC in the context of other cancers may reveal that it is relatively smaller number of targeted molecular agents that have been tested. Some studies indicate that there may be a significant association between the response to treatment and the tumor phenotype, characterized by changes in gene, protein and metabolic expression. The phenotypes that characterize the tumor microenvironment are hypoxia (HIF-1a), glycolysis increase (GLUT1, HKII, GAPDH) and acidosis (CAIX). Activation of the IGF system (IGF1, IGFII, IGF1R) by ionizing radiation induces accelerated cellular senescence. Activation of IGF-1R can result in signaling through two pathways, PI3K/AKT and Ras/MAPK, and as a consequence increases proliferation, protein synthesis and glucose metabolism, and decreased apoptosis. The development of therapeutic approaches directed against IGF1R and signaling pathways related to accelerate cellular senescence can reduce radiation-mediated tissue damage. IGF1R&EGFR may be considered as potential targets for radiosensitization within DNA repair pathways. Within work that we have been developing, reported that gene expression of IGF1R is a strong predictive marker for lack of response to radiotherapy (p=0.018, 95% CI(1.7-41.2)), patients (HPV16 (+), European variants (+), Non-European variants (+)) have 28.6 times higher risk of failure treatment; the presence of anemic hypoxia (hemoglobin (Hgb) 11 g/dl) and the expression of GLUT1 and/or HKII influence treatment response and are associated with a lower overall and disease free survival; GAPDH overexpression and co-expressing IGF2 and IGF1R in the presence of Hgb 11g/dl suggest a possible role of GAPDH as a regulator of tissue response to hypoxia (p=0.04). Objective: To determine whether expression of IGF-IR, GAPDH, HIF-1 alpha, Survivin, GLUT1, CAIX, HKII, presence of HPV16 variants and clinicopathological parameters can be used as prognostic and predictive biomarkers to treatment outcome and as possible molecular targets. Patients & Methods: This prospective cohort study included 149 patients with squamous cell carcinomas of the uterine cervix in FIGO stages IIB (n=53) and IIIB (n=96) between 2008 and 2011. The mean

age was 46 years. Of the 149 patients, 61 were treated with radiotherapy and 88 with concurrent radiochemotherapy. Expression of the proteins CAIX, GLUT-1, HIF1a, HKII, IGF-IRa, IGF-IRb and Survivin, was determined by immunohistochemistry, and presence of HPV16 variants was detected by PCR-SSCP and Reverse line Blot in biopsies taken before treatment. Results: The highest increase was found in expression of GAPDH (100%), Survivin (87%), followed of, IGF-IRa (76.5%), IGF-IRb (74.5%), IGF-IRa and IGF-IRb concordance in the expression(73%), HIF1a (74.1%); strong expression was observed with low frequency for GLUT-1 (31.1%), CAIX (16.2%), HKII (10.6%). Hgb level was significantly correlated with treatment response (p=0.01). With a median follow-up of 2.1years, OS was decreased for patients over-expressing IGF-1R b (p=0.04). A similar trend with GLUT-1 over-expression was observed (p=0.18). The OS of the sub-group of patients with anemia (Hgb < 11g/dL) and concomitantly over-expressing IGF-1R and GLUT-1 was significantly decreased compared to the opposite control group (p=0.015). The European variants of HPV16 was identified in 88% and non-European variants in 12%. Greater presence of European variants E-350G and non-European (eg.AA) with overexpression of IGF1R in the non-complete response group compared to the complete response group was observed. Conclusions: The presence of E-G350 and non-european (eg. AA) variants and overexpression of IGF1R in the non-complete response group could be related with radio-resistance. The expression of GLUT-1, IGF-1R and Hgb (11g/dl) are associated with poor prognosis, and thus appear to be interesting biomarkers of radiation resistance. If pre-clinical studies suggested such proteins to be part of the biological pathways leading to radio-resistance, the present clinical study confirms their role among UCC patients. Using the expression of GLUT1, IGF-1Rß and Hgb (11g/dl) as therapeutic molecular targets could contribute to an appropriate therapeutic management as individualized neoadjuvant treatment.

Planning study of comparison of dose in target volumes and volumes of organs at risk in patients with high grade glioma. Intensity Modulated Radiotherapy versus Three- dimensional Conformal radiotherapy (3D-CRT).

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Introduction: Postoperative radiotherapy, together with surgery and temozolomide chemother- apy is one of the treatment modalities with curative intent in patients with high grade glioma (HGG, WHO Grade III). Survival of these patients is significantly longer compared with patients with WHO Grade IV tumors and long term CNS toxicity could be expected after radiotherapy treatment in this group of patients. Recent clinical data on long term survivals in group of high grade glioma patients is showing that decreasing dose in region of hippocampus could have positive impact on mental function in this group of patients. In our institution, standard treatment of patients with high grade glioma is 3D-CRT radiotherapy.

Methodology: In our study we made retrospective planning study on 15 previously treated patients with HGG with 3D CRT. For this purpose we made treatment plan using same CT dataset with MR fusion and performed IMRT planning using inverse planning algorithm on Varian Eclipse Treatment Planning System (TPS). Comparison of 3D-CRT and IMRT plan data has been done. Dose volume analysis of following structures has been done: V57 Gy (volume receiving dose of 57 Gy and more), maximal dose in brain stem, maximal doses in optic lenses, maximal dose in eye bulbus, maximal dose in hippocampus, maximal dose in optic nerves, optic chiasm and cochlea.

Results: Statistical analysis on patient data has been done and statistically significant difference in favor of IMRT Plans has been shown in V57 Gy volume ($p=0.0461$) and maximal dose in right cochlea ($p=0,0431$). Other critical structures has been shown decreased dose in organs of risk, but without any statistical significance. Maximal dose in right hippocampus has shown highest decrease but without statistical significance ($p=0.0547$)

Conclusion: IMRT treatment of patients is feasible and decrease of dose is possible in some of the organs at risk. Selection of appropriate clinical cases is important to prove value of IMRT in treatment of patients with high grade glioma.

Radiotherapy utilization in developing countries: an IAEA study.

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Radiotherapy utilization in developing countries: an IAEA study Eduardo Rosenblatt, Elena Fidarova, Eduardo H. Zubizarreta, Michael Barton, Glenn W. Jones, William J. Mackillop, Lisbeth Cordero, Joel Yarney, Gerard Lim John V. Gan, Valentin Cernea, Susana Stojanovic-Rundic, Primoz Strojan, Lotfi Kochbati, Aldo Quarneti Background The planning and monitoring of national radiotherapy services requires a thorough knowledge of the national cancer epidemiology profile, the radiotherapy utilization (RTU) rates and a realistic future projection of these data. Previous studies have established RTU rates in high income countries. Methods The IAEA conducted a project to investigate the optimal and actual RTU rates in 9 middle-income countries. The aim was to estimate the actual RTU rate and compare it with the optimal RTU in each country to estimate the gaps in service provision. The countries selected for the study were Costa Rica, Ghana, Malaysia, Philippines, Romania, Serbia, Slovenia, Tunisia and Uruguay. Optimal RTU (oRTU) was determined following the epidemiological evidence-based method using cancer incidence data from Globocan-2012 and radiotherapy indication trees from the CCORE group. The actual RTU (aRTU) rates were calculated dividing the total number of new notifiable patients treated with radiotherapy in 2012 by the total number of cancer patients diagnosed in the same year. An analysis of the characteristics of patients and treatments in a series of 300 consecutive patients receiving RT shed light on the particular patient, diseases profile and techniques used in the participating countries. Results The calculated median oRTU rate for the group of 9 countries was 52% (Table 1). There was a difference of 9% between the lowest oRTU in Costa Rica (47%) and the highest in Tunisia (56%). This was due to variations in the incidence of some cancer types treatable with radiotherapy that have a lower incidence in Costa Rica than in Tunisia. The aRTU rate for the 9 countries was a median of 28% with a range from 9% (Ghana) to 46% (Tunisia). The results show that the actual proportion of cancer patients receiving RT is lower than the optimal RTU with a rate difference between 10% (Tunisia) and 42.7% (Philippines). The median percent unmet need was 47% (range 18-82.3%). Patient's mean age at diagnosis was 55 years and the gender distribution m/f was 36/64%. Mean delay caused by the medical system was 280 days, and mean delay caused by internal center's procedures was 73.5 days. 67% of patients were treated with palliative, and 33% with curative intent. A mean 54% of patients had previous surgery and 21% received concomitant chemo-radiotherapy. From the RT technique viewpoint and out of the total of 2549 patients analyzed, 49.1% were treated with 2D, 42.6% with 3D, 3.2% with IMRT and 4.9% with other techniques. 16% of patients were treated with hypofractionated regimens. The median re-irradiation rate was 11% and the most frequent irradiated sites were: pelvis (27.3%), breast (26.8%), head-and-neck (12.8%), CNS (11.8%) and "other" (11.1%). Conclusions The optimal RTU rate in this group of middle-income countries did not differ significantly from that previously found in high income countries. The actual RTU rates were consistently lower than the optimal, ranging from 9% to 46%. The gap between optimal and actual RTU rates in these 9 middle-income countries as well as the calculated percent of unmet need could be explained by obstacles in

access to existing RT services and other factors. National radiotherapy services should be rationally planned in order to improve access to RT.

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Evaluation and validation of the Fast Superposition, Super- position and FFT Convolution algorithms for IMRT of low density treatment sites on CMS XiO Treatment Planning System.

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Dose calculating algorithms play an important role in patient treatment planning in radiotherapy. Morden complex treatment techniques for example intensity modulated radiotherapy (IMRT) require accurate and fast dose calculating algorithm to enhance delivery of quality in the treatment of low density sites. The study evaluated three algorithms used in IMRT and these include Super- position, Fast Fourier Transform (FFT) Convolution and fast Superposition. These algorithms were evaluated when applied to low density treatment sites, which include larynx, stomach and lung. An inhouse phantom with low density material was designed and constructed for use in both point dose and planar dose distribution measurements using ionisation chamber and MapCHECK 2 respectively. The evaluation involved a comparison and quantification of deviation between the TPS predicted dose and that experimentally measured, for each algorithm and treatment site. The percentage deviation of the ionometric measurements was between 2.09% and 6.03%, while the gamma index method had ≥ 80% points satisfying the acceptance criteria of (3%/ 3mm). Therefore the outcome of the IMRT treatment is affected by the choice of the algorithm per each treatment site. An affordable inhouse phantom can be used for algorithm evaluation.

New insights into metallic nanoparticles for enhancement of particle therapy in hypoxic tumors

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Low oxygen concentration in cancer cells results in significantly lower cell death after exposure to ionizing radiation. Thus, tumor hypoxia is associated with radiation resistance and reduced survival in cancer patients. The oxygen effect can be expressed quantitatively by the Oxygen Enhancement Ratio (OER) which is the ratio of radiation doses under hypoxic to normoxic conditions for the same biological effect. The OER depends on many factors such as the oxygen level, the tissue and the linear energy transfer (LET) of the radiation.

It has been obtained a decrease in the OER with increasing LET 1. Hence, particle therapy benefit the treatment of hypoxic tumors compared to conventional radiotherapy. However, the irradiation of healthy tissues at the entrance channel remains a major limitation. Therefore, increase of radiation effects in tumor whilst preserving healthy tissues is a challenge in particle therapy.

Recent developments in nanotechnology brought new perspectives of using high-Z nanoparticles (NPs) to increase local radiation effect [2]. Previous studies performed by the group demonstrated that the radio-enhancement due to platinum NPs is mostly related to the production of water radicals (OH) produced in the vicinity of the NPs [3]. In parallel, Hirayama and co-workers observed that the contribution of OH-mediated cell damage is strongly influenced by the presence of oxygen [4]. Hence, it is of fundamental interest to better understand the role of oxygen on the effect of NPs.

In the collaborative work performed at the Heavy Ion Medical Accelerator in Chiba (Japan), we investigated the effect of Pt and Au NPs on human cancer cells incubated in normoxic and anoxic conditions, and irradiated by carbon ions. This first study shows a strong attenuation of the amplification effect by NPs in the absence of oxygen. This gives new insights in the processes involved in the radio-enhancement by NPs.

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Two Dimensional (2D) vsThree dimensional (3D) treatment planning in Paediatric Radiation Oncology. Less technology can be acceptable?

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Introduction: In our country and others Low Income Countries (LIC) the difficulty to access technology cause delay in Radiotherapy (RT) and decrease survival. Children have their treatments delayed especially if their treatments include 3D plannings. We thought that could be educative to evaluate when 2D plannings could be used safely in paediatric radiation oncology cases. During a project supported by IAEA –PRON- Optimization of radiotherapy in low resource settings: pediatric cancer patients"– we compared 2D and 3D plannings in patients that had agreed to participate and/or performed also 2D planning for any reason. The goal was compare inside of the same patient the two different modalities 2D vs 3D to detect in which situations would be acceptable to perform a 2D planning. Methodology: All patients were planned at the AccuityVarian digital simulator using planar RX (2D). The physician defined fields and protections based in bone marks and/or Computed Tomography (CT), magnetic resonance image (MRI) to evaluate the target, margins and OAR. All the 2D plannings were performed first. After the procedure at the simulator, all the patients were also submitted to CT planning and all the structures (GTV, CTV, PTV and OAR) were contoured by the same physician in the TPS. The patients were then planned to 3D treatement. They were planned using a TPS Eclipse Varian to calculate the 2D and 3D plannings. The fields and MLCS defined by the physician at the Simulator were copied to the CT of the patients and the 2D planning reconstructed and calculated in TPS. The comparison of the 2 plannings (2D vs 3D) were performed at the TPS and the doses to the targets and OARs analyzed using dose volume histogram data. Statistic analysis were done using Wilcoxon Non parametric Test. BioEstat 5.0 software - p 0.05. Results: We studied 28 patients, 15 male, 13 female, (18 months to 21 years old), mean age 8,5 years. We had different cases and sites: Cranio-Spine Irradiation (CSI)(4) leukemia (Brain to C2-3 irradiation) (3); lymphoma (2) , wilm´s tumor(5)(whole abdominal irradiation (WAI+ boost) (3), Whole lung irradiation WLI (2); combined sites (1); Soft tissue tumors (STT) (6): face (2) extremities (2), thorax (2), combined sites (2); Central Nervous System(CNS) tumors (8). We observed that: In CSI and Leukemia cases 2/7 (28,5%) of cases the cribriform plate was not well covered 70%vol with dose prescription, but the difference in coverage were not significant p = 0,06. The dose to the lens and eyes were increased in 3D plannings. The dose to the caudal extent of thecal salc was efficient in all the four patients. The dose to the kidneys were significantly reduced with 3D planning (volume 23Gy – decreased 40%). The coverage of CTV and PTV were not statistically significant different, p = 0,25. Lymphomas cases plannings – the dose to the GTV, CTV and PTV were similar however the dose to the lungs was increased in 2D plannings – V20 –50%, V15 30% V5 15%. Wilm's tumor cases plannings to WLIand WAI followed by boost showed no difference in terms of target coverture between 2D vs 3D planning. The OAR doses were lower with 3D but not significantly different p = 0,056. Soft tissue tumor cases (STT) – STT face- The dose to the GTV were unsatisfactory, in general 20% lower than 3D planning. The doses to the OAR were in general increased with 2D in special optic nerves and optic chiasm. Dose to CTV and PTV was unacceptable 30 to 40%lower than 3D. The coverage of PTV and CTV was statistically significant better to 3DP = 0.034. STTs extremities – The coverture of GTV and CTV were acceptable in extremities but the PTV had lower doses 80% vs 93% coverture. The STT thorax planning showed the 20 to 30% lower coverture to CTV and PTV in and the OAR (heart nd lung) had increased doses with 2D. CNS tumors cases plannings showed the dose to GTV were lower with 2D but not significant p =0,64 mean dose to CTV and PTV were significantly better to 3D p
= 0,04 and p = 0,02 respectively. Significant protection to optic chiasm was observed with 3D. Brain, temporal lobe dose were not significant different. Conclusions: Based in this cases. 2D plannings of WLI, WAI in Wilm's tumor and STT of extemities are safe and acceptable, CSI and leukemia 2D plannings can be done relatively safe but with care to cribriform plate coverture. Plannings of STT face, STT thorax and lymphomas were unacceptable. The worst situation was the CNS tumors to perform 2D plannings.

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Skin reaction to cetuksimab (CMb) as a criterion for treatment selection in patients with locally advanced squamous cell carcinoma of the head and neck (LASCCHN): results of prospective study

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Introduction of the study: In LASCCHN, a combination of radiotherapy (RT) and CMb: (1) significantly improves overall survival rate compared with RT alone; (2) CMb-treated patients with a prominent CMb-induced rash survived significantly better than patients with no or grade 1 rash, who experience no survival advantage compared to irradiated only patients. Comparing the benefits of concomitant immunoradiotherapy and chemoradiotherapy with RT alone, the outcome in CMb-treated patients with a skin rash of grade 2-4 (hazard ratio [HR] 0.49; Bonner et al, Lancet oncol 2010.) seems more favorable than in cisplatin (CP)-treated patients (HR 0.74; Pignon et al, Radiother Oncol 2009). The aim of the present single-institution non-randomized prospective phase II study was to test the hypothesis that early assessment of a CMb-induced skin rash can be used for treatment stratification of patients with LASCCHN: in patients who would develop a grade 2-4 skin rash after concomitant CMb administration, the treatment results will be improved compared with RT-CP combination. In patients without a prominent skin rash no beneficial effect of CMb is expected and concomitant chemoradiotherapy with CP should be more effective.

Methodology: Patients with LASCC (stages III-IVB) of the oral cavity, oro-hypopharynx or larynx and WHO PS 0-2 were considered eligible. In the week before RT, all patients received a loading dose of CMb (400 mg/m2). During the first week of RT, a combination of CMb (250 mg/m2) and CP (30 mg/m2) was concurrently administered. At the end of the second week of RT, a multidisciplinary assessment of the skin rash was done: CTCAE v3.0 grade 0-1 – patients proceeded with chemoradiotherapy with CP (arm A); CTCAE v3.0 grade 2-4 – patients proceeded with immunoradiotherapy with CMb (arm B). Concomitant boost IMRT was used in all patients (56-63-70 Gy/35 fractions). The planned number of patients in the study: 120 (recruited over 3 years). The primary objective: the radiological complete response (CR) rate at 12-14 weeks post-therapy. Secondary objectives: locoregional control (LRC), progression-free survival (PFS) and overall survival (OS) at 2 years after therapy, acute and late toxicity.

Results: Between 12/2011 and 7/2013, 39 patients (males 87%; median age 57 years, range 42-75) entered the study which was prematurely terminated due to an unexpectedly high number of CTCAE v3.0 grade 3/4 allergic reactions to CMb. There were 31 active smokers; sites of origin were the oropharynx 30 (p16/HPV positive 8, status unknown 4), hypopharynx 5, oral cavity 2, and larynx 2. The majority (89.7%) of tumors were of TNM stage IV (T4 53.8%, N2b-3 71.8%). The RT dose was 70 Gy in all patients. During administration of the CMb loading dose, an allergic reaction of CTCAE v3.0 grade 3/4 developed in 11 patients (28.2%) who proceeded with chemoradiotherapy with CP (4-8 cycles, median 6); at 12-14 weeks post-therapy, a locoregionally CR was determined in 6 patients (54.5%). A grade 0-1 skin rash was recorded in 10 patients (35.7%) who continued with RT-CP (6-8 cycles, median 7); 8 patients (80%) from this group had a CR. A grade 2-4 skin rash was recorded in 18 patients (64.3%) who proceeded with RT-CMb (3-8 cycles, median 7) and 10 of them (55.6%) were complete responders. The difference in CR rates between the three groups was not significant. No differences in distribution of the primary tumor sites, T- and N-stage, or HPV status were found between the two arms or those with allergic reaction to CMb. The median follow-up time was 39 months (range, 26-49). Actuarial survival rates at 2 years in patients treated with chemoradiotherapy (arm A and patients allergic to CMb, N=21) and those treated with immunoradiotherapy (N=18) were as follows: LRC 38% (95% confidence interval [CI], 17-58) vs. 39% (95% CI, 16-61), P>0.05; PFS 35% (95% CI, 14-56) vs. 39% (95% CI, 16-61), p>0.05; and OS 52% (95% CI, 31-74) vs. 44% (95% CI, 21-67), p>0.05.

Acute toxicity was assessed separately for patients who received concomitantly with RT either CP or CMb. Evaluation of late toxicity was done only in patients who survived 6+ months post-therapy and had no residual or recurrent disease above the clavicles (Table).

Conclusion: CMb administration resulted in an unexpectedly high rate (28.2%) of grade 3/4 allergic

reactions. A prominent CMb-induced skin rash developed in two thirds of the patients. Immunoradiotherapy in these patients did not result in a survival advantage over chemoradiotherapy with CP but increased acute toxicity.

End-to-end test and TPS QA using heterogeneous anthropomorphic phantom

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The procedure of radiotherapy chain testing, from CT imaging to treatment planning and dose delivery, like a part of the quality assurance programme in the N.N. Blokhin Russian Cancer Research Center was implemented and investigated in 2015. CIRS Pelvis is used to perform such QA procedure in the radiation therapy department the phantom. Phantom CIRS Pelvis has an elliptical shape and an anatomical structure that mimics the pelvic of average person. Phantom has a body made of plastic ("solid water"), bony structure and five cylindrical holes for plugs of various densities (bone, muscle, fat) and ionization chamber cylindrical adaptor. These holes enable verification in the most interesting areas. The first step of end-to-end test is CT-scanning of the phantom on GE Lightspeed 16. Phantom was scanned in two configurations
an ionization chamber in the middle hole with air space in the bottom, and vice versa. The muscle and adipose tissue inserts were located in upper insert hole in both configurations. The correspondence between HU and electron density was checked based on CT scans. It should be emphasized that the results of HU measurements, obtained by the phantom CIRS, are sufficient only for periodical checks of CT calibration curve test existing curve CT. To enter a new curve in the TPS it is recommended to use a phantom with a large number of inserts made of materials with different densities of wide range. Particular attention is paid to the verification of treatment planning system Eclipse with different settings and dose calculation algorithms. Beam energy, field sizes, gantry rotation angles, angles of dynamic wedges were varied among test plans based on TECDOC 1583 (IAEA) and Booklet #7 (ESTRO). IMRT plans were created on the basis of the TG-119 (AAPM) recommendations. Several points of prescription and dose measurement have been selected to study the influence of heterogeneities on the accuracy of dose calculation. The next phase of work with phantom consists of creating test plans with two different dose calculation algorithm (Pencil Beam Convolution (PBC) and Anisotropic Analytical Algorithm (AAA)). Testing covered the following aspects: - The impact rate of grid size on the accuracy of dose calculation - Verification of the various types of heterogenity corrections - Rectangular fields (30x10,cm2) - Small field sizes (4x4,cm2) - Oblique incidence, lack of scattering and tangential fields - Complex field shapes (MLC) - Dynamic wedges of different angles and directions - Various SSD - 4-field box - IMRT plans Evaluation of results was carried out in terms of relative dose differences. As we have other model of CIRS Phantom than described in TECDOC 1583 we couldn't take the same criterias for deviation evaluation. But the similar approach was applied
allowable difference between the calculated and measured dose depends on detector position relative to heterogenity regions and on complexity of field configuration. For the fields, passing through the heterogeneous region, as well as containing wedges or MLC allowable difference between the calculated and measured dose is 3%; for beams with simple geometry - 2%. Results Both algorithms have shown acceptable results. In the absence of correction for heterogeneity, relative difference reached 9.8% for the PBC and 7.7% for AAA, when the detector was positioned not only behind bone structures but also behind the air cavity. In the case when the camera is located in the center of the phantom, the air cavity didn't have a strong influence on the dose calculation even without correction for heterogeneity. The calculation algorithm PBC usually overestimates dose in areas with a low density, and near the borders with these regions, since it does not account for the lateral scattering of electrons. The existing phantom doesn't contain large areas with a low density (imitating the lungs), so the difference observed after the calculation with two algorithms was not big. Equivalent TAR method turned out to be more accurate than other inhomogeneity correction factors considering the effects of heterogeneities on scatter, as well as on primary. As recommended by the AAPM TG-119 several clinical plans were made for IMRT verification. The contours and maximum doses for each volume were taken from this document also. Dose measurement showed appropriate results – discrepancies were not more than 3% for all cases. *All numeric results are contained in tables

Quality audit of IMRT treatment using EBT3 film and RPL glass dosimetry system

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This work presents the main results of INOR's participation in the IAEA Coordinated Re- search Project (CRP) E2.40.18. on "Development of Quality Audits for Advance Technology in Radiotherapy Dose Delivery". The national External Audit Group (EAG) has developed a procedure, based on the CRP's step 9, for using a radio-photo luminescent glass dosimetry system (RPL-GD), combined with a radiochromic dosimetry system, based on EBT3 films, for IMRT treatments´ commissioning and auditing. It was implemented in three linear accelerators (Elekta Precise and Elekta Synergy), licensed for IMRT procedures, in order to verify the feasibility for accurate and precise assessment of dose calculations, both in high dose-low gradient regions. The plans were calculated with two computerized treatment planning systems (TPS), i.e., XIO and PrecisePlan. A phantom specially designed by the CRP was used for irradiations in the accelerators, and relative and absolute dose measurements in the phantom were performed with RPL-GD and EBT3 systems, respectively. Redundant absolute dosimetry measurements with ionization chamber (Semiflex 0.125cc) were used. PTW Verisoft software´s Gamma analysis tool was used to compare the isodoses maps obtained from the TPS and measured with EBT3 dosimetric film. The RPL-GD system, donated by IAEA through a technical cooperation project was commisioned for 6 MV photon beams, to obtain the dose in the PTVs and OARs. The results showed a 4% and 3% differences between the calculated dose and measured dose at the PTVs and OARS, on the accelerators Synergy and Precise respectively. The absolute doses obtained with RPL-GD were consistent with the ionization chamber measurement. Further experience and skills should be gained by the EAG in order to ensure the required accuracy for the purposes of auditing advanced treatments as IMRT, however, the combination RPL-GD/EBT3 seems to be an adequate alternative for performing the recommendations of the CRP.

Is there a role for Cobalt-60 radiation therapy in the world

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Introduction: The invention of the cobalt-60 (Co-60) treatment unit in the 1950's established high energy radiation therapy, but the use of Co-60 treatment began to decline in the late 1970s. At that time linear accelerator based radiation treatment became prevalent, especially in the developed world where today utilization standards recommend that 50% of cancer patients would benefit from radiation therapy at some time during their care. Recently, the World Health Organization has reported that low and middle income countries (LMICs) account for over 60% of the world's new annual cases of cancer and over 70% of the world's cancer deaths. However, despite being home to 85% of the world's population, LMICs have less than 35% of the world's radiotherapy facilities. It is evident that most cancer patients in LMICs do not have access to beneficial radiation treatment.

Until recently Co-60 units still served a dominant role in many LMICs, mainly because these reliable devices are simple and robust, and require manageable maintenance programs and little facility infrastructure. But Co-60 based radiation therapy has dwindled also in LMICs and its use is not considered even in areas that could benefit from it. We postulate that this can be attributed to a lack of development of Co-60 treatment machines and, until recently, a lack of evidence that modern dose delivery techniques are feasible with Co 60. In this paper we will present results of our research advancing modern Co-60 radiation therapy along with reports of image guided conformal treatment delivery with the MRIdian Co-60 unit (ViewRay, Cleveland OH), and developments of dedicated units (e.g. for breast treatment and total body irradiation), to support recommendations for further Co-60 development.

Methods and Results: We have been investigating Co-60 based radiation treatment for 15 years through measurements on a Theratron 780C (T780C) Co-60 teletherapy unit (Best Theratronics) installed at the Cancer Centre of Southeastern Ontario (CCSEO). Additional equipment, such as the binary MIMiC multileaf collimator (MLC; Nomos Corp., Pittsburgh, PA), and the XRD1640 (Perkin Elmer Optoelectronics, Fremont, CA) and aSi500 (Varian Medical Systems Palo Alto, CA) electronic portal imaging devices (EPIDs) were added to the unit to emulate serial tomotherapy conformal dose delivery and enable MV imaging. The beam characterization was complemented by EGSnrc Monte Carlo simulations enabling the development of an in-house inverse treatment planning program. Results will be presented that indicate that modern radiation delivery is achievable using an existing gantry-mounted Co-60 source (Figure 1, right). Rotational treatment delivery with beam parameters modeled in a treatment planning system (including profiles under open leaves across the binary MLC) enable planned delivery to compensate for the Co-60 penumbra and penetration issues often cited as barriers to conformal delivery. Investigations of EPID imaging of anthropomorphic head, torso and pelvis phantoms (Figure 1, left) indicated that basic image guidance could be incorporated into Co-60 units. The potential for advanced image guided radiation therapy has also been clinically proven in a number of centres using the MRIdian Co-60 treatment unit.

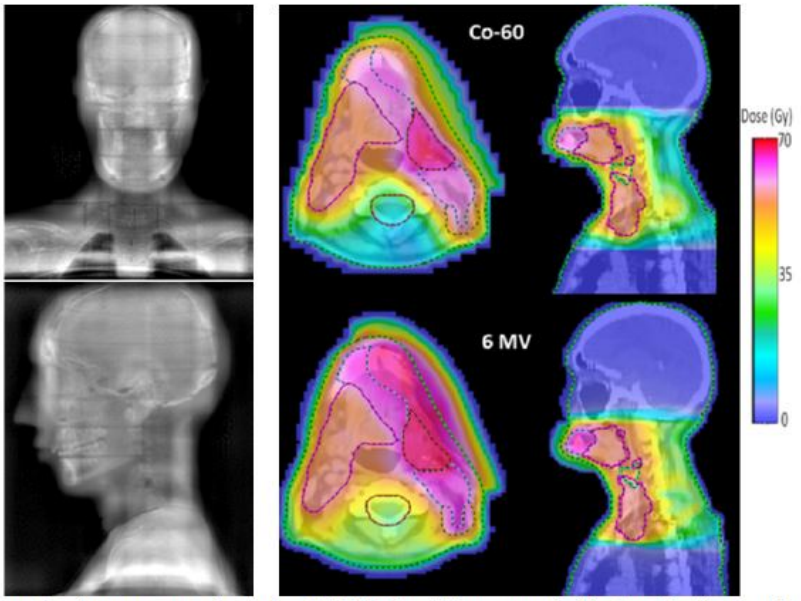

Figure 1. Results from research at the CCSEO in Kingston. (left) Co-60 electronic portal images of the Rando phantom head (right). Comparison of Co-60 (using a sliding window tomotherapy technique) and 6MV based IMRT dose distributions for a clinical head and neck case. Co-60 dose conformality compares favourably with 6MV IMRT.

Discussion and Conclusions: The widespread perception that Co-60 devices are unable to provide suitable modern radiation treatment is incorrect. Yet this viewpoint is strong and hinders the appropriate reception of Co-60 treatment units, particularly in regions where a significant patient population may have restricted access to radiation therapy. A suitable approach to ensure that radiation therapy is made more available worldwide includes further development of conventional gantry based single source Co-60 units. Furthermore, our analysis of the current status of Co-60 radiation therapy suggests the development of three classes of Co-60 based systems: (1) fully IMRT and IGRT capable machines to provide modern state of the art treatments in clinics that require this technology, at a lower cost than linear accelerators; (2) less elaborate versions with basic imaging and conformal delivery hardware to provide basic but efficient conformal therapy, possibly through an upgrade path for clinics with basic cobalt units; and finally, (3) simple, robust Co-60 machines that can be quickly deployed in regions that currently lack any form of radiotherapy and that have limited infrastructure to enable the deployment of linear accelerators. Arguments for each of these three classes of Co-60 units will be presented.

Reduction of signal quenching in PRESAGE R dosimeters irradiated with protons

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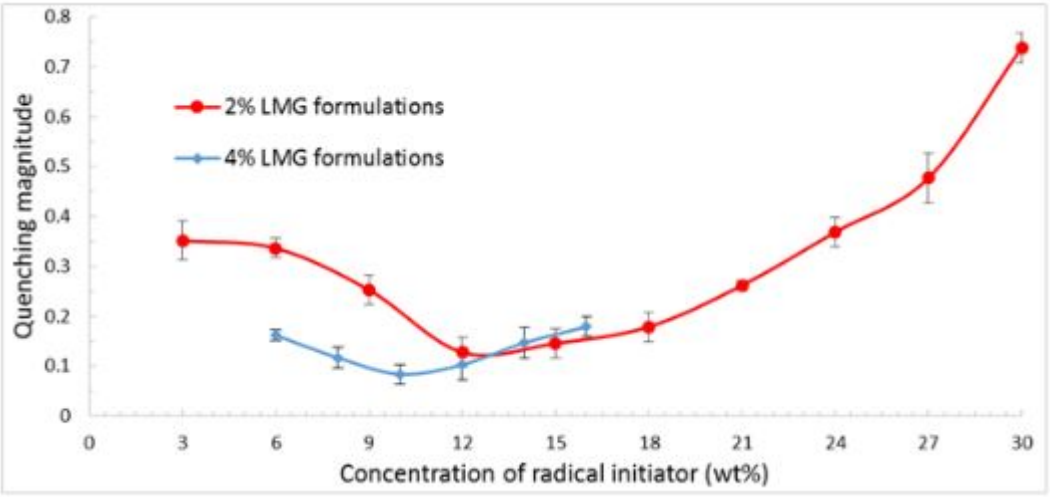
Introduction of the study: As radiotherapy techniques have advanced over the last two decades, dose planning has become significantly more complex. This is explicitly seen in proton therapy where the Bragg peak produces extremely steep dose gradients, enabling highly conformal treatment plans. Limitations in characterizing these plans using conventional QA systems has led to increased interest in 3D dosimetry systems. One such 3D system, PRESAGE® (Heuris Pharma, LLC, Skillman, NJ), is a radiochromic polyurethane that has shown potential in conventional radiotherapy systems. When irradiated by protons, however, signal quenching is observed in regions of high LET making accurate dosimetry so far impossible. This work investigated the relationship between the formulation and signal quenching to determine if PRESAGE can be further optimized to minimize or eliminate quenching.

Methods: PRESAGE® was manufactured in-house under standardized conditions using a method described by Alqathami et al (2016) and consisting primarily of a Leuco Malachite Green (LMG) dye, a chloroform (CHCL3) radical initiator (RI), and a polyurethane resin (Crystal Clear 204, Smooth- On, Easton, PA, USA). Sixteen formulations were manufactured with selected concentrations of RI (3-30 wt%) and LMG concentrations of 2 % and 4 % (wt%). The formulations were poured into spectrophotometer cuvettes (1x1x4.5 cm3) and stored at <3 ° C prior to irradiation.

Irradiations were performed in a solid water phantom using a passive-scattered 225 MeV proton beam with a 10 cm spread-out Bragg peak (SOBP). The cuvettes were placed at four points along the beam depth profile. One point in the plateau region was used to measure low-LET signal response while the other three points were taken along the SOBP to measure the response in a uniform dose region of varying LET. The photo-absorption spectra were measured for each formulation and the optical attenuation coefficients at the photopeak were compared. The dose responses were normalized using cuvettes irradiated with the 6 MV beam from a clinical linear accelerator and were compared to ion chamber measurements of the proton beam to determine the quenching magnitudes.

Results: At the plateau region dose measurement point, all formulations demonstrated quenching <1%. In the proximal-most SOBP region, 3% quenching was measured for all formulations with RI concentrations between 10-21%. All formulations demonstrated increased quenching with greater depth in



the SOBP. The distal-most points in the SOBP showed the largest quenching variation between formulations (Figure 1). Formulations with RI concentrations below 12 % showed less quenching with 2 % LMG than with 4 % LMG; formulations with 12 % RI showed more quenching with 2 % LMG. At the distal-most point, the least quenching of all formulations was 8.4 % as measured by the formulation with 4 % LMG/10 % RI. The greatest quenching was 73.8 % and was observed in the 2 % LMG/30 % RI formulation.

Conclusion: This study has demonstrated that changes to the formulaic composition of

PRESAGE® is a method of reducing signal quenching in PRESAGE® when irradiated with a proton beam. While a lower quenching limit was found for composition ranges investigated in this work, this demonstrates that further reduction maybe possible with continued study and an optimized PRESAGE® formulation may eventually allow accurate proton dosimetry.

The role of radiation therapy in the schedule of the medical physics MSc course of BME University

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Introduction: The subject covering particular areas of radiation therapy is of primary importance in the curriculum of a Medical Physics MSc course. These areas include dose measurements, pertinent dosimetry and treatment planning tools. Advanced radiotherapy techniques, such as intensity-modulated radiotherapy, image-guided radiotherapy, stereotactic body radiation therapy (SBRT), 3D brachytherapy etc. have become available. However, the safe introduction of these treatment modalities requires adequately trained human resources. By increasing the complexity of radiotherapy procedures, the role of medical physicists is becoming more important. The discipline of medical physics covers the human application of physical science and development thereof, primarily in the areas of diagnostic imaging and radiation therapy. The first gradual medical physics course in Hungary was launched six years ago at the Faculty of Natural Sciences of Budapest University of Technology and Economics (BME) managed by the Institute of Nuclear Techniques. Methods: The course curriculum comprises fundamental physical subjects (atomic and molecular physics, nuclear physics, particle physics) as well as fundamental medical knowledge (anatomy, physiology) required for subjects of diagnostics and therapy. Students at this MSc branch may chose further subjects from the "compulsory optional" array concerning medical imaging, X-ray diagnostics, radiation therapy, magnetic resonance and its clinical applications, ultrasound diagnostics and nuclear medicine, respectively. Radiation therapy and dosimetry form a relevant part of all interdisciplinary sciences, so they receive considerable significance in the medical physics course as well. The subject "The Physical basis of Radiotherapy" presented in the second semester of the course fosters students for both clinical and R&D activities as well. Students become familiar with radiation treatment planning, the theory and practice of radiation therapy physics measurements; in order to be prepared for their future tasks concerning accident prevention and provision for radiation therapy safety of patients and professionals of health services. The subject „Radiation therapy II" presented in the third semester gives more knowledge and experience about advanced radiotherapy techniques such as intensity-modulated radiotherapy, image-guided radiotherapy, stereotactic body radiation therapy (SBRT) and 3D brachytherapy. Results: Student laboratory exercises of the subject "Radiation Therapy" comprise measurements of film and ionisation chamber dosimetry, radiation therapy treatment planning in addition to getting familiar with radiation protection aspects of radiation therapy centres. Measurements of the subject "Laboratory Practice in Medical Physics" are also related to radiation therapy. The National Institute of Oncology is the facilitator of all laboratory practices in the radiation therapy field. These tasks include amongst others dosimetric measurement with linear accelerators; radiation treatment planning with VARIAN Eclipse, Philips Pinnacle; QA/QC based on the IAEA-TECDOC-1583 with Cirs IMRT Thorax phantom; brachytherapy I-125 seed prostate treatment; measurement with film, ionisation chamber and diode. Conclusion: The medical physics specialisation aims at providing high level interdisciplinary theoretical and practical knowledge and readily applicable skills that can put into practice in both the clinical and the R&D fields. Overall, the education and training of medical physicists is vital to ensure the safe and effective use of radiotherapy.

Wednesday morning - Poster Presentations - Screen5 **/** 268

Dosimetric optimization of BATD-3D interstitial prostate treatments with 60Co and Multi-image technique

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INTRODUCTION:
It is presented an efficient and quick method to dosimetric optimization using multi-imaging technique for intersticial prostate cancer HDR brachytherapy (BATD-3D) with 60Co Source- BEBIG.

MATERIALS AND METHODS:
Establish an optimization process for interstitial needle placement, target volume contour, Organs at risk contour, and treatment planning with the use of different image thechniques (MRI, CT and US) that optimize application time, planning time, and treatment total time. Also it is done dosimetric planification evaluation using different index such as COIN, Paddick Index (PI), conformity/gradient Index (CGI).

RESULTS:
In table 1 it is seen that dosimetrical values obtained for each organ at risk, achieving constraints for each case. In Table 2 it is also shown quality index to CTV coverage, observing a COIN- prom=0.738 and stablish the use of the Paddick PIprom=0.757 and accordance/gradient Index ICGprom=78.7%. This way we could see to parameters to quality control for a correct treatment placement.

CONCLUSIONS:
The correct use of Multi – Imaging optimize the different procedures in the application of interstitial HDR Prostate Brachytherapy (Fig. 1), as well using quality index such as (COIN, PI and ICG) in order to assure a correct treatment dosimetry.

Organs at risk dosimetry needs to be in a narrow relation with CTV quality index, achieving the constraints for prostate volumetric treatments in our centre: • Rectum: D0.1cc≤80%, D1cc≤70% y D0.1cc≤60% • Bladder: D0.1cc<90%, D1cc≤60% y D0.1cc≤50% • Urethra: D0.1cc≤120%, D1cc≤70% y D0.1cc≤10%

Radiotherapy in Peru: shortage and inequities in access and solution proposal

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Cancer is a health problem in the world and Peru, because of the increased incidence, from 154.5 (estimated GLOBOCAN 2012) to 216.9 (Lima Cancer Registry 2010-2012). Since 2012, the “National Plan for Comprehensive Cancer Care and Improved Access for Oncological Services in Peru” (Plan Esperanza)of Health Ministry offers full coverage of treatment cost by the Seguro Integral de Salud (SIS). The lack of geographical access is shortage and centralization of radiotherapy, with 7 machines in the whole country. It causes treatment delay or abandon due to the long waiting times, high transportation costs, stay, food and laboral absentism of the patient and relatives, among other issues.
The purpose of this poster is to propose the decentralization of public radiotherapy in Peru, improving geographic and economic access for cancer patients.
SIS affiliates in the country at September 2016 count 17´497,944. Lima is on first place with 22.5%. The 6 northern and southern regions have 29.7% and 17%, respectively. Jungle regions with only have aerial access, Loreto and Ucayali; represent 4.9 and 2.4% respectively.
According the IAEA and WHO reccomendations, Peru need 52 Megavoltaje units(MU), dis- tribuited as follows: 11.8 in Lima, 3.6 in Cajamarca, 3.5 in Piura, 3.1 in La Libertad, 2.8 in Cusco, 2.6 in Loreto, 2.5 in Puno, 2.3 in Junin and Ancash, 2.2 in Lambayeque, 2.1 in San Martin, 2.1 in Huanuco, 1.6 in Ayacucho, 1.5 in Arequipa, 1.3 in Callao, 1.2 in Ucayali, 1.1 in Amazonas and Apurimac, 1 in Huancavelica and Ica, 0.5 in Pasco, Tumbes and Tacna, 0.3 in Madre de Dios and Moquegua.
We propose in short time (first phase) to setting up of radiotherapy facilities in the hospitals and to distribute 37 MU in 7 regions grouped considering population, preexistence of other oncological services and land transport facilities: 4 MU in Piura, 4 MU in Lambayeque, 2 MU in Loreto, 3 MU in La Libertad, 12 MU in Lima, 4 Mu in Junin, 4 MU in Cusco and 4 MU in Arequipa (see figure). One unit of high dose rate brachytherapy per installation is highly recommended, considering high gynecological cancer incidence.
In the medium-long term (second phase), the facility program should continue and expand to other regions with population demand and availability of the other oncological services (chemotherapy, oncologic surgery), such as Cajamarca, San Martin, Ancash, Puno and others.

Friday morning - Poster Presentations - Screen2 **/** 270

Three years of practicing Intensity Modulated Radiation Therapy (IMRT) in a war-torn country – 1st report from an Iraqi institution

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Background: Intensity Modulated Radiation Therapy (IMRT) is one of the modern radiotherapy (RT) techniques after the 3-Dimentional Conformal Radiation Therapy (3D-CRT) that became available early 2000s in the developed countries. Iraq, a war-torn country since 1980s, is a developing country where many of the civil services had been affected, including the health sector in general and the cancer care in particular. In spite of all the challenges, IMRT was started in this nation in April 2013 and it is still running. Although the fact that this report is primitive on its type, but the authors thought that it might be of interest to the RT community in the developing countries. Methods: Descriptive report of the patients who received IMRT in Zhianawa Cancer Center (ZCC) in Sulaymaniyah city, the only IMRT facility in Iraq since 2013. Results: A total number of 38 patients was treated with IMRT during the period of April 2013 through June 2016, with an average of one patient per month. 97% of the patients were planned for curative intent; 40% are from other Iraqi governorates and 32% were females; Age range was 8-76 year (mean of 46.3 year old) and 24% are in the pediatric age range (8-17 year). 90% are with head and neck cancers (mainly nasopharyngeal carcinoma) with just two patients with prostate cancer, one with chest wall sarcoma and one with brain metastasis for palliative re-irradiation. Among those in follow-up (31 in total, with a mean follow-up period of 2 years), 22 patients are in complete remission (71%). Conclusions: In spite of the great shortage in RT machines, IMRT successfully launched in Iraq in April 2013. A total of 38 patients got this service in ZCC for free, from different Iraqi cities. This low number of patients is due to the huge work-load of patients and very long waiting time in ZCC and the fact that IMRT is more time-consuming in comparison with the 3D-CRT service, the reason that led us to be very careful in selecting those who are in absolute need to IMRT. Most of our patients are of advanced head and neck cancers. Further reports will be required to fully understand the outcomes of this new service in Iraq. Attention to increase the machines in this war-torn country is important to expand the IMRT service to other centers.

Challenges and solutions, advantages and disadvantages of launching 1st 3-Dimensional brachytherapy in a developing war-torn country (Iraq) using Co-60 High Dose Rate (HDR) source

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Background: Brachytherapy (BT) is a well-known part of radiotherapy services for cancer treatment globally for almost a century and can be generally of low dose rate (LDR) or high dose rate (HDR) via using different radioactive isotopes. This service was used to be in Iraqi radiotherapy institutes till 1990s when the wars and embargo started to affect all the aspects of life. All the patients who were in need for this modality of treatment had to travel abroad, incurring great cost as they did so. Recently, this service became available again free of charge inside Iraq. In this paper, we will describe the challenges and solutions, advantages and disadvantages of launching the 1st 3-Dimensional BT in a developing war-torn country using Co-60 HDR source.

Methods: Zhianawa Cancer Center (ZCC), a public radiotherapy facility established in 2009 in Sulaymaniyah city – Kurdistan – Iraq, wanted to add BT to the list of treatment modalities offered. We had to choose between delivering BT through LDR or HDR in addition to choosing the type of source. All while trying to overcome multi-layers of challenges.

Results: 1. The choice of the HDR after-loader over LDR was made for two reasons: HDR delivers similar clinical outcome as LDR but without the hassle of hospitalizing the patient. An important challenge to keep in mind as our facility is a stand-alone RT clinic and lacks the required in-patient care for the LDR implants. 2. Once the choice of after-loader was made, we had to look at the type of source to buy. The popular iridium, Ir-192, vs the more recent Cobalt, Co-60, source. Co-60 has a half-life that is about 26 times that of Ir-192, 5.26years vs 74 days. This means that we have to worry about the difficulties and the red-tape of exporting a radioactive material once every few years. The bureaucratic delays and multi-layers red tapes that are abundant the public health system in Iraq, makes purchasing equipment very difficult. Other advantages of using a long-lived source is less transport difficulties and less need for performing source exchanges and hence acceptance testing. 3. The center does not have a Well-chamber to measure the source activity when it arrives, so we requested that the appropriate set of quality assurance tools be delivered with the machine. We were surprised to receive the Krieger Phantom. The vendor delivered the Co-60 after-loader and its control and planning systems, along with that we received an electrometer, a 0.6cc ion chamber and the Krieger Phantom. As this phantom is not very popular outside Germany, we had to contact many experts and search many protocols (some in German) to know how to use the phantom for source measurement. This alone, took a good part of 2 years. 4. Two decades of war and embargo had led to a severe lack of local expertise in brachytherapy physics and clinical services. To overcome this situation, we setup multiple in-house workshops and training courses, experts from the region and internationally provided hands-on training for our staff. To gain enough knowledge and to be confident, this part also took some 2 years. A regional expert was present during the treatment of the first HDR patient. The machine was available on site in 2013, however, the first patient was treated in mid-2016, and since we have treated 10 patients for gynecological tumors, each for 2-5 sessions.

Conclusions: In spite of the difficult challenges, BT was successfully re-started in Iraq. As of now, our center in Kurdistan is the only one delivering such service to the entire population of Iraq free of charge. In this synopsis, challenges and solutions, advantages and disadvantages of using the Co-60 HDR BT were explored. The authors believe that this piece of knowledge might be of interest to the colleagues in the international communities who are facing similar challenges.

Tuesday afternoon - Poster Presentations - Screen5 / 272

Feasibility of 27 Gray in 5 daily fractions adjuvant radio-therapy in breast cancer ladies – 1st report from an Iraqi institution

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Background: Breast cancer (BC) is the most common cancer in Iraqi ladies and the need for the adjuvant (Adj) Radio-Therapy (RT) as part of the breast cancer treatment, is important in many of the cases. RT centers are few in this war-torn country (10 in total) and they are over-loaded with the cancer patients and under-equipped with the required machines and staff (16 functioning linear accelerators in total for around 35 million of population while the ideal requirement is around 70 machines, ie, less than 23% of the requirement). Subsequently, most of the patients have to wait for long time reaching to eight months in our center in order to get the treatment, and few are being able to travel abroad to seek the required care in-time. The standard Adj. RT in BC is ranging from 40 Gray (Gy) / 15 fractions (fr) / 3 weeks (wk) as in the British institutions, to 50 Gy / 25 fr / 5 wk as in the American institutions. The practice of short-course adj. RT in BC (5 fr, once a day, over one week or once a week over five weeks, to a total of 26 - 30 Gy) has been studied previously by some colleagues and was a reasonable option in general, this is beside the extensive studies in Accelerated Partial Breast Irradiation approaches via brachytherapy or external beam radiotherapy. By mid of 2016, we launched a short course protocol in breast RT and we would like to share our modest knowledge here, as we feel that its feasibility outcomes can be of interest to some colleagues in RT community who are facing similar challenges.

Methods: Descriptive report of the patients who received Adj. RT for BC, in a dose of 27 Gy in 5 daily fr., in Zhianawa Cancer Center (ZCC). Field of radiation was either whole breast or chest wall, with or without regional nodes with an additional boost as indicated. Tolerability of this study was assessed by checking the willingness of the participants to be managed in this approach. The trial design is a single arm feasibility study. Primary end point was the percentage of patients receiving the full course of treatment as planned. We assumed that more than 80% [CI: 60-80] of the participants will tolerate and complete the full course. We estimate that we will have 0.9 power to demonstrate the feasibility using 45 number of patients. The protocol concept of the study was discussed at / and accepted by the ASCO International Clinical Trials Workshop (ICTW) in Istanbul, May 7-8, 2016 and we started to recruit patients after that.

Results: 20 ladies with a mean age of 51 year (range 27-79) were managed according to this study for curative adj. intention during the period of June to early November 2016 (the remaining 25 required patients will be collected in the coming months till the time of the ICARO in June 2017). Half of them underwent breast conserving surgery (BCS) and the other half with modified radical mastectomy (MRM). 90% with invasive ductal carcinoma (IDC) and 50% with grade II and 55% of right side BC. All received 27 Gy in 5 fr. (5.4 Gy daily fr. size) in one week and 4 of them received an additional boost that ranged from 3-4 Gy times 3 fr. All the patients tolerated the treatment well without any interruption (100% compliance from the starting date to the date of the last fraction).

Conclusions: In this provisional report, 27 Gy in 5 fr. seems a feasible approach in BC to deal with the great shortage of RT machines in Iraq in general and in ZCC in particular. In spite of the scarce literatures in this approach, our study revealed that this fractionation is well tolerable with encouraging outcomes. Further follow-up is required in our study and more international phase three trials are warranted in this regard.

Session 11b - Quality in Radiotherapy: various dimensions / 274

IT safety requirements in the Radiation Therapy field: risks and solutions all over the process

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Introduction An impressive evolution of the Information Technology (IT) tools and systems since the invention of computers has radically modified Radiation Therapy. From standalone systems with limited and dedicated functionalities, to networks of all equipment through a common system, all these developments have resulted in a tremendous enlargement of the IT area, of the data transfer capacities and of the interactions between modalities (linacs, software, imaging devices). Maintaining this growth over the last half-century has been successful thanks to safety and security methodology. From aviation to nuclear power plants, from pharmaceutical process to surgery, from basic manual manufactures to complexes automatic industries, everywhere checklists have been introduced to ensure an optimal level of process quality achievement. On the way to improve safety and efficiency in our Radiation Oncology department, we initiated an in-house software development in 2004. The need emerged from the sharp increase in complexity when IMRT was introduced as a routine treatment. The need was to keep a constant overview of the workflow as well as the detailed “to do lists” to be completed, at the right time and in the right order. A permanent flow of information is exchanged between systems, requiring specific quality control procedures of the accuracy of these transfers.
Material and methods: A web-based, open-source software has been developped, which is able to display the list of all the patients currently supported in the Radiation Oncology department. The system is called iTherapy Process (iTP, figure 1). The patients are distributed in various steps of the process (from the first consultation to the last radiotherapy session). Each step consists of a checklist relative to the process. Each step has also a colour code indicating which group of staff is in charge (for example planning in orange for physicists, or contouring in green for physicians). Whenever a step is completed, the person in charge validates it, and the name of the patient appears in the next step. This allows for immediate warning of the next person in charge that the file is ready to progress (from simulation to contouring for example). Some steps consist of checklist to verify the accuracy of digital data transfer. This is considered an efficient safety measure in a domain where risk is frequently underestimated. The different key points of the development story of this open source (AGPL Licence) software will be discussed, focusing on the pros and cons. The current challenges and our needs for the future will also be addressed.
Results: This software entered in production in 2005; it has been completely redesigned in 2012, and is called now iTherapy Process (iTP). Patient workflows are deeply detailed and frequently brought up-to-date by an ad-hoc department standing working party (the iTP committee). Next to the workflow management by checklists, several iTP steps contribute to automatize, standardize and centralise control tools (existing in the past as separate “Excel” sheets), like in-vivo dosimetry, brachytherapy sources management, patient delivery quality assurance, eNal protocol, communication book, incident reporting system, team planning, breakdown database and downtime calculation, . . . From the CT-scan room, where the Hounsfield Unit (HU) must be well known and calibrated, to the treatment delivery, our daily activities are supported by the digital world (IT) which has, in the end, an impact on the treatment delivery itself and his quality. The safety and quality of the treatments is a permanent goal but a perpetual challenge. We face today a high level of complex process. The checklists help to keep the teams on the right track.
Discussion and conclusions: Working on a complex process within a multi-disciplinary team calls for a very well organized “information transfer system”. Interaction between systems (TPS, OIS, Image viewer, linacs, . . .) usually works fine. But what is the safety level of those data transfers? How far can we trust the standard protocols (Dicom-RT, HL7, . . .), our storage areas, the modules used to transfer dosimetric information? Trustable data exchange protocols, automated and cross-check tools, standardizations, are currently lacking or are insufficient. iTP is an attempt to help the user to verify, after data transfer from a system to another one that the data have been transferred appropriately. But, in the long term, solutions to strengthen the big data world still need to be developed.
Different area like aeronautic, chemistry, nuclear industry, banking or pharmaceuticals have developed (from the business as well as the legal point of view) a strong “safety and QA” oriented on the data transfer side. The medical world just starts to think about it. With all the technologies at our

disposal, we must open our minds to new risks, to new challenges and also to new ways of working.

Session 24b - Brachytherapy / 275

Realization of the absorbed dose to water for electronic brachytherapy X-ray Sources

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INTRODUCTION:Today, miniaturized x-ray sources (MXS) are widely used for radiation therapy treatment (RTT) with more than 400 devices worldwide. The German National Metrology Institute (PTB) is developing a primary standard in terms of absorbed dose to water for the two mostly used devices:
The Intrabeam R -system from Carl Zeiss Meditec AG and the Axxent Inc.).tube from Xoft (iCad),
Both devices emit an X-radiation field with an energy distribution given by a continuous Bremsstrahlungspectrum with a maximum energy of 50 keV superimposed by characteristic fluorescence lines induced by the material of the electron target and the materials in the pathway of the emitted photons. The angular distribution of the emitting field of both MXS is different: The emitting field of the Axxent tube is at maximum perpendicular to the axis of the needle, as it is the case for common radioactive Brachytherapy sources. The Intrabeam R -system has its maximum intensity in forward direction. In this direction the variation of the intensity is small for polar angles less than 30 degree.
The emitted field the dose reference point of the two sources are defined in separate positions due to the different spatial distribution: For the Axxent source it is defined in 1cm distance perpendicular to the axis and for the Intrabeam-system in 1cm distance along the source axis.
MATERIALS AND METHODS:
The spatial and energy distribution of the radiation fields of the sources were characterized with several methods and then detailed MC-models were designed to be consistence with the measurements.
Spectra were measured with an HPGe-Detector in combination with an analogue desktop spectrum analyser with pulse pile-up rejector circuits. Remaining pulse-pile up artefacts were eliminated by an algorithm developed in MATLAB R . The spatial distributions of the focal spots were measured with a pinhole (1 mm thickness, 50 μm diameter) camera set-up using the camera obscura principle. The detector of this system is based on X-ray storage films.
Relative 3D- dose distributions in distances below 3 cm were determined with radiochromic gel dosimeters. Gels response was evaluated using optical computed tomography resulting in full 3D maps of distribution of relative optical densities in the whole volume of the gels. From the 3D map, 2D planes and 1D profiles were selected and compared to the results of the Monte Carlo simulations.
The principle of the primary standard (iPFAC, in phantom free air chamber) is based on a free-air chamber located in a phantom of water-equivalent material. It has parallel-plate geometry, and the gap between the two plates embodying the measuring volume can be varied continuously up to a distance of 20 cm. The proximal front plate is [U+FB01]xed and its thickness de[U+FB01]nes the depth of measurement.
The evaluation method is based on radiation transport theory. The new method offers a clear analytical expression to determine D_W by applying a conversion factor $C(x_i, x_{i+1})$ to the difference of ionization charges measured at two plate separations x_i and x_{i+1}. This factor is composed of quotients of kerma values determined for different plate separations in the chamber.
Monte Carlo simulations were performed for the characterization of the utilized measuring devices, and to calculate the conversion and correction factors for the primary standard.
RESULTS: The results of the measurements for the characterization of the sources and the complementary Monte Carlo simulations will be presented with a special emphasis on the information required for the realization and dissemination of the desired quantity absorbed dose to water.
Shown in Fig. 1 are measurements with the iPFAC for the Intrabeam source at 50 kV tube voltages and with 40 μA beam current. Given are the values of the determined water-kerma rate at plate sep- aration zero for specific plate separations x_{i+1} within the phantom of the primary standard. From the mean value $K^{Ph}{w}=(71.30 \pm 0.006)\mu Gy/stheabsorbeddoseratein1cmdistancewithinawaterphantom(10x 65.4$ mGy/s.
CONCLUSION: The absorbed dose to water for electronic brachytherapy sources has been realized

for the first time. It is intended to offer a regular calibration service by the end of 2018. In a further step, transfer standards suitable for the dissemination of the quantity need to be established as well as consistent procedures or protocols.

Wednesday afternoon - Poster Presentations - Screen1 **/** 276

Electro-hyperthermia as a radiosensitiser for locally advanced HIV positive and negative cervical cancer patients in South Africa

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INTRODUCTION: 5-year survival rates for cervical cancer can be as much as 50% lower in developing countries than in developed countries. The treatment of cervical cancer patients in State facilities in South Africa is complicated by the advanced stage of disease at presentation, limited resources in the facilities and high HIV incidence amongst patients. These challenges contribute to the poorer prognosis of State patients in South Africa. The high morbidity and mortality rates associated with cervical cancer increases the socio-economic burden of the disease on the community and the healthcare system. The investigation of a feasible radiosensitiser which can be used in conjunction with cisplatin to improve clinical outcomes for locally advanced cervical cancer is therefore warranted. The aim of this study is to determine the clinical and economic benefit of the addition modulated electro-hyperthermia to standard treatment protocols for locally advanced HIV positive and negative cervical cancer patients in State healthcare in South Africa. METHODS: This is an ongoing phase III randomised clinical trial with a target sample size of 236 participants. The trial is being conducted at the Charlotte Maxeke Johannesburg Academic Hospital in South Africa. Eligibility criteria include female participants between 18 and 70 years of age with FIGO stage IIB (initial distal parametrium involvement) to IIIB cervical cancer. HIV positive participants with a CD4 count above 200/μL and who have been on ARVs for at least 6 months are included. Participants with bilateral hydronephrosis or a creatinine clearance below 60 mL/min are excluded. Participants are being randomised into a “Hyperthermia” group and a “Control” group. Randomisation stratum: HIV status, age and stage of disease. Participants in both groups are treated with 50Gy of external beam radiation administered in 25 fractions, 3 doses of 8Gy HDR and up to 3 doses of cisplatin (80mg/m2). Participants in the Hyperthermia group are treated two local electro-hyperthermia (EHT) sessions per week, each lasting 55 minutes at 130W. EHT sessions are administered directly before external beam radiation using the EHY 2000 Plus capacitive coupling technique (device is supplied by Onotherm Gmbh). The measured outcomes are local disease control, quality of life, early and late toxicity and 2 year survival. Local disease control is assessed by Positron Emission Tomography (PET) scans and toxicity is graded according to the CTCAE version 4. EORTC and EuroQoL forms are used for the assessment of quality of life. RESULTS: Our preliminary results show a benefit in local disease control in the hyperthermia group without the addition of any unexpected early toxicities or adverse events and without a large increase in treatment costs. CONCLUSION: mEHT appears to be a safe an effective radiosensitiser which may be used in low resource settings to improve clinical outcomes.

Thursday afternoon - Poster Presentations - Screen4 / 288

The use of MAGIC-f gel to perform RTP clinical checks, a first approach

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Introduction: When we receive a breast patient after mastectomy with an expandable prosthesis containing a valve with a rare-earth metal magnet a special protocol has to be designed. The magnet is used to guide the surgeon by means of a gimbal to the right spot where to inject small quantities of saline solution to create a cavity that further on will be filled with a permanent breast prosthesis in a restorative surgery. The problem is that during this period, the patient has also to undergo a radiotherapy treatment and the presence of metal is a complicating factor. Several groups since 2004 has being discussing this problem, by means of dosimetry with Diodes, TLD, radiological films, Monte Carlo simulations, and Gafchromic films. Up to now the results are not conclusive. Thus, we want to implement the use of gel dosimetry as a possible application to help the understanding of this interface problem. Methodology: Glass, Boron-Silicate phantoms were produced at the SP-Ribeirao Preto campus glass workshop according to a design proposed. They were made by glass balloons of two-liter capacity. At the bottom, of the balloons, a dome was created to insert the SILIMED/470 prosthesis. The final volume of the glass flask phantoms was 1.1 L and 0.89 L , both filled with Magic-f gel. Because of the dome was created using a manual procedure it is difficult to produce both flasks with equal volumes. The preparation of Magic-f starts dissolving the gelatin in water, during at least half-an-hour, separately the other reagents are added, the addition of reagents are performed at 35-40 degrees Celsius. Finally, the phantoms are filled with the gel and left at 5 degrees Celsius for at least 12 hours before the irradiation. The phantoms were taken to a CT-scanner Brilliance Big Bore,(Philips Medical Systems, Cleveland) of the Hospital and Clinics of the Faculty of Medicine, University of S. Paulo, RP-SP-Brazil, hereafter (HC-FMUSP-RP). The CT scan was sent to XIO–CMS RTP system. A treatment plan using a two opposed tangential asymmetric beams with field size of 19 x 20 square centimeter, at gantry angles of 90/270 degrees; using wedges of 15 deg, at isocenter, for 15 MV and 6 MV. Where a 2 Gy/fraction daily dose was calculated. Contouring was performed in a Varian's Eclipse workstation and then calculated by XIO superposition algorithm taking into account inhomogeneity. The results were then transferred to the Siemens Oncor medical linear accelerator by means of Lantis. The phantoms were irradiated in the following sequence the 1.1 L by a 15 MV x-rays, and the 0.89 L by the 6 MV x-rays respectively, with a 2 Gy absorbed dose normalized to the isodose of 97.5% and 95% respectively. Magnetic resonance images (MRI) of the two phantoms were acquired 1 day after irradiation using a 3T scanner (Phillips, Achieva). These images were centered in the head coil (where the phantoms were positioned) using a 3D multi spin echo sequence with 8 echo times multiples of 35 ms, repetition time of 560 ms and voxel size of (2 x 2 x 2) mm3. The calibration vials were scanned using the same sequence, but with a slice thickness of 5mm. The R2 maps were calculated in a program developed in MatLabQR . Results and Discussion The relaxation rate or relaxivity (R2=1/T2) maps that are proportional to the dose. In the figures each pixel was normalized by the intensity of the isocenter, thus what is being shown is the relative R2 value.(In Figure X4. R2-Relaxation maps obtained by MRI imaging of the phantom after irradiation with a 15 MV beam) It is easier to visualize any changes from the planed dose. As it can be seen there are no change from the planed dose to the delivered dose. Only at the "neck" of the phantom we can see some changes that are probably due to oxygen diffusion in the phantom. The magnet is close to the lower surface of the phantom and possible changes of the dose would be reflected in the relaxation rates near this interface. In summary, these first experiments show that there is not a detectable change in dose due to the presence of the magnet. The results are consistent with the Ann Arbor-UMMC studies.

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Dose distribution characteristics and initial clinical results of two different dynamic tracking techniques for stereotactic body radiation therapy for solitary lung tumors

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Purpose / Objectives Recently, stereotactic body radiation therapy (SBRT) using dynamic tumor tracking (DTT) techniques has been increasingly used. DTT technique has been successful in reducing the size of the PTV and doses to the normal tissue. In our hospital, we have been performing two different DTT techniques, namely, robot arm-based DTT (RA-DTT; CyberKnife System) and gimbal-based DTT (G-DTT; Vero-4DRT System). We investigated the dose distribution differences between the two techniques and the initial results of SBRT for solitary lung tumors treated with these DTT techniques.

Materials / Methods Between March 2013 and December 2015, 28 cases received DTT SBRT in our hospital. Among them 10 received with RA-DTT and the other 18 received with G-DTT. There were 15 primary lung tumors and 13 metastatic lung tumors. Twenty-seven tumors were located in the lower lobe. Their median age was 73 (range: 40-88). The male to female ratio was 20 to 8. The TNM stages for primary lung cancers were T1a in 6, T1b in 6 and T2a in 3. Histologically, there were 6 adenocarcinomas, 4 Squamous, 2 NSCLC, and 3 histologically unknown tumors. As for the primary site of metastatic lung cancers, there were 4 H&N, 3 esophagus, 2 colon cancers, etc. Regarding the reasons for declining surgery, there were metastatic tumors in 13, poor respiratory function in 8, old age in 6, refusal of surgery in 3, etc. CTV ranged from 1.2 ml to 32.5ml (average 12.9+/-11.7ml). Average CTV of RA-DTT was 10.6+/-7.9ml and that of G-DTT was 14.1+/-13.4ml (p=0.4). Average total normal lung volume (TNLV) was 2654+/-714ml. Average TNLV of RA-DTT was 2882+/-865ml and that of G-DTT was 2489+/-565ml (p=0.22). Average respiratory tumor movement was 16.9 +/- 6.4 mm (range: 6.7˜ 31.2 mm). Fractionation regimen was 50Gy/4fr/1wk with the prescription point of D95 of PTV. Eighty to 100 beams were used for RA-DTT SBRT and 7 to 8 beams were used for G-DTT. Median follow-up period was 21.6 months (range: 2.6 to 37.7 months).

Results Regarding dose distributions, average of maximum tumor dose was higher in RA-DTT (66.5+/-4.7 Gy vs. 59.1+/-2.9 Gy p<0.0001). Lung V20 was smaller in RA-DTT (4.9+/-1.6% vs. 8.0+/-4.9%; p<0.025). Lung V5 was similar in both techniques (25.3+/-6.9% vs.21.7+/- 11.7%). Thus, the ratio V5/V20 was significantly smaller in G-DTT (5.36+/-1.65 vs. 3.00+/-0.90; p<0.0006). Overall local control rate at 2 year (LCR2) was 96.3%. LCR2 was 100% for primary lung cancers, and 91.7% for metastatic lung cancers. Regarding overall survival rate at 2years, it was 87.5% for primary lung cancers and 75% for metastatic lung cancers. As for toxicities, 2 grade 3 radiation pneumonitis have been occurred. One of them was primary lung cancer and the other was metastatic. Lung V20 value of both cases was greater than 15%.

Conclusions By dose distribution intercomparison, with the same D95 prescription, RA-DTT gives higher maximum tumor dose. The ratio of lung V5/V20 is higher in RA-DTT. Although our clinical results are preliminary, DTT SBRT for solitary moving lung tumors might be promising with high local control rate and acceptable toxicity. However, higher lung V20 value (> 15%) might cause severe radiation pneumonitis even if this technique has been reported to decrease V20 values significantly compared with static SBRT.

Project to implement an OSL Dosimetry System in Argentina

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Project to implement an OSL Dosimetry System in Argentina A. V. DEMURU a, A. M. STEFANIC a, F. A. PISANO a, M. VALLEJOS a a Comisión Nacional de Energía Atómica, Ezeiza, Argentina. E-mail address of main author: demuru@cae.cnea.gov.ar

The Regional Reference Center with Secondary Standards for Dosimetry (CRRD) carries out a National Program for independent verification of the dose delivered by cobalt therapy equip- ments and LINACs at radiotherapy centers in Argentina, through the use of thermoluminescent dosimeters (TLDs) in rectangular fields of radiation and in irregular fields shaped with MLC. The objective of this program is to verify that the participating institutions, through their treatment protocols, are consistently delivering the prescribed dose of treatment, minimizing its uncertainty. Optically stimulated luminescence dosimetry (OSL) with aluminum oxide doped with carbon Al2O3:C, has a number of advantages over the TLD thermoluminescence dosimetry system currently used. The OSL dosimeters can be used at room temperature and they can be stored for longs periods of time without significant loss of information. At the same time, the OSL dosimeters are more sensitive than TL dosimeters. One of the major advantages of OSL dosimeters is that they can be read out repeatedly and their readings can be corrected using a predetermined decay constant. The OSL allows operations with simple process, also allows successive readings of a single exposure to the radiation providing a low degree of uncertainty between the repeated readings. In addition, the OSL dosimeters can be reused until it reaches the saturation dose (before the linearity or saturation in the dose response), only at this point is the optical annealing. Since optically stimulated luminescence dosimetry (OSL) has been widely used to monitor occupational radiation doses and dose measurement at therapeutic levels, the CRRD has decided to implement the use of these dosimeters in its dose verification program. To achieve this, it has acquired a commercial system: the MicroStar® reader equipment with the InLight® dosimeters knows as dots.

The objective of this work is to perform an evaluation of this system through the following activities:

Calculations of the sensitivity of the system, as well as of the dosimeters, and their normalization.

Reproducibility of the different tests and readings of the dosimeters, in order to design an optimal procedure.

Determine and study the characteristics of the dose response, as well as the linear response of the system and dosimeters, and the dose response signal.

Calculate and define the optimum time of annealing through an annealing device designed by the laboratory.

Calculate and determine the fading by decay of the signal through time and through successive readings of the dosimeters. - Determine the optimal linearity corrections for the implementation of the system and thus calibrate the equipment and the system.

Design special holders for the OSL dosimeters irradiations to be used by the participants.

Determine the uncertainty of the system, and apply it in order to determine possible variations.

Design the procedures for the implementation of the system.

Methodology. In this work, a beam of 60Co will be used to irradiate the dosimeters. OSL dosimeters, commonly known as “dots”, will be read in a MicroStar® reader equipment. Starting from these irradiations, different tests will be performed to study the dosimeters response. The reader equipment consists of an automatic system for the reading the dosimeters which uses diodes (LEDs) to stimulate the nanodots and, by means of a photomultiplier, absorbs the emitted light and transforms it into absorbed dose. This photon counting system is highly sensitive. This study will base on the characterization of the OSL dosimetry system in order to estimate the stability and reproducibility of the readings, as well as to calculate the uncertainty and apply it to the system. The first test already performed was the verification of the parameters suggested by the manufacturer of the equipment. This means that the calibration readings have been performed. Next steps will imply the irradiation of dosimeters with known doses, in order to study the response obtained and if it corresponds to the delivered dose, as well as the study of the holder designed for its irradiation.

New IAEA end-to-end on-site IMRT audit methodology: Pi- lot test results

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Introduction Keeping pace with rapid development of radiotherapy technology during recent years, many cancer centres have transitioned, or are about to do so, from 3-dimensional conformal radiation therapy (3D CRT) to intensity modulated radiation therapy (IMRT) including volumetric modulated arc therapy (VMAT). In view of the complexity of advanced radiotherapy techniques, the IAEA has developed an audit methodology to review the physics aspects of IMRT dose delivery. Pilot test results of the proposed methodology are presented in this report.

Methodology Procedures were developed for end-to-end, on-site auditing of head and neck (H&N) IMRT treatments using a specially designed anatomical phantom named “Shoulder, Head and Neck, End-to-end” (SHANE) (CIRS, Norfolk, VA). During the audit, the phantom undergoes processes similar to a radiotherapy patient treatment, i.e., it is imaged on a computed tomography (CT) scanner, the irradiation is planned using a treatment planning system (TPS) and the plan is delivered using a linear accelerator. Normally the audit is expected to take two days. The ultimate goal of the audit is to verify the quality of IMRT treatment from a physics perspective by comparing the calculated and measured doses. The SHANE phantom can accommodate: (1) an ionisation chamber in four different locations to measure the dose at selected points associated with planning target volumes (PTVs) and an organ at risk (OAR), and (2) a film in a coronal plane to measure the dose distribution. Prior to the on-site visit, the participating centre is required to provide clinically used data of output factors, small beam profiles, and MLC QA tests. In addition, the centre has to prepare an IMRT plan for a virtual H&N patient represented by CT images of the SHANE phantom along with predefined structures. Specific dose constraints are defined for the planning process. Following the preparatory phase, an on-site visit is scheduled. Initial auditing activities include CT scanning of the phantom, importing the newly acquired CT phantom images into the TPS, transferring of the preliminary H&N plan and structures on these images, and re-optimizing the preliminary plan. The calculated doses at the ionisation chamber positions and in the coronal plane corresponding to the film position are recorded. These activities are followed by measurements of the beam output and subsequent film irradiations in a slab phantom for the film calibration, for checking small field profiles and for MLC QA tests. The local patient-specific QA of the treatment plan is also performed. Next, the SHANE phantom is positioned on the treatment couch using the local treatment position verification protocol and is irradiated according to the plan. The phantom is irradiated four times with an ionisation chamber in four different positions; the film located in the coronal plane is given three fractions. Finally, forms with preliminary results are filled in. In the following weeks, the auditing organization analyzes the results and sends the audit report to the participating radiotherapy centre with the appropriate comments and recommendations. The methodology described above has been pilot-tested in three radiotherapy centres in Europe.

Results Pre-visit evaluation of small beam output factors showed results within 2% between the participants’ data and the reference dataset, except for a 2 x 2 cm2 field where differences of output factors up to 5% occurred. MLC QA results were within 1.0 mm for both the leaf positioning bias and the leaf opening width. The results of ionisation chamber measurements in the SHANE phantom are shown in Figure 1. The measured to TPS calculated dose ratios range between 0.962 and 1.027. The results pertain to routinely used IMRT treatment modalities in participating centres. Other modalities, commissioned but not used clinically (i.e., Eclipse and Monaco step-and-shoot and

dynamic MLC, not shown in the graph), were also included in the study, with the results having a broader range of 0.930-1.082. For the clinically used techniques, film evaluation results, using a global gamma pass rate with the criteria of 3%/3mm and 20% threshold, ranged from 90.6% to 98.2%. Results for the non-clinically used techniques ranged from 88.6% to 93.0%. Generally, the participants noted that the treatment planning exercise was demanding; it required considerable time and effort to fulfill the planning constraints.

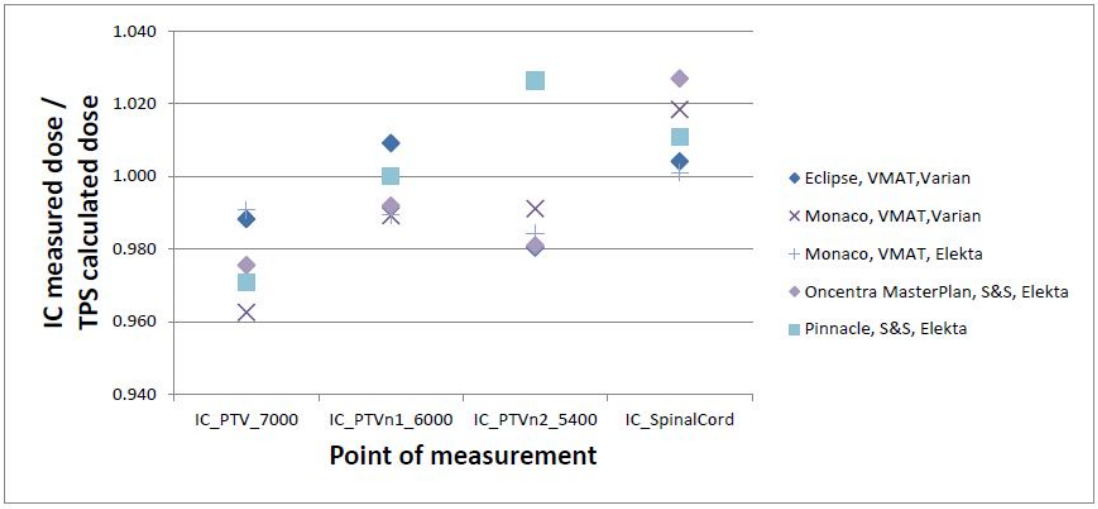

Figure 1. Ratio of ionisation chamber (IC) measurement and TPS calculations for participants in the study in three PTVs and OAR (spinal cord).

Conclusion The pilot-testing of the newly developed end-to-end on-site IMRT audit methodology using the SHANE phantom was successful. Feedback from participants helped to improve the procedures and to clarify the associated instructions. Development of the audit methodology is in its final stage with further tests on-going. Once finalized, the IMRT audit should provide additional support for radiotherapy centres in Member States in the safe use of modern IMRT techniques.

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Availability of radiotherapy in Africa: past and present of an unsolved problem

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Purpose/objective To present data on availability of megavoltage (Mv) units (cobalt machines (Co) and linacs) in Africa from 1991 to 2015 and the additional resources needed to reach full capacity, including a cost analysis.
Material and methods The list and income classification of countries were taken from the World Bank, Country and Lending Groups, 2017 fiscal year 1. Data on population, number of cancer cases per country, and number of cancer cases for each cancer site was obtained from GLOBOCAN 2012 [2]. The number of radiotherapy courses needed to treat all patients with an indication for radiotherapy was calculated using the methodology form the Collaboration for Cancer Outcomes Research and Evaluation (CCORE) [3,4]. Data on availability of radiotherapy (RT) equipment was obtained from the IAEA Directory of Radiotherapy Centres (DIRAC) [5]. For the cost analysis we used an internally produced Excel sheet with data from December 2013. 51 countries were included in the analysis. Historical data was obtained from different published data [6,7,8,9]. Most of the other variables used for the calculations were taken from the GTFRCC report [10].
Results The population in Africa is 1.07 billion, with a weighted GNI per capita of US$ 2,086, and it is calculated that 438,000 cancer cases need radiotherapy annually. Mv units were 103 in 1991 (71 Co and 32 linacs), 155 in 1998 (93 Co and 62 linacs), 277 in 2010 (88 Co and 189 linacs), 278 in 2013 (84 Co and 194 linacs), and 291 in 2015 (86 Co and 205 linacs), representing an increase of 283% in almost 25 years (fig 1). The proportion of Co units decreased from 69% to 30% in that period (fig 1).
Conclusion A total of 813 Mv units are required to treat 438,000 cancer patients needing RT. Only 149,000 can be treated with the installed capacity, which represents a coverage of 34% of the needs. Low income countries can only treat 4,800 cases, 3% of the needs.

Africa radiation oncology network (AFRONET): an IAEA pilot telemedicine project for anglophone Africa

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BACKGROUND AND CONTEXT In many low income countries, the number of existing radiotherapy centers is insufficient, equipment is often outdated, and there is a dearth of training opportunities for professionals. Many centers work in isolation with limited access to up-to-date published literature, international meetings, and expert opinion. Telemedicine can be used for closing this gap and providing best possible expert advice and patient care.

AIM The IAEA established Africa Radiation Oncology Network (AFRONET) in June 2012 as a pilot project for Anglophone African countries. The purpose of AFRONET is to strengthen the process of clinical decision-making in radiotherapy centres in Anglophone African countries.

The AFRONET project was established as a multi-disciplinary virtual tumor boards (VTB) where cancer professionals present, discuss and review challenging cancer cases. A secondary objective was to upgrade the knowledge of radiation oncology residents. It provides a unique opportunity for participating centers to present and discuss cases with experts (from within and outside Africa) both as an academic exercise, and a way to support an evidence –based management approach. STRATEGY/TACTICS AFRONET meetings are held once monthly using the WebEx platform. The agenda includes case presentations, and a presentation on pre-announced topic of common interest and relevance. Open-discussion is allowed to facilitate decision-making and/or as educa- tional exercise. After the meeting, minutes along with copies of the presentations are circulated to participants for further comments, suggestions and ready reference.

PROGRAM/POLICY PROCESS The project was intended to test the feasibility of the platform to deliver VTB in the real conditions prevailing in African countries. A feedback survey showed positive results, and it was decided to continue the project in its present form. Based on the success of the project and experience gained, such VTB are being planned for other regions (Francophone Africa, Asia-Pacific, Latin-America), and in other languages (French and Spanish). Development of a dedicated website is under consideration for promoting open-access. Furthermore, new software tools will be included in order to facilitate and support contouring and plan review exercises. Support from professional/academic bodies and other organizations is being sought to increase impact and render this endeavour more meaningful.

OUTCOMES Since June 2012 to April 2016, 44 monthly AFRONET meetings were held. The average number of participating centers per meeting was 9 (range 3-14).

A total of 121 cases (2.75 per meeting) were presented for discussion, according to table 1. Sarcoma 19 Breast 16 Genito-urinary 15 Central Nervous System 14 Gynecologic 13 Head and Neck 12 Lymphoma 7 Lung 7 Gastr-intestinal 5 Neuroendocrine tumors 4 Carcinoma Unknown Primary 3 Skin 3 Miscellamea 4

WHAT WAS LEARNED • In Anglophone African countries VTB is feasible and acceptable • Most cases present in advanced stages in young patient's age (Mean age: 34) • HIV positive cases represented 7% of the total • Access to pathology, imaging, endoscopy and specialized surgery is challenging in many African countries • Management questions discussed were not limited to radiotherapy • Participation of other allied medical disciplines (pathology, imaging) would be useful • Most professionals in Anglophone African countries work as Clinical Oncologists, delivering both radiotherapy and chemotherapy. • Some participating centers offer 2D radiotherapy only • Many patients need palliative care • Reliable internet connection remains challenging in many African countries, although use of mobile technology can address this challenge The broad exposure to a

much wider spectrum of cancers and cancer-associated conditions is of interest and potential benefit to the advisory panels too

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MRTDosimetry - Metrology for clinical implementation of dosimetry in molecular radiotherapy

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In the last few years there has been an increase in Europe in the development and use of radiopharmaceuticals for treating cancer as well as an increase in the number of molecular radiotherapy (MRT) clinical trials that are expected to start in the near future. Currently, MRT provides a valuable treatment modality to around 50 000 to 100 000 cancer patients per year in Europe, including patients whose cancer responds poorly to all other types of treatment (e.g. neuroendocrine tumours). A similar number of treatments are estimated to be given for non-cancer diseases such as hyperthyroidism and joint effusions. However, in spite of the growing acceptance that an accurate knowledge of the radiation absorbed dose to critical tissues would provide a more effective targeted use of MRT, most patient treatments still follow the historical practice of administering a nominal activity of the radiopharmaceutical with a standard activity determined on the basis of Phase I or I/II clinical trials in order to find the activity level that causes serious normal tissue damage to less than an acceptable fraction of the clinical trial population (typically 5 %). The EC Directive 2013/59/EURATOM, Article 56 states that “For all medical exposure of patients for radiotherapeutic purposes, exposures of target volumes shall be individually planned and their delivery appropriately verified taking into account that doses to non-target volumes and tissues shall be as low as reasonably achievable and consistent with the intended radiotherapeutic purpose of the exposure.”
The main objective of the European Metrology Programme for Innovation and Research (EMPIR) project MRTDosimetry is to provide metrology for clinical implementation of absorbed dose calcu- lations in Molecular Radiotherapy (MRT). The focus of this project is on clinical implementation and is strongly directed by the involvement of leading scientists at MRT clinics across Europe while building on metrology expertise and involving stakeholders.
This will be achieved by
determining branching ratios and emission probabilities for 90Y and 166Ho in order to enable improved quantitative imaging (QI) accuracy and dose estimation for these radionuclides, and to exploit new technologies in order to develop a suitable transfer instrument optimised for accuracy of measurements of the activity of MRT agents in clinics and radiopharmaceutical companies
developing 3D printing methods in order to generate a range of quasi-realistic anthropomorphic phantoms containing compartments fillable with known activities of radioactive liquid or stan- dardised sealed radioactive test sources, having a range of geometrical complexity for validation of multimodal QI or absorbed dose measurement, and estimation of the uncertainties of measurement generating multimodal images either from SPECT or PET-CT phantom measurements or Monte Carlo (MC) simulations to provide material for an open-access database of reference images to be used as reference data for commissioning and Quality Control (QC) of QI using SPECT or PET-CT
improving the accuracy and metrological traceability in the calculation of dose from time- sequences of QI measurements
determining uncertainties in relation to the full MRT dose measurement chain from a primary standard to a range of commercial and non-commercial dosimetry calculation platforms
facilitating the take up by healthcare professionals (clinical centres) and industry (scanner man- ufacturers and software developers) of the technology and measurement infrastructure developed by the project.
MRT dosimetry, as currently performed, has no traceability to primary standards of absorbed dose. Therefore there is an urgent need to achieve traceability and to validate the calculation methods used for dose. Further to this, and central to any recommendations for dosimetry methods, is knowledge of the overall uncertainty associated with any particular method. Hence, the uncertainties in relation to the full MRT dose measurement chain (i.e. from a primary standard to a dosimetry calculation platform) also need to be determined. The MRT community has an urgent need for dosimetry calibration standards, validation methods, and clear guidance on how to implement MRT dosimetry in every European clinic offering MRT. Without this, it will not be possible to comply with EC Directive 2013/59/EURATOM, Article 56, which states that individual dose planning for radiotherapy patients (including MRT) must be enforced in legislation by EU member states by 6 February 2018.
The current, main source of uncertainty in MRT dosimetry is in taking the step from dose

measurements on simple reference geometries to QI measurements of the complex and varying geometries of the activity localised in real patients, as well as activity measurements over the time of treatment. All these issues will be addressed by this project using SPECT and PET methods, through the development of 3D printed quasi-realistic anthropomorphic phantoms and by creating a database of reference images of geometries covering typical clinical situations.
The presentation will visualize the objectives and results of MRTDosimetry and invite the community to participate and share their knowledge.

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Uncertainties in measuring absorbed dose from a low-energy miniature X-ray source

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Introduction In brachytherapy, miniature low-energy X-ray sources offer a number of advantages over traditional radioactive sources. These include their ease of portability, and reduced regulatory and shielding requirements. However, the dosimetry of these devices is challenging due to their steep dose gradients, soft X-ray spectra (< 100 kV) and influence of target spectral lines. Accurate and precise knowledge of the absorbed dose would allow for better confidence in target dose delivery, tracking of dose to organs at risk and optimisation of treatment plans. A greater understanding of the delivered dose is also important for combining modalities (i.e. brachytherapy with external beam radiotherapy), and for exploring treatments with these devices in other cancer sites.
In this work, we evaluate the uncertainties in the measurement of absorbed dose to water from a commercially available miniature X-ray system, the INTRABEAM System (Carl Zeiss, Germany). The dose measurement method investigated was an air-kerma calibrated ionization chamber situated in a water phantom with the INTRABEAM.
Methodology Depth-dose rate measurements were performed with the INTRABEAM System X-ray source (XRS) using a dedicated water phantom offered by Zeiss. The self-shielded phantom includes a platform stage for mounting and positioning the XRS, and two waterproof holders for mounting a soft X-ray ionization chamber (PTW 34013 parallel plate chamber) connected to an electrometer. Charge measurements were performed at depths between 1.7 to 20 mm from the source tip.
The absorbed dose rate to water was calculated from the measured charge by two different methods: the absorbed dose formula recommended by Zeiss, and our own derived dose formalism for ionization chambers calibrated in terms of air-kerma. This dose formalism relies on a Monte Carlo (MC) calculated conversion factor, C_Q, to go from air-kerma in a reference beam to absorbed dose to water at a beam quality of interest. This conversion factor was calculated using the EGSnrc particle transport code.
The sources of uncertainty investigated in the dose measurement were:
source positioning accuracy
uncertainty in the geometry of the PTW 34013 ionization chamber in the calculation of C_Q
MC statistical uncertainty in the calculation of C_Q
The dose uncertainty associated with source positioning error was determined by calculating the percent difference in dose due to a depth shift of 0.1 mm. The uncertainty due to geometry tolerance was evaluated by calculating C_Q with the maximum and minimum chamber cavity dimensions as specified by the manufacturer. Assuming a rectangular distribution, an uncertainty was extracted from these extreme values. Lastly, the statistical uncertainty of C_Q was estimated by the standard error in the tally statistics as reported by EGSnrc. The total combined uncertainty in measured dose was estimated by adding these effects in quadrature.
Results Due to the steep dose gradients near the INTRABEAM source, the dominant source of uncertainty was determined to be in the source positioning. A positioning error of 0.1 mm led to an uncertainty of 7 % in absorbed dose at a depth of 3 mm in water. This uncertainty decreased as a function of depth to 1.4 % at 20 mm. In the calculation of C_Q, the dimensional tolerance of the PTW 34014 ionization chamber had a significant contribution to the uncertainty, ranging from 5.6 to 1.8 %. The MC statistical uncertainties were kept below 1.2 %, and could be further reduced by increasing the total number of particle histories in the simulations. The total uncertainty in measured dose was found to range from 8.9% at 3 mm, to 2.8 % at 15 mm depth in water. However, the absorbed dose as calculated using the recommended formula was shown to disagree with the results from our method by up to 14.8 %, going beyond the uncertainties investigated in this work.
Conclusion Despite all their advantages, accurate dosimetry of miniature low-energy X-ray sources remains a challenge. Steep dose gradients lead to large dose uncertainties, both from source positioning error and ionization chamber dimension variations. The results of this work show a measurement uncertainty of up to 8.9 % at 3 mm depth, which reduces with increasing distance from the source (2.8 % at 15 mm). To reduce this uncertainty further, another ionization chamber with tighter dimension tolerances could be investigated.

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Monte Carlo calculated correction factors for nine detectors in Leksell Gamma Knife Perfexion unit

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Introduction: The Leksell Gamma Knife (LGK) Perfexion unit is a radiosurgical device deliv- ering a single high dose of radiation and small radiation fields. The dosimetry of LGK should be based on the formalism for the reference dosimetry of small and nonstandard fields since the reference conditions of TG-51 or TRS-398 cannot be established on this unit. There are few published studies on reference dosimetry of the LGK Perfexion. The goal of the present study is to calculate the $k^{f_{msr},f_{ref}}_{Q_{msr},Q_0}$ factors, introduced in the small field formalism, for nine detectors used in the reference dosimetry of the LGK Perfexion using Monte Carlo simulation. This study provides a comparison of EGSnrc and PENELOPE for the calculation of $k^{f_{msr},f_{ref}}$ factors for two possible orientations of the detector.

Methodology: Nine chamber types including Exradin-A1SL, A14SL, A14, A16, IBA-CC04, CC01, PTW-31010, 31014 and 31016 were simulated in EGSnrc using the specifications provided by the manufacturers. Five of them including: Exradin-A1SL, A14, A14SL, A16 and IBA-CC04 were also modeled in PENELOPE. For the machine specific reference field (*msr*) set-up, the water phantom, the Solid Water phantom and the Elekta Acrylonitrile Butadiene Styrene (ABS) phantom were modeled as 16-cm diameter sphere made of water, Solid Water and ABS respectively. The reference point of the chamber was positioned at the center of each spherical phantom. In the ABS phantom, calculations were performed for two orientations of chambers with the chamber stem positioned parallel and perpendicular to the symmetry axis of the collimator block. The mean absorbed dose to the air cavity of chamber was calculated for both the reference set-up (D).

Results: Figure 1 shows the calculated $k^{f_{msr},f_{ref}}_{Q_{msr},Q_0}$ values for all chambers in the water phantom. The uncertainties on $k^{f_{msr},f_{ref}}_{Q_{msr},Q_0}$ factors shown in figure 1 are type A and less than 0.1% (one standard deviation). Depending on the chamber type, the difference between EGSnrc and PENELOPE data of this study varies between 0.02-0.49% in the water phantom. Given that both codes are algorithmically self-consistent with respect to their own cross sections (i.e., they pass the Fano test at the 0.2% level) and the geometries modeled were identical, this difference may be due to slight cross section differences or differences in cross section implementation details in both codes. The EGSnrc and PENELOPE calculated $k^{f_{msr},f_{ref}}_{Q_{msr},Q_0}$ values for all chambers in Solid Water and ABS phantoms are given in table 1. The difference between $k^{f_{msr},f_{ref}}_{Q_{msr},Q_0}$ values in parallel and perpendicular orientations is largest for PTW-31010 (3.5%) and 31014 (2.3%). It is smallest for Exradin-A1SL (0.4%) and A14SL (0.5%). This is due to the cavity lengths to radius ratio, which is the largest for the PTW-31010 and 31014 chambers as well as the fact that these chambers have electrodes made of Aluminum.

Conclusion: $k^{f_{msr},f_{ref}}_{Q_{msr},Q_0}$ factors introduced in the small field formalism were calculated for nine detectors and three phantoms using Monte Carlo simulation. Good agreement is observed between $k^{f_{msr},f_{ref}}_{Q_{msr},Q_0}$ values determined with EGSnrc and PENELOPE. The %RMS deviation between EGSnrc and PENELOPE calculated $k^{f_{msr},f_{ref}}_{Q_{msr},Q_0}$ values for Exradin-A1SL, A14, A14SL, A16 and IBA-CC04 chambers studies in this work was found to be 0.4%.

Dosimetric verification of the small field dose calculation using Acuros XB dose algorithm for heterogeneous media.

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The experimental determination of relative output factors presents the greatest challenge, especially for small fields with different detectors yielding measurements that exhibit a high degree of uncertainty and deviate significantly (Westermark et al., 2000). The position and configuration of jaws above tertiary collimators could change dosimetric characteristics in both SRS and IMRT. The X-Y jaw setting can significantly change the fluence of the incident beam, distribution of dose and output of small fields. Dose linearity, dose-rate dependence, pprofiles, percent-depth-dose and output factors were performed at Hôpital Chahids Mahmoudi (Tizi Ouzou, Algeria) with a Varian iX21 linear accelerator on a 6 MV photon beam in MLC and X-Y jaws shaped beams with a field size of 10 10, 6 6, 5 5, 4 4, 3 3, 2 2 and 1 1 cm2. Various detectors were chosen between the unshielded PTW p-type silicon, the PTW 31014 Pin-Point ionization chamber, the PTW semiflex 0.125 ionization chamber, the PTW microdiamond dosimeter, the PTW microLion liquide chamber and EBT3 films. The dosimetric characterization undertaken in the present study demonstrates that the diamond detector is an appropriate measurement system for small field measurements. The investigated data for the effect of jawposition away from the field edge generated by different tertiary collimating systems inferred that the opening of X-Y jaw highly influences the small field output factors. The orientation of the detectors and the position of the jaws could influence the output factors considerably in small fields. The present results were validated by studies published in the literature.

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Radiotherapy in Nepal: a view from medical physics

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In October 2016 a team comprising three Radiation Oncologists and one Medical Physicist made a visit to Kathmandu, Nepal. The purpose of the visit was to deliver a Radiotherapy Treatment Planning course to trainees, Consultant Radiation Oncologists and Physicists. Visits were made to three radiotherapy centres in Kathmandu : Bir Hospital Kathmandu (1 Co60), Kathmandu Cancer Centre(1 linac) and the Nepal Cancer Centre (1 linac). This paper provides a snapshot of the challenges facing the delivery of Radiotherapy services in Nepal. There is a shortage of trained Medical Physicists. Each of the centres visited has only one Physicist for all treatment planning and machine related activities. The staff are enthusiastic, eager to learn and, like physicists worldwide, aspire to deliver high quality treatment using the latest technologies. However, the lack of support in both human and material resources presents significant challenges to delivering safe and timely radiotherapy. This results in a large workload for individuals and limits the process and workflow to a single person environment. Due to a lack of access to healthcare most treatments are palliative and, while cancer incidence is expected to rise, Radiotherapy is not a public health priority in Nepal. The expansion of services are only taking place in the private sector. The course was delivered in two sessions to staff from the three centres. The topics covered included: the physics of photon and electron beams, 3D conformal planning and plan evaluation, planning volumes, contouring (H&N and cervical), breast planning, Quality Assurance, protocols and guidelines.

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Dosimetric verification of the small field calculation using Acuros XB dose algorithm for homogeneous and heteroge- neous media.

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In this study, the comparison of dosimetric accuracy of Acuros XB and AAA algorithms were investigated for small radiation fields incident on homogeneous and heterogeneous geometries. Small open fields of Varian iX21 linear accelerator on a 6 MV photon beam 1 1, 2 2, 3 3, 4 4 cm2 were used for this study. The fields were incident on homogeneous phantom and phantom containing lung, air, and bone inhomogeneities. Measurements were performed with micodiamond chamber for homogeneous phantom and with EBT3 Gafchromic films for heterogeneous phantoms. Using the same film batch, the net OD to dose calibration curve was obtained using 6 MV energy by delivering 0–800 cGy. Films were scanned 48 h after irradiation using an Epson 1000XL flatbed scanner. The dosimetric accuracy of Acuros XB and AAA algorithms in the presence of the inhomogeneities was compared against measured dose distributions. Open field tests in a homogeneous phantom showed good agreement between two algorithms and measurement. For Acuros XB, the minimum gamma analysis passing rates between measured and calculated dose distributions were 99.3% and 98.1% for homogeneous and inhomogeneous fields in the case of lung and bone respectively. For AAA, the minimum gamma analysis passing rates were 99.1% and 96.5% for homogeneous and inhomogeneous fields respectively for all used energies and field sizes. In the case of the air heterogeneity, the differences were larger for both calculations algorithms. Overall, when compared to measurement, the AcurosXB had better agreement than AAA. The Acuros XB calculation algorithm in the Eclipse TPS is an improvement over the existing AAA algorithm. Dose discrepancies were observed for in the presence of air inhomogeneities.

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Application of the PTW microDiamond in small field dosime- try on different accelerators: Comparative measurements and Monte Carlo calculations

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Introduction - Volume averaging and detector mass-density effects are crucial for dosimetry in radiotherapy photon beams with small field size. Although for solid state detectors as silicon diodes and diamond detectors the two effects tend to balance each other, correction factors are in general required for field output factor measurements of small beams. Recently several studies have been published on output correction factors for the PTW 60019 microDiamond (mD) and a good agreement is observed for results referring to field sizes down to 1 cm. On the contrary results for very small field sizes are sometimes controversial thus requiring further investigation. In this study output correction factors for the microDiamond are determined by Monte Carlo (MC) calculation and applied to detector measurements (OFdet) perfomed by a set of ten mD detectors, in 6 MV photon beams produced by different clinical accelerators. The study mainly aims at: i) assessing up to what extent the accelerator type and collimation choice affect the mD response; ii) evaluating the variability of the dosimetric properties among the investigated mD detectors; iii) checking the consistency of MC calculation for the mD by comparing the corrected OFdet results obtained both by the set of investigated mDs and commercial silicon diodes.

Materials and Methods - 6 MV beams from three linear accelerators were used: a Varian DHX, an Elekta Synergy and a CyberKnife M6 system. Nominal square field-sides of 100, 60, 30, 16, 10, 8 and 6 mm were obtained from the Varian and the Elekta accelerators. For the CyberKnife system, circular beams with a field diameter of 60, 30, 15, 12.5, 10, 7.5 and 5 mm were obtained by using fixed collimators. The accelerator outputs in terms of absorbed dose to water in reference conditions were determined by means of a Farmer-type ionization chamber according to the IAEA TRS 398 dosimetry protocol. For CyberKnife, a specific MC correction factor was applied to account for the use of 60 mm diameter as reference field size.

The mD detectors, provided with calibration factor in terms of absorbed dose to water for the Co-60 quality, were used in the clinical beams. Two PTW 60017 unshielded Ediodes were also used in the clinical beams for comparison. Using the Co-60 calibration factors and the measurements in the accelerator reference field, the variation of mD response from Co-60 quality to 6 MV clinical beams was evaluated. Field output factors were obtained from the ratio of the detector readings in the non-reference and the reference fields applying MC output correction factors specifically determined for each beam using the EGSnrc code.

The 6 MV beams produced by the three accelerators were independently simulated by means of the BEAMnrc code. The phase-space files obtained for all the field sizes considered for experimental measurements were used as input sources in the EGSnrc/egs_chamber code for calculating the output correction factors of the two types of detectors. To this purpose, the mD and the Ediode were modelled according to the blueprints provided by the manufacturer. The output correction factors were determined by calculating the absorbed dose in the detector sensitive volume and in a small voxel of water for the reference field and each non-reference field.

Results – Very homogeneous results were obtained by the ten mD detectors, with a standard deviations of OFdet values within 0.5% for all the considered field sizes. A response variation of about 2% was observed between the Co-60 quality and the clinical 6 MV beams with a maximum deviation among individual detectors below 1%. Preliminary results on mD output correction factors show a weak dependence on accelerator type and collimation system. Correction factors are within 2% for field sizes down to 5 mm. Larger corrections, up to about 5%, were obtained for the Ediode. Applying the MC calculated correction factors, field output factors obtained by the mDs and the Ediodes agree within 1% for the CyberKnife system and preliminary results confirm such an agreement for the Varian and the Elekta accelerators as well.

Conclusions - The results of this study show that very similar dosimetric properties are obtained from ten mD detectors, thus indicating a good reproducibility of their fabrication process. On the basis of the present results, the MC method is proved to be capable of providing reliable output correction factors for the mD detector. A set of mD output correction factors is provided, with an uncertainty estimate including contributions accounting for differences among individual detectors and beams produced with different accelerators.

End-to-end audit tests for advanced radiotherapy treatment modalities involving patient-specific 3D dosimetry phantoms

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Introduction of the study Dosimetry audits in external radiotherapy are mainly performed by national and international organizations implementing thermoluminescence dosimetry, ion- ization chamber measurements and radiochromic film dosimetry. However, the introduction of contemporary complex radiotherapy techniques with high target conformality and steep dose gradients has revealed the necessity to validate 3D spatial and dosimetric accuracy as a part of a quality assurance program. The scope of this study is to investigate the feasibility of including a real 3D relative dosimetry (as opposed to existing pseudo-3D techniques) end-to-end test on external auditing procedures. For this purpose, patient specific head phantoms (also acting as dosimeters) were developed and implemented for external auditing on Stereotactic Radiosurgery (SRS) and Intensity Modulated Radiation Therapy (IMRT) techniques. **Methodology** Two iden- tical hollow head phantoms with radiologically equivalent bone material (in terms of Hounsfield Units) were constructed by a 3D printer based on anonymized CT DICOM data of a real patient. Subsequently, the phantoms were filled with water equivalent normoxic VIPAR polymer gel 3D dosimeters. Irradiations of phantoms were performed by CyberKnife and TomoTherapy modalities implementing SRS and IMRT techniques, respectively. The irradiation plan for an SRS treatment simulating a hypothetical multiple brain metastases case consisted of 7 small targets spread all around the brain, while for the IMRT treatment the plan consisted by one centrally located target with the brain stem being the spared Organ at Risk (OAR). All steps of the radiotherapy chain of the specific cases studied were strictly followed providing an end-to-end auditing procedure. R2 relaxation rates of the irradiated-polymerized gel filled phantoms were performed by the department's MRI unit clinically employed for SRS and IMRT treatment planning. For this purpose, appropriate multi-echo pulse sequences were used that combine adequate spatial resolution (of approximately 1 1 2mm3) with acceptable scan time of the order of 30 minutes. This step also offered the attractive feature of including MR-related geometric distortions in this end-to-end audit test. A mutual information based spatial registration was performed between the two modalities (i.e., CT and MR image stacks). Relative 3D dose maps for both phantoms were obtained by normalizing the R2 relaxation rates after a background subtraction step. DICOM-RT data including contoured PTVs and OAR as well as calculated 3D dose distributions were exported from the Treatment Planning Systems (TPSs) in order to perform a detailed qualitative and quantitative 3D dose comparison between measured and calculated distributions. The aforementioned comparison involved spatial agreement, 1D profile comparison, 2D isodoses, Dose Volume Histograms (DVHs) and plan quality metrics (e.g., the minimum dose received by at least the 95% (D95) and 50% (D50) of the structure's volume). Gamma Index (GI) test was also employed with passing criteria of 5% local dose difference and 2mm distance to agreement. **Results** Although all sources of geometric uncertainties (i.e., set-up errors, MR-related geometric distortions, dose delivery geometric uncertainties and regis- tration uncertainties) were involved, 3D spatial comparison between measured and calculated dose distributions did not reveal any concerns for either modalities. All 1D profiles evaluated showed agreement within experimental uncertainties in high dose areas, while an increased gel over-response was observed in the low dose shower (<2.5 Gy) of the IMRT modality which can be attributed to the limited low-dose resolution of the polymer gel formulation. Similar remarks were deduced following the DVH comparison for both targets and OAR. In agreement with isodose comparison, GI analysis yielded failing points mainly in the low

dose regions. Regarding target coverage metrics, a maximum difference of 0.6% for the D50 metric and 2% for the D95 one was measured for the SRS irradiation, while for the IMRT application corresponding differences were both found to be less than 0.5%. **Conclusion** An end-to-end dosimetric quality assurance test, using patient specific head phantoms which involved bone equivalent inhomogeneities, was performed to validate 3D spatial and dosimetric accuracy of SRS and IMRT techniques as part of an external audit procedure. The implemented methodology is in advantage compared to common practice auditing dosimetry in terms of the ability to evaluate complicated plans involving multiple small targets in a single measurement as well as to offer the possibility of real 3D dose and DVH measurements. Despite that dose prescription or gel formulation should be further optimized to avoid gel over-response in low dose areas, the introduced methodology has also the advantage of being a time efficient 3D dosimetry test for auditing purposes of clinical modalities as the whole implementation did not burden the clinical workflow by more than four hours.

Can desktop 3D printers be used to build patient specific heterogeneous phantoms for QA purposes?

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Purpose: To investigate the feasibility of making a heterogeneous humanoid phantom from the CT DICOM image set of actual patient using a commercially available desktop 3D printer and cost effective materials that have radiological characteristics of human tissue and bone Methods and Materials: gMAX 1.5XT+ Desktop 3D printer (gCreate, NY) was used to build a 3D model reconstructed from a portion of the CT of the CIRS-Thorax phantom model 002LFC (CIRS Inc). The filament type used to print this phantom is PLA (PolyLactic Acid), which is a biodegradable plastic. The 3DSlicer (3DSlicer, MA), which is a free open source software package for visualization and image analysis, was software used to convert DICOM image CT to a Stereolithographic (STL) format, which is the format of 3D object compatible with all 3D printers The 3DSlicer can extract or segment a specific density with specific Hounsfield Unit (HU) object from any DICOM CT image set, and then this segmented object can be imported by the 3D printing software to prepare it for printing. In this study, the bone structure of the CIRS phantom was extracted from the CT image set in order to keep only the tissue medium. There are many printing parameters that control the printing process and the filament consumption as well. In order to save the amount of filaments, we have selected very low (2%) infill ratio (defined as how much a solid model should be filled-in with material when printed), this will save us time and reduce the amount of filament consumed to print this phantom. with bone and air materials were extracted from the image and replaced by empty space. Then a silicon solid gel material was used to fill the tissue equivalent areas and left for an hour to dry. The bony area (extracted) was filled with gypsum powder (hydrated calcium sulfate CaSO4 2H2O) that was mixed with water. Results: The processes of printing 4 cm thick slice of the CIRS phantom with 2% infill ratio and 100 mm/sec print speed took 3-4 hours. The infill ratio used to generate a wall that is strong enough to contain the materials added inside the phantom (i.e. silicon in tissue equivalent regions gypsum in bone equivalent regions). Figure 1 shows the axial slice of the actual CIRS phantom and that of the 3D printed one. As a last step, a CT Image set was acquired for our phantom, the HU value was ranging from -8 to 10, with relative electron density of 0.984 up to 0.998. Whereas for gypsum material, the HU value was ranging from 1070 to 1150, with relative electron density of 1.63 up to 1.72, which represents the relative electron density of cortical bones (1.65-1.7). Conclusions: The process of making a portion of heterogeneous humanoid phantom from the CT image set of every specific patient is possible and can be optimized to be cost and time effective. The air gaps showing on the CT image of the 3D printed CIRS phantom (figure 2) can be avoided by using casting liquid silicon, which will fill all the space without air bubbles and without leaking outside the 3D printed phantom. By mixing water with gypsum in different proportion, we can obtain different bone type (spongy, cortical, etc.). All difficulties faced in our first trail will be avoided in our next 3D printed phantom, especially when the casting silicon liquid arrives.

Implementation of the IAEA-TECDOC-1583 with IMRT and VMAT test plans as a dosimetric verification for AAA and Acuros XB algorithms using heterogeneous phantom

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Purpose: To compare the dosimetric performance of anisotropic analytical algorithm (AAA), Acuros XB Dose-To-Water (AXB-Dw), and Acuros XB Dose-To-Medium (AXB-Dm) in hetero- geneous phantoms following the test cases recommended by the IAEA-TECDOC-1583, a set of IMRT and VMAT test cases were also included to cover all clinically used techniques. Methods and Materials: A collection of 15 clinical test cases (T1, T2, . . . T15) were selected to cover the whole spectrum of the beams used in external radiotherapy treatments. Different beam arrangements that are clinically relevant were tested for different setups (SSD & SAD). The plans (3D-CRT, IMRT, & VMAT) were generated using Eclipse treatment planning system (ver. 13.6; Varian Medical Systems, Palo Alto, CA). The generated plans were delivered on TrueBeam linac (ver. 2.0; Varian Medical Systems, Palo Alto, CA). In this study, the plans were calculated using three photon energies (6X, 10X and 15X) using the CIRS-Thorax phantom model 002LFC (CIRS Inc) as the heterogeneous test phantom for all the test cases, shown in figure 1. The standard
0.6 cc Farmer ion chamber (IC) Model No. TN30013 (PTW, Freiburg, Germany) was placed in different media using the different inserts in the CIRS phantom, the CT images were imported to Eclipse and the IC was contoured and assigned to water equivalent material (HU=0). The dose was measured by the IC, after applying all the required correction factors to convert the reading to dose. The level of dose complexity varied gradually per test, tests 1-6 were using SSD setup, and tests 7-15 were using SAD setup. Test can be summarized as follows: T1&T2, dose evaluated for all energies in tissue (4X4 and 10X10 cm2, respectively); T3, open field (20x20 cm2) dose evaluated for all energies in bone; T4- T6, MLC static tests (T4 & T5) with different collimator angles and dynamic field-in-field MLC test (T6), dose evaluated for all energies in tissue; T7, four field box with enhanced dynamic wedge (EDW), dose evaluated for all energies in tissue; T8, oblique field with EDW, dose evaluated for all energies in tissue; T9 & T10, IMRT and VMAT plans, respectively, dose evaluated for 6X & 10X beams in tissue (PTV); T11 & T12, IMRT and VMAT plans, respectively, dose evaluated for 6X & 10X beams in bone (spine); T13-T15, 10x10 and 4x4 cm2 off-axis (T13 & T14) and oblique MLC off-axis field (T15), dose evaluated for all energies in lung. Results: For all the 15 test cases included in this study calculated and measured using different clinical beams (6, 10, and 15 X), the dose calculated by AXB, both the Dw and Dm, regardless of the medium (tissue, lung, or bone), the maximum detected percentage differences was less than 2% when comparing planned and measured dose values. Whereas for AAA the calculated dose deviated from the measured ones by -5.36% for T1 (6X beam), -5.1% & -4.73% for T3 (10X and 15X, respectively), 4.93% for T8 (6X beam), and -4.31% for T15 (10X beam). The detailed analysis of the data is presented in table (1) and figure 2. Conclusions: AXB-Dw and AXB-Dm showed better match than AAA when calculated dose values were compared with the measured ones for different media, energies, beam arrangement, and plan complexity level. AXB-Dw calculated dose mostly had less deviation from the measured dose compared to the dose obtained from the AXB-Dm, this may be due to the water assignment of the IC contour in all CTs of the CIRS phantom.

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Evaluation of dosimetric controls for patients treated with IMRT for a prostate cancer

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Purpose : The aim of this study was to analyse our pre-treatment verification of intensity modulated radiation therapy (IMRT) treatment plans for prostate cancer in order to establish a clinical action level. **Materials and methods** : Pre-treatment verification was performed for 100 fields from 20 patients treated for localised prostate cancer and 196 fields from 20 patients treated for high risk prostate cancer : Absolute measurements were performed at high dose/low gradient zone for individual beams and for all beams using flat and cylindrical phantom, respectively. Indeed, planar dose distributions were measured using electronic portal imaging devices (EPID) and ionisation chamber array. Agreement of planar (measured and calculated) dose distributions were evaluated using gamma index set at 3% and 3mm. Two gamma scaling parameters, percentage of points with a gamma value lower than 1.0 (g_%<1) and average gamma (g_avg) were calculated for each fields. **Results** : Correlation between absolute dose measurement performed for individual beams and for all beams with maximum difference of 2% and 3.6% respectively. The mean values of (g_%<1) and g avg) calculated using (EPID) and ionisation chamber array were depicted in table 1.
Conclusion : Using our findings, we set an acceptance criteria of (g_avg<0.5) and (g_%<1) better than 95% for planar dose comparison using EPID, as well as, absolute field by field dose comparison using flat phantom must be lower than 2%. This approach is fast and reliable comparatively to the use of ionisation chamber array or absolute composite measurements for pre-treatment verification.

The use of hypofractionated radiotherapy after breast conservative surgery or mastectomy in Albanian women with breast cancer

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Background: After the results of prospective randomized trials, hypofractionated external beam radiotherapy replaced the conventional dose fractionation in women with early stage breast cancer after breast-conserving surgery. However, its efficacy and toxicity after mastectomy is still under evaluation and not routinely used. The aim of this study was to demonstrate our experience in using hypofractionated radiotherapy in breast cancer women, and evaluation of acute toxicity profile. Methods and materials: Between May and October 2016, all 55 consecutive women with breast cancer referred to the Oncology Service of the University Hospital Center "Mother Theresa", received hypofractionated 3D conformal radiotherapy (40.5Gy in 15 fractions) via a Linear Accelerator of 6 and 18 MV. 23 patients were irradiated to the whole breast with an additional boost dose of 10Gy in 5fractions at the tumor bed and 32 others to the chest wall. From all treated women, 33 of them were also irradiated concomitantly to the supraclavicular fossa. The dosimetric parameters and exposure to heart and lung were analyzed. Acute toxicity assessment was done based on RTOG toxicity criteria. Results: Hypofractionated radiotherapy was well tolerated by all patients, without interruptions. The mean age was 54 years (range 29-79 years) and 64% of women were postmenopausal. Early stage disease (Stage I and II) constituted 53%, while locally advanced 47%. The majority of patients (79%) had prior chemotherapy. The maximum radiotherapy dose received was on average 42.61Gy (range 41.84-43.38Gy). The mean lung dose was 7.39Gy and V20 was 16%. The mean V25 to the heart was 3.3% for left side and 0% for right side tumors. Acute toxicities were mostly skin toxicities of grade 1 in 73% of patients and grade 2 in 18% of them. Dysphagia and hematological toxicity grade 1 was seen in 2 and 3 patients respectively. No one had grade 3 toxicity. Conclusions: Hypofractionated external beam radiotherapy seems to be a feasible treatment for women with breast cancer not only after breast conserving surgery but also after mastectomy and treatment of supraclavicular fossa. It has shown low acute toxicities. However further follow-up is needed for better evaluation of patient's outcome. Key words: Breast cancer, hypofractionation, radiotherapy, toxicity

Session 8 - Education and training **/** 308

Implementation of the Brazil's National Training Program for Radiotherapy Technicians - Preliminary results

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INTRODUCTION In Brazil, there is a shortage of radiotherapy machine in relation to the number of cancer cases to be treated. To reduce patient waiting time, the Brazilian Ministry of Health has decided to buy eighty linear accelerators to be installed throughout the country. As consequence it became urgent to train professionals to work in these Health Facilities, such as radiological oncologists, medical physicists, radiotherapy technicians, nurses. In this way, the National Radiotherapy Training was conceived by the Cancer Foundation and developed in partnership with National Cancer Institute and Universidade Estadual do Rio de Janeiro in order to supplement the training and updating courses for radiotherapy area professional. OBJECTIVE The goal is to prepare professionals qualified to work in radiotherapy. Particularly, the Professional Qualification Course for Radiotherapy Technicians (PQCRT) will train 80 radiotherapy technicians, divided in four classes. METHODOLOGY The Program's PQCRT has the characteristics: 1040 hours of activities, divided into 3 Modules: - Basic (345 h): theoretical-practical - Intermediate (350 h): internship in teletherapy - Advanced (345 h): internship in advanced teletherapy and brachytherapy Target audience: radiology technicians Duration: four group of 20 students are distributed in two years with each course lasting six months After the Basic Module, the students were sent to several institutions to have the clinical experience under the supervision of a local preceptor. The coordinator and tutor of the course follows the students' performance through detailed weekly reports on the practices. The main objective is to reinforce all concepts, treatment techniques, in-depth safety barriers, information transfer, etc. The emphasis has been on detailing the processes in teletherapy and brachytherapy: Simulation, Planning, Treatment and patient care. In addition, they need to follow and describe the local Quality Assurance program with special attention safety barriers implemented during the treatment of the patient. The Intermediate and Advanced Modules are focused in the different phases of the radiotherapy routine process and reported weekly to the Coordinator. Local visits to the training site were conducted when needed. RESULTS The PQCRT finalized the first course 19 radiotherapy technicians. Evaluating the internship with weekly reports, many students became aware to the fact that what they learned in classes were not observed the health services where they trained. They began to describe, within each topic studied, what they had learned in the Basic Module comparing with what they were following in patients' treatments. What was be perceived is that many Brazilian radiotherapy services did not follow the national norms some of them presented below: Fail to reproduce the simulation and treatment Extremely short time scheduled to attend each patient. Lack of information about simulation data in the Treatment Chart The patient is not assisted when entering or leaving treatment. Treatments with IMRT and RAPID ARC, sometimes are performed even with doubts about the procedure, endangering the quality of the treatment and the patient safety. Generally, there is one technician per turn on each machine. The technologist is the one who performs double check, not the second physicist. In brachytherapy, when X-ray equipment was under maintenance, individual planning has not been performed, and only some templates recorded in the source to release system was being used. Two scans are performed on computed tomography because the displacement is done with a ruler and redone for treatment area visualization. CONCLUSION The students finished the course with sufficient technical and physical background and can already work in the Radiotherapy Services. With the routine reports they presented, one may conclude that, there is an urgent need to implement a continuous education program to professionals already working in the radiotherapy centers. The results clearly show the lack of a comprehensive Quality Assurance Program in the services resulting in the expected positive clinical outcome and the patient safety. However, students who have successfully gone through the program, have shown sufficient proficiency to treat the patients
with the working knowledge as required by the recommended quality standards of practice.

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Beam quality index for arbitrary reference fields.

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Introduction. Readings of detectors used for reference dosimetry depend on beam energy therefore reference beam calibration requires utilization of beam quality correction factor kQ,Q0. This correction factor was calculated and published in IAEA TRS – 398 for wide range of detectors and beam quality indexes (Q). Beam quality index is used because in clinical practice it's impossible to determine beam energy spectrum and it is defined as TPR20,10(10x10 cm2). All beam quality index definitions are utilizing a reference 10x10 cm2 field which cannot be achieved in case of some special radiotherapy irradiators such as CyberKnife® and TomoTherapy® (Accuracy Inc., Sunnyvale, CA). In this work we want to compare beam quality index calculated from TPR20,10 for non reference circular field with TPR20,10 (10x10) on the same LINAC.

Materials and methods. Sauer et al. proposed to use formula (1) to calculate beam quality index from TPR20,10(s) measured in arbitrary field s.

Q=(TPR20,10(s)-b1-A1(1-e\^{}(-s/t)))/ (b2+A2(1-e\^{}(-s/t))) (1),

where b1= -0.208 0.022, b2= 1.213 0.030, A1= 0.625 0.036 A2= -0.679 0.050 t= 19.5 2.0cm. TPR20,10 for CyberKnife FFF beams and for Varian Clinac WFF beams was measured, including small beams made with BrainLab cone collimators. In spite of ionization chambers, which are widely recognized as a reference detectors for such measurements, it was decided to use diodes PTW diode E because that they shows better agreement with data from MonteCarlo simulation in small beams.

Results. According to measured data with formula (1) it was calculated beam quality index. Figure 1 shows correspondence between beam quality index and field size from whereof it was calculated for two medical accelerators, CyberKnife and Varian Clinac. Beam quality index, calculated from different field sizes shows better than 1% agreement for fields bigger than 1 cm between each other and measured data for 10 x 10 field.

Conclusion. As was shown in results calculated data was in good agreement with measured for fields bigger then 1 cm. So Sauer's method is acceptable in clinical practice. As a continues of this work we want to measure TPR20,10(s) with range of detectors, such as microchambers, diodes and diamond detector and compare beam quality index calculated from data measured with different detectors.

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Evaluation of IGRT techniques in prostate cancer patients with registration of bony anatomy and implanted gold markers

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Introduction Our IGRT protocol for external beam radiotherapy for low and intermediate-risk prostate cancer patients requires registration of internal fiducial gold markers implanted in the prostate. On the other hand, registration of images of the setup fields at high-risk prostate cancer patients are based on bony structures without using gold markers, which might require larger margin for the prostate. The aim of this study is to determine the accurate CTV-PTV margin of the prostate for patients treated without gold markers. Methodology In this retrospective study, 10 low and intermediate-risk prostate cancer patients with 3 implanted internal fiducial gold markers were selected for evaluation. Varian TrueBeam linear accelerator was used for the treatments and the patient position verifications were based on a kV-kV image pair before each fraction. In agreement with our protocol, either simultaneously integrated boost or traditional sequential irradiation technique was applied, thus 28-39 sets of image pairs were registered for each patient. The patients were treated after online matching using the gold markers. Varian Offline Review option was used by two independent observers with manual matching in 3 directions on two perpendicular images according to bony anatomy (Figure1). Vertical (VERT), longitudinal (LONG) and lateral (LAT) differences between the online and offline matched positions were calculated. Differences between skin-marked setup position and online corrected position were also read out in order to calculate margins if daily image guidance is not available. According to the van Herk equation, standard deviations of the systematic and random treatment set-up errors for all patients in all three directions were calculated. Finally, CTV-PTV margins for prostate were determined for the two scenarios. We investigated if the overall mean population errors are greater than the standard deviation of the errors. Results On average, 31 sets of kV image pairs were involved in the study. In case of daily image guidance, the systematic set-up errors were found 3 mm, 2 mm and 1 mm and the population inter-fraction random errors were 2 mm, 2 mm and 1 mm in VERT, LONG and LAT directions, respectively. The overall mean systematic errors for all patients were 0.1 mm, 0.4 mm and 0.1 mm in VERT, LONG and LAT directions, respectively. Without image guidance, the systematic and inter-fraction random errors were 4 mm, 4 mm, 2 mm and 5 mm, 3 mm, 2 mm in VERT, LONG and LAT directions, respectively. For this scenario, the overall mean systematic errors were 1 mm in VERT direction and 0 in the other two directions. These values resulted in 9 mm, 7 mm, 3 mm and 11 mm, 12 mm, 7 mm margins for the prostate in VERT, LONG and LAT directions if daily image guidance is applied or not, respectively. Currently, our clinical protocol requires 8 mm and 10 mm uniform margin in case of the above mentioned two scenarios. The standard deviation of the sampling distribution in each direction was determined and no statistically significant systematic errors were detected. Conclusion The results show that applying daily image guidance and matching the image sets according to bony structures without internal fiducials could reduce the margin with 2 mm, 5 mm and 4 mm in VERT, LONG and LAT directions. Besides, if internal fiducials are applicable and daily image guidance is available, on average an additional uniform 3 mm margin reduction is applicable. The overall mean systematic errors do not indicate any large inaccuracy in our set-up procedure, however further investigation with larger population is recommended for statistically stronger results.

UV versus MV irradiation response of 3D dosimeters

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Introduction of the study: Due to limitations in accessing clinical linear accelerators and other MV sources of radiation, preliminary assessments of radiation sensitivity and response of 3D dosimeter materials have been conducted using easily accessible and inexpensive UV irradiation devices. These results are generally not published due to their irrelevance for MV radiation therapy treatments but may be valuable for UV phototherapy quality assurance (QA) applications. This study demonstrated the differences in sensitivities of iron based radiochromic dosimeters for UV phototherapy and MV radiotherapy QA applications.

Methodology: Three iron-reduction formulations and two iron-oxidation formulations were created in-house and tested for this study. All formulations were water-based except for one iron-reduction formulation that used chloroform as the solvent and free radical source. All irradiations were conducted in cuvettes for optical readout using a spectrophotometer. Samples were exposed to UV irradiation at 365 nm in the UVA phototherapy range with four bulbs at 36 W, and MV irradiations were delivered with a Co-60 source (1.25 MeV).

Results: All of the water-based iron-reduction formulations demonstrated a linear response to UVA dose to a saturation dose with a net optical change of more than 4 cmˆ-1. One of the iron-reduction formulations demonstrated a non-linear relationship upon incorporation into a gelatin matrix while the water-based formulations maintained a linear relationship. The two water-based iron- oxidation formulations demonstrated almost no response to UVA dose with a net optical change of no more than 0.5 cmˆ-1 after exposures up to 43200 J/cmˆ2. The two iron-oxidation formulations in gelatin matrix demonstrated a linear response to UVA dose to a peak optical density followed by a non-linear decrease in response. All three iron-reduction formulations demonstrated greater response to UVA dose compared to the two iron-oxidation formulations.

Following MV irradiation, one of the iron-reduction formulations showed an immediate linear response with respect to MV dose up to 100 Gy, and two of the formulations showed a linear response delayed by at least 4 days. The two iron-oxidation formulations showed immediate linear response with respect to MV dose up to a saturation dose of around 20 Gy. Both iron-oxidation formulations demonstrated greater optical response to MV irradiations compared to the three iron-reduction formulations. The optimal formulations and representative calibration curves for both UVA and MV responses are shown in Figure 1.

Conclusion: Iron-reduction formulations are recommended for UV phototherapy QA applications, and iron- oxidation formulations are recommended for MV radiotherapy QA applications due to greater sensitivity and linear optical response for each energy range, respectively. All of the water-based formulations can easily be incorporated into gelatin and molded into the desired 3D dosimeter form.

A Delta TCP tool, based on biological parameters of tumor voxels, to quantify effectiveness of different dose distributions in tumor control

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Introduction: Tumor control is the principal aim of curative radiotherapy. For the last decades great advances have been achieved on radiotherapy for delivering highly conformal dose distributions allowing for dose escalation to the most resistant areas. In order to adequately develop strategies for the redistribution of dose (or dose boosting), the predicted effectiveness of the created dose distribution should be quantified in terms of tumor control. In 1999 Sánchez-Nieto and Nahum introduced the concept of the ΔTCP DVH-bin-based model. The aim of their work was to provide a tool to quantitatively evaluate the in[U+FB02]uence of delivering non-uniform dose to a tumor and evaluate how this affects the probability of controlling that tumor. In this work, we propose a ΔTCP voxel-based model using the patient information and the computational tools available nowadays. The developed tool evaluates the impact on the TCP of different dose distributions with the possibility of incorporating information about the oxygen distribution and number of clonogens within a voxel in the target.

Methods: The software was developed on C++ language using ITK. As input data, the following information is uploaded into the program: anatomical information of the patient (Planning CT), tumour contour (CTV), possible sub volumes within the tumour (BTV) and dose distribution of either 1 or 2 different plans, one used as a reference and the other one as a tested dose distribution. If previous information on the tumour sub volumes is available (i.e. PET-defined hypoxic area), oxygenation levels are assigned to the tumour, being expressed as oxygen histograms associated to different regions of the tumour. Oxygen-corrected radiosensitivity parameters, a(p), are calculated using literature equations and parameters for all the possible oxygen pressures within the histograms.

Using this information, the probability of controlling all the cells in every voxel, or Voxel Control Probability (VCPs), is calculated using the linear-quadratic model. This is done for both, the tested dose distribution (D_t) and for the reference dose distribution (D_r) taking into account the local a(p) and, if available, the specific clonogenic cell density. If there is only one dose distribution and the oxygenation levels available, VCPs are calculated considering one dose distribution, but making the difference if the oxygen levels are taken into account or not.

It was shown by Sánchez-Nieto and Nahum that the VCP distribution by itself was not a useful ndicator due to the lack of sensibility to changes on the dose . Because of this, using the VCPs calculated on the previous step, a ΔTCP is defined for every (ijk) voxel as the impact on the final TCP of having the tested dose (D_t) instead of the reference one (D_r)

ijk

This ΔTCP is computed according to equation (1), where $TCP(a(p)*x) is calculated as the multiplication of all the V CP sf o−patientvariabilitiesareconsideredusinga*{ox}= 0.35\, Gyˆ{-1},s_a =0.06 \,Gy*andconstanta*/b.*Homogenousnum*

\Delta TCP_{ijk}=\sum_{x=1}ˆn(g_x)TCP(\alpha(p)*x) \left[1-\frac{VCP*{ijk}(\alpha(p)*x,D_r)}{ *VCP*{ijk}(\alpha(p)_x,D_t)}\right] (1) $$

As voxel influences are sometimes too small, volume based calculations were also evaluated. In this case the (*ijk*) on the equation, will be changed to the identification of the different sub volumes.

Results: For testing the tool two different H&N cases were used. The first cases is a treatment delivered with homogeneous dose through the tumor without considering oxygenation levels. Based on FDG PET images three differently oxygenated regions were identified. The tool was used to compute the ΔTCP distribution considering as D_r a uniform dose and oxygen distributions and as D_t

the effect of the same dose distribution considering the information about the oxygenation inhomogeneity. Voxel wise, and volume wise calculations were computed. For second case included on this study 2 different dose distributions are available, a homogeneous dose and a boosted dose distribution. The tool in this case was tested to compare the impact of the boost, in both cases considering the inhomogeneity on the oxygen distribution. Results of the examples can be found on the attached table
Conclusions: A functional useful tool was created and tested; It I possible to identify the impact on the TCP of delivering inhomogeneous dose to inhomogeneously oxygenated tumors. Further improvements will be done to the tool allowing to create “megavoxel” considering regions with similar oxygenation level and delivered dose.

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Implementation of IMRT technique in treatment of prostate cancer Experience of oncology radiotherapy department of Habib Bourguiba Hospital

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Purpose : The aim of our study was to share our transition experience from 3D conformal radiotherapy to intensity modulated radiotherapy (IMRT) in treatment of prostate cancer. Patients and methods : From 2011 to 2016, 84 patients were consequently treated with curative intent for localized prostate cancer with 3D conformal radiotherapy in 46 cases (group 1) and IMRT in 38 cases (group 2). The median age was 69.5 years (50-81 years). According to D'Amico classification, 25 patients (54.3%) and 29 patients (76.3%) were at High risk in group 1 and 2 respectively. The positioning control was made by repeated portal imagery (PI). The objective was to carry out a PI per week for the 3D technique and at least 3 PI per week for the IMRT technique. Patients were followed weekly during treatment to determine the acute toxicities which were graded according to the Common Terminology Criteria for Adverse Events (CTCAE)

v.4. Results : The dose of radiation was greater or equal to 74 Gy in 19 patients (41.3%) of the first group and 31 patients (81.7%) of the second group. No patient in the first group had prophylactic lymph node radiotherapy against 20 patients (52.6%) of the 2nd group. The median number of PI during treatment was 8 (3-11) for the first group and 15,5 (6-40) for the second group. We note that for the first 7 patients treated with IMRT IP was repeated almost daily to a better control. During radiotherapy 42 patients (91.3%) in group 1 had developed urinary toxicity, including three patients with Grade 3 toxicity. In addition, 18 patients (39.1%) had gastrointestinal toxicity, mainly grade 1 (17 patients). For the second group, 36 patients (94.7%) had developed urinary toxicity grade 1 in the majority of cases (73%). Gastrointestinal toxicity was found in 18 patients (47.3%), mainly from grade 1 (14 patients). No grade 3 toxicity was noted. The difference was not significant between the 2 groups. Conclusions : The results of our study show that IMRT allows dose escalation beyond 74 Gy and prophylactic lymph nodes irradiation without increasing incidence and grade of acute toxicities with essentially the absence of acute toxicities grade 3. On the other hand the IMRT was associated with an increase of the time of occupation of the treatment machine especially in relation, with the repetition of the PI.

Adjuvant chemoradiotherapy (ACHR) for gastric cancer

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Aims & Objectives. Evaluation of ACHRT in improving local control and survival in patients with resectable gastric cancers. Materials & Methods. Between 2008-2015, 254 patients with gastric cancer (stage IB-IV), were prospectively randomly assigned to two groups. 122 patients underwent ACHRT combined with radical gastrectomy (ACHRT group) and 133 patients underwent radical gastrectomy without ACHRT (control group). From 4 to 6 weeks after radical surgery, the ACHRT was applied by using a hypofractionated radiotherapy, dose per fraction 4 Gy, 8 fractions, total dose 32 Gy in combination with daily oral administration of phtorafurum at 10-15 mg/kg followed by phthorafurum (tegafur) monochemotherapy (MCT) during 4.5 months. Results. During ACHRT, no grade IV side effects were recorded. In the course of administering the phtorafurum MCT, gastrointestinal toxicities (anorexia and nausea) of grade III (at CTCAE
v.3 scale) were observed in 5 patients (4,5%). Discontinuation of treatment was observed in 29 patients (26.1%). Grade III hematological toxicities (neutropenia and thrombocytopenia) were registered in 4 patients (3.6%). None of the patients died due to the treatment administered. We noted survival improvement in the ACHRT-treated group. Overall 5-year survival (Kaplan-Meier) for the ACHRT group was 58.6 5.4%, that for the control group was 45.4 4.9 % [p=0.0456]. 5-year disease-free survival for ACHR group was 53.8 5.6%, that for the control group was
41.6 4.9 % [p=0.0228]. Loco-regional control was higher in 3.46 times in ACHRT group [p=0.002]. Distant metastases were occurred more often in 3.05 time in group without ACHRT [p=0.041]. Conclusions. ACHRT using dose hypofractionation regimen of radiotherapy can be an useful and effective treatment approach in certain cases of gastric cancer due to improving survival rate among gastric cancer patients. The treatment results in low toxicity and good tolerability.

Session 16b - QA from simulation to delivery **/** 315

Polymer gel dosimetry: a promising 3D quality assurance tool for magnetic resonance-image guided radiotherapy

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INTRODUCTION OF THE STUDY Safe and accurate delivery of radiation therapy treat- ment has been the focus of quality assurance (QA) programs. Advances in treatment delivery require development of new quality assurance tools and ongoing evaluation of existing tools. Magnetic resonance-image guided radiotherapy (MR-IGRT) has been proposed as a new advanced treatment modality in which either a linear accelerator or cobalt sources are combined with a diagnostic MR scanner. Delineation of tumors and adjacent, critical organs is improved by superior soft tissue contrast available on MR images. MR-IGRT devices enable MR image acquisition simultaneously with treatment for an assessment of the tumor volume and its response to treatment in real time. The presence of a strong magnetic field brings new challenges to the selection of QA detectors as the response of ion chambers and electronic devises can be influenced under such conditions. MR-compatibility is key when choosing detectors. Polymer gel dosimeters are a useful tool for capturing complex 3D dose distributions with steep dose gradients. The polymerization as a response to radiation dose can be measured with an MR scanner as spin-spin relaxation rates (R2) increase linearly with increasing radiation dose. These properties make them favorable detectors for volumetric QA in MR-IGRT.

METHODOLOGY Custom-designed glass cylinders of 4 cm height and 5 cm diameter filled with polymer gels were provided by MGS Research Inc (Madison, CT). Two dosimeters were placed separately in a full phantom to assure full scatter conditions and electronic equilibrium. The center of the cylindrical volume was positioned at isocenter distance and a total dose of 5 Gy was delivered with 3x3 cm2 fields at three gantry positions with a non-clinical MR-linac pilot system (MR-Linac, Elekta AB, Stockholm). This MR-IGRT machine combines a 7 MV linear accelerator with a 1.5 T MR scanner. The first dosimeter was irradiated with the gantry at 0°, 90°, and 180°. For the second dosimeter the gantry was positioned at 0°, 270°, and 180°. Due to an asymmetric phantom design all four cardinal gantry angles weren't feasible. The entire volume of each dosimeter was imaged with a 3T GE MR scanner 24 hours after irradiation using a 2D spin echo sequence with a repetition time TR = 1000 ms and four echo times TE = 10, 20, 60, and 100 ms. R2 maps were generated for each slice and stacked into a 3D matrix. Field size and penumbra widths were evaluated on the central slices. The magnetic component of the MR-IGRT treatment delivery unit was turned off for irradiation of these dosimeters. The experiment was repeated in the same order with two more dosimeters with the magnetic field turned on.

RESULTS The irradiated volume was visible in all dosimeters. In the absence of the magnetic field, the field width measured along the central cross-plane R2 profile across the radiation field was determined to be 28 mm for the first dosimeter and 29 mm for the second. The 80/20 penumbrae widths were 5 mm at both field edges in each dosimeter. With the magnet ramped up, the field width along the central cross-plane R2 profile measured 29 mm for the third and 28 mm for the fourth dosimeter. The R2 profiles were symmetric as the two opposing beam deliveries appeared to compensate the effect of the Lorenz forces on the shape of the profile. The in-plane R2 profiles exhibited an asymmetry as a result of Lorenz forces being exerted on secondary electrons. For the third dosimeter, the deflection of the electrons resulted in a 5 mm wide penumbra where electrons were swept into the radiation field and a 4 mm wide penumbra on the opposite field edge. The difference in penumbra widths wasn't as distinct for the fourth dosimeter; both field edges were 5 mm wide. All measurements fell within the uncertainty of positioning the dosimeters without the lasers that are usually present inside a linear accelerator vault and the uncertainty of selecting the line profiles on the R2 maps (pixel size = 0.8 mm). The irradiated volume of each dosimeter was visualized well with the 3D matrix.

CONCLUSION Polymer gels show great promise to measure relative, volumetric dose distribu- tions delivered with an MR-IGRT delivery unit in a clinically relevant fashion. We have previously demonstrated that these detectors could capture and resolve steep dose gradients in the presence of a strong

magnetic field. The current study encourages further investigation of polymer gels for measuring 3D dose distributions in the presence of magnetic fields.

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Dosimetric evaluation of dose distributions delivered to an in-house developed respiratory chest phantom

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Introduction
In radiotherapy, intra-fractional movement of organs can cause important discrepancies between planned and delivered dose distributions. The magnitude of the discrepancy will depend on several factors, including the range and direction of organ movement, the margins of the planned distribution, the algorithm used for the dose calculation and the type of treatment, among others. The photon radiotherapy treatments of tumors located in the lungs are therefore especially prone to face this challenge. There are several techniques that have been clinically implemented to deal with the issue of organ motion during the delivery of the treatment; respiratory-gating is one of those.
Objectives The purpose of the study was to assess the impact of the respiratory motion on the delivered dose distributions to an in-house developed respiratory phantom by using different dosimetric systems, planning strategies and delivery conditions, including respiratory-gating.
Materials and methods The chest phantom consisted in a rigid plastic frame with two cavities simulating the lungs mounted in a platform which allowed the installation of motor powered mechanical systems that moved a simulated tumor inside the lung and a vertical platform above the surface of the phantom. The simulated tumor target was a 4 cm diameter sphere made of plastic. This was able to move in different directions (longitudinal and rotational) for user defined waveforms, as it was connected through an insert to the external mechanical system. The platform simulating the chest surface, where markers are placed to act as surrogates of tumor motion, moved vertically also following a predefined waveform. The movement of the target and the platform was computer controlled by a program developed in LabView, allowing the user to control the waveform parameters and correlation between the surface and tumor motion. Inside the tumor, it was possible to measure the delivered dose using different dosimetric systems: a photon diode, TLDs and radiochromic films. The phantom was scanned and different treatment plans were elaborated. The plans included different strategies for motion management: no motion consideration, increased margins and respiratory gating. The dose was computed using pencil beam, collapsed cone and Monte Carlo based algorithms and then delivered to the phantom in static and dynamic modes. The dose calculated by the treatment planning system for the target was compared with measurements made by the detectors inside the tumor and evaluated.
Results It was found that the abrupt changes in density between the target material and the air surrounding it made it very challenging for the calculation algorithm to reproduce the delivered dose, generating values that overestimated the dose within the target, even in static conditions. The differences were up to 8% in the center of the target, where the discrepancies between algorithms were smaller compared to the borders of the target. Therefore for the rest of the study only Monte Carlo based calculations were used, as it was the only algorithm able to reproduce the delivered dose in the experimental conditions. As expected, important differences from the prescribed dose were found if no motion compensation strategy was applied (up to 20%) for a longitudinal movement of 8 mm range. For the gated-therapy case, a very good agreement between measured and planned distributions was found (within 2%). The discrepancies for the gated case indicated that its implementation would not increase the uncertainty in the delivered dose, as the differences between measurements and calculation for a static plan (no motion management) and delivery were of the same order.
Conclusions The study confirms the importance of using an adequate dose calculation algorithm when dose calculations are performed in the presence of inhomogeneities where there are abrupt changes of electron densities. Otherwise, the dose can be overestimated for the target and underestimated in the surrounding healthy tissues, in lung tumor cases. The phantom was useful to reproduce clinically relevant conditions and to evaluate the effect of intra-fractional target motion. Its design would additionally allow for the estimation of dose uncertainties related to the implementation of other motion management techniques such as tracking and respiratory gating using only an external surrogate, such as a reflective marker or a pressure belt.

Small cell lung cancer: A retrospective study of 70 cases

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Small cell lung cancer: A retrospective study of 70 cases Background: Small-cell lung carcinoma (SCLC) is an aggressive form of lung cancer. Therapeutic strategies are chemotherapy (CT), radiotherapy (RT) and supportive care. This study aims to investigate the clinicopathologic characteristics, therapy methods and prognosis of SCLC. Methods: We conducted a retrospective study of 70 cases of SCLC collected in the department of medical oncology of Salah Azaiz institute in Tunis over a period of 6 years (2008-2013) Results: The study population comprised 66 men and 4 women. The median age was 58 years. All patients were smokers. At presentation, the vast majority of patients were symptomatic. Pathological diagnosis was obtained essentially by the performance of bronchoscopic biopsy .It revealed a lung small cell neuroendocrine carcinoma
.50[U+2105] of tumors were immunoreactive for TTF-1 , 90[U+2105] for keratin and 73[U+2105] for EMA .Tumors cells stained positively for markers of neuroendocrine differentiation including chromogranin A , synaptophysin and CD56 . The disease was metastatic in 75[U+2105] of cases. According to the VALCSG classification ,the tumor was staged as limited-stage disease in 15 cases and extensive-stage disease in 55 cases .13 patients received a curative –intent CT : 10 patients had induction CT before RT and 3 patients had concomitant radio-chemotherapy
.Etoposide with cisplatin (EP) was the used regimen. The median overall survival (OS) in the limited-stage disease group was 16 months. 81[U+2105] of patients with extensive-stage disease received palliative chemotherapy. The main regimens were EP, etoposide with carboplatin and CAV (cyclophosphamide, doxorubicin and vincristine). 17 patients received second line CT. Only 6 patients had third- line CT. A whole brain RT, thoracic RT, analgesic RT and RT of spinal cord compression were administrated in respectively 35[U+2105], 28[U+2105], 11 [U+2105] and 6[U+2105] of cases. The median OS in this group was 9.3 months .91[U+2105] of patients received morphine.30 [U+2105]of patients were oxygen dependent. Evacuative thoracentesis was performed in 24 [U+2105]of cases. The median overall survival of the study population was 10.32 months.
Conclusion: Small cell lung cancer has poor prognosis. Developing prognosis biomarkers and experimenting new agents are needed to improve outcomes.

Implementation of the brazilian national education program on radiotherapy – Professional master degree on medical physics

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The Master's degree course in Medical Physics currently in progress is a joint effort of the Cancer Foundation and the State University of Rio de Janeiro is one of the components of the National Education Program in Radiotherapy. The purpose of this program is to train, qualify and update professionals, linked to public, philanthropic or private therapy centers, which treat patients from the Brazilian Health Care System (SUS). The project is financed by the Ministry of Health through spontaneous donations from companies and individuals specifically to the National Program to Support to Cancer Oncology (PRONON). This program aims to train 21 medical physicists during the period 24 months to work in Radiotherapy. This effort is intended to help to minimize the present gap of qualified medical physicists in Brazil that will be increased after the installation of 80 new Linacs within the next 3 years in different areas of the country. The total workload of the course is of 5588 hours was divided in 635 hours of academic education and lab work and 4853 hours of experience in a clinical environment. An academic infrastructure for the development of the Project was installed and each student was awarded with a fellowship, a laptop with a treatment planning system installed and internet access to reference paper, lectures and clinical cases. This paperless Project allows a direct interaction of the students and professor with the coordination of the Project, and all exams, lab reports, homework are loaded into the managing software called Tandle (Teach and Learning). For the practical activities, several agreements were signed with major cancer centers in order to allow the students the use of their facilities and equipment for the training and work in close cooperation with the local staff. An academic staff of 37 teachers (15 PhDs, 11 Masters, 9 Bachelor's and 4 technicians) the majority from Rio de Janeiro was selected in order to cover the different topics of the program. The academic, theoretical and practical activities are distributed in eight modules with an increasing level of complexity:
Module I:
Anatomy and Physiology
Sources of Radiation
Statistics and Epidemiology
Radiation physics and Dosimetry
Nuclear Instrumentation I (Basic Principles)
Nuclear Instrumentation II (Laboratory - Practical)
Imaging Physics
Radiobiology
Nuclear Instrumentation III (Practical Applications)
Measurement Uncertainty
Physical Basis of Radiotherapy levels I and II
Module II
Physical Basis of Radiotherapy level III
Physical Bases of the TPS algorithms
Quality Control of TPS and Management Systems
Treatment Simulation
Training with the TPS with several real patient data
Treatment Planning of 2D, 3DCRT, IMRT, VMAT and SRS b.
Brachytherapy HDR
Radiological Protection
Shielding calculation of a 6 MV Photon and a HDR rooms)
Quality Assurance in Radiotherapy

The 6 remaining modules of about 15 weeks are specific to the training in the clinical environment with a workload of 60 hours/wk. The local Physicist (preceptors) Board Certified by the Brazilian Association of Medical Physics (ABFM) supervises all activities. After each module, the students return to the Cancer Foundation for a week of discussions based on their of the reports and the following week, 1 short course of 40 hours in different topics as listed below:
Dosimetry procedures and international protocols- TRS#398

Commissioning, modeling and data validation of TPS (Treatment Planning Systems)
Quality assurance in IMRT
Small field dosimetry
Safety Culture and Risk Analysis
Those courses are mandatory for Master students and open to up to 20 physicists from different parts of the country already in the field. The activities of the trainees are guided by a script previously established by the coordination, whose objective is to focus in the clinical training. The student shall elaborate reports on the performed activities, to allow the program coordination to evaluate their evolution during the training. The emphasis of the clinical training in the radiotherapy centers have been planned as follows. Clinical Module I: Dosimetry and linear accelerator quality control Clinical Module II: Treatment Planning of 2D and 3DCRT clinical cases and the respective QA. Clinical Module III: Treatment Planning of clinical cases 3DCRT, IMRT VMAT and the respective QA Clinical Module IV: Treatment Planning of clinical cases in Brachytherapy and the respective QA Clinical Module V: Treatment Planning of clinical cases involving radiosurgery, SBRT and the respective QA. Module VI A general review of the course and prepare the students to take the Board Certification Exam by the ABFM and the National Regulatory Agency. Finally, during the 24 months, the students will develop a small Project to be presented before a Committee.

Development and refinement of the canadian national system for incident reporting in radiation treatment (NSIR- RT)

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Introduction Incident reporting, investigation and learning are core elements of quality improvement in radiation treatment. A programmatic approach to learning from one's mistakes, and the free exchange of this information with others on a regional, national or international scale, has the potential to improve patient safety by preventing incident recurrence or propagation, identifying and correcting system vulnerabilities and promoting a 'just' culture of transparency and sharing.

The Canadian National System for Incident Reporting in Radiation Treatment (NSIR-RT) was developed over the last three years and is presently being refined as a collaborative initiative between the Canadian Partnership for Quality Radiotherapy (CPQR) and the Canadian Institute of Health Information (CIHI). As an alliance among the key national professional associations in the delivery of radiotherapy in Canada, the CPQR is well-placed to provide the content expertise and community-level representation needed to ensure usability and utilization. CIHI are an independent not-for-profit organization that manages Canadian health data. As such, they bring to the project their technical and data-handling expertise as well as prior experience from development of a reporting system for Canadian medication incidents.

We describe the development and refinement process for NSIR-RT and the results to date from a pilot deployment of the system.

Methodology A key objective was to make NSIR-RT relevant to all radiation treatment programs in Canada regardless of location, size or practice orientation (academic vs. community care delivery). While participation in NSIR-RT is intended to be voluntary, development and refinement of the system was structured to motivate uptake and utilization by broadly engaging the Canadian radiation treatment community at every step of development. Figure 1 provides an overview of the development and refinement process.

Development A process of community engagement and consensus-building was used to design the elements of an initial minimum data set (MDS) for pilot testing of NSIR-RT. A total of 27 participants, with pan-Canadian representation and inclusion of all three professions involved in radiation medicine, took part in a modified Delphi study in Quebec City in January 2014 during which the initial taxonomy of the system was defined. A subsequent inter-user agreement study incorporating 32 experts who classified 20 example incidents was used to glean alignment and areas for adjustment before development of the MDS. The MDS was subsequently incorporated by CIHI into a secure web-based reporting system and released as a pilot study in September 2015.

Refinement The pilot study concluded in October 2016 with a survey of users to gather feedback and suggestions for improvement. A group of expert users met in November 2016 to examine the pilot data and the feedback received. An upgrade of the system, to incorporate the changes recommended by the expert users group, as informed by the pilot survey, is currently in progress.

Results The final incident-reporting taxonomy that was used for the pilot study comprised three incident types (actual incident, near miss and reportable circumstance), six data groups (impact, discovery, patient, details, treatment delivery and investigation) and 37 data elements with predefined menu options. The incident types are defined as:

Actual incident - Any incident that reaches the patient
Near miss - An incident that was detected before reaching the patient
Reportable circumstance - A hazard that did not involve a patient but that has the potential to impact patients if not corrected
There was high agreement about the final suite of data categories, and broad alignment of these categories with the WHO-ICPS and other American and European radiation treatment incident classifications. During the pilot study, between September 2015 and October 2016, 22 radiation oncology centres (almost half of the total number) from 5 Canadian provinces reported nearly 1100 incidents to the national system. Approximately three quarters of the participating facilities provided direct descriptive feedback regarding the system.
Conclusions The Canadian NSIR-RT data standard has been implemented and tested as a pilot online, web-based incident reporting and analysis system. The pilot study is now complete following participation and feedback from almost half of the radiotherapy centres in Canada. A process of refinement has begun to implement improvements recommended by an expert user's group based on the feedback of the participants.

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International cooperation of radiation oncology in RCA Asia

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International cooperation of radiation oncology in RCA Asia Takashi Nakano,MD, PhD Professor, Radiation Oncology , Graduate School of Medicine, Gunma University Director, Heavy Ion Medical Research Center, Gunma University

The International Atomic Energy Agency (IAEA) has objective of the contribution of atomic energy to peace, health and prosperity throughout the world. For the objective, the IAEA has promoted the effective use of radiotherapy for control cancer worldwide and especially in developing countries. In Asia-pacific region, the Regional Cooperative Agreement for Research, Development and Training Related to Nuclear Science and Technology for Asia and the Pacific (RCA) established to pursue the purpose which is an intergovernmental agreement in 1972. The membership has increased from its original 10 Member States to the present number of 22 Member States in the Asia-Pacific Region. The RCA is an intergovernmental agreement in Asia-pacific region established in 1972 and the members of the RCA are 22 Member States in the region. The number of cancer patients in RCA Member States is growing rapidly and the disease has become a burden on national development. Bilateral and multi-lateral co-operation with international partners constitute an important part of the efforts by the regional countries / to develop and use their national capacity to solve cancer problems with nuclear based technology in national cancer control programs. The IAEA and the RCA play important roles in accelerating the development and application of nuclear techniques for cancer control and human welfare. IAEA/ RCA has implemented more than 30 regional projects in the fields of radiation oncology, nuclear medicine and medical physics since 1980's, and 8 radiation oncology projects have been implemented since 2000. The themes of these radiation oncology projects were brachytherapy for cervical cancer, 3D image-based radiotherapy, 3D image-guided brachytherapy, stereotactic body radiation therapy, and intensity modulated radiotherapy. Japan and I have taken the role of Project Lead Country in 7 projects of these. The purpose of these project is to improve the knowledge and skill of radiation oncology professionals through regional training courses and expert mission for national training activities to disseminate the relevant technology and knowledge to national level. Similar activities have been taken in FNCA activity of radiation oncology is also presented. FNCA is a Japan-led cooperation framework for peaceful use of nuclear technology in Asia. The cooperation consists of FNCA meetings and the project activities with the participation of Australia, Bangladesh, China, Indonesia, Kazakhstan, Korea, Malaysia, Mongolia, Philippines, Thailand and Vietnam. The 1st International Conference for Nuclear Cooperation in Asia (ICNCA) was held by the Atomic Energy Commission in March 1990 to promote cooperation in the field of nuclear energy with neighboring Asian countries more efficiently. In March 1999, it moved to a new framework, "Forum for Nuclear Cooperation in Asia" intending more effective and organized cooperation activities. Under this framework, view and information exchanges are made on the fields of Radiation Utilization Development (Industrial Utilization/ Environmental Utilization, and Healthcare Utilization), Research Reactor Utilization Development, Nuclear Safety Strengthening, and Nuclear Infrastructure Strengthening.

Under FNCA program, protocol study on standardized radiation therapy for uterine cervical cancer had been carried out since 1994. The objective of this joint clinical study is to contribute to the improvement of the radiation treatment techniques in eight Asian participant countries in accordance with the standard protocol. The standard protocol was established as the Standardized Radiotherapy Protocol for Treatment of Uterine Cervix Cancer (CERVIX-1) and its guidebook Radiation Therapy of Stage IIIB Cervical Cancer for Asians and report and guideline from the cooperative Trials was published in 2001. This guidebook is now actively used by Asian radiation oncologists and has been utilized in training courses of the IAEA to increase synergy of activities of FNCA and IAEA. A clinical trial of the accelerated hyper-fractionation radiotherapy had been implemented among the FNCA countries since January 2000 in order to further improve the treatment outcome of cervical cancers. 103 patients with cervical cancers cases have been treated and the data showed increase in local control and survival as well as decrease of side effects of the surrounding normal tissues. Two new cooperative studies started from the year 2003. One is chemo-radiotherapy (CRT) for cervical cancer and the other is CRT for nasopharyngeal cancer. In CRT for cervical cancer, superior results of survival was demonstrated in compared to CERVIX-1. In RCA Asia, regional cooperation in terms of improvement of practice of radiation oncology as well as multi-institutional clinical research have been accelerating and expanding steadily.

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Applied radiation biology and radiotherapy coordinated research projects of the International Atomic Energy Agency (IAEA)

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The Applied Radiation Biology and Radiotherapy (ARBR) Section of the Division of Human Health at the Department of Nuclear Sciences and Applications of IAEA performs a number of Coordinated Research Projects (CRPs). Radiation oncology research is represented but not limited to: (i) Randomized Phase III Clinical Trial of Stereotactic Body Radiation Therapy Versus Transarterial Chemoembolization in HCC - Hepatocellular Carcinoma (2014-2018), which was designed to demonstrate equivalence/superiority of SBRT given upfront over TACE in terms of any disease progression in previously untreated patients with HCC; (ii) Evidence-Based Assessment of Radiotherapy Demand and Quality of Radiotherapy Services (2014-2017), this project estimates the optimal and actual radiotherapy utilization (RTU) rates in developing countries using an evidence-based methodology; (iii) Radiation Therapy Planning of Non-Small Cell Lung Cancer based on PET/CT (2014-2018) was set to improve the clinical outcomes of patients with NSCLC in Member States (MS) by the use of PET/CT in radiation therapy planning; (iv) Resource Sparing Curative Radiotherapy for Locally Advanced Squamous Cell Cancer of the Head and Neck (2010-2016) is a major project to improve policies in MS concerning radiotherapy and cancer treatment for HNSCC. Radiobiological research conducted by ARBR includes biodosimetry CRP: (i) Strengthening of Biological dosimetry in IAEA Member States: Improvement of current techniques and intensification of collaboration and networking among the different institutes (2012-2016). Another important area is tissue banking research, which was addressed by CRP (ii) Safety and Optimisation of Radiation Sterilisation in Tissue Banking: Studies on Functional Properties of Irradiated Tissue Grafts (2010-2015). It is followed by the tissue engineering CRP: (iii) Instructive Surfaces and Scaffolds for Tissue Engineering Using Radiation Technology (2014-2018).

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A study on safety and efficacy of hypofractionated radiotherapy in post-operative breast cancer patients

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Introduction
FNCA (Forum for Nuclear Cooperation in Asia) is a Japan-led cooperation framework for peaceful use of nuclear technology in Asia. The cooperation consists of FNCA meetings and the project activities with the participation of Australia, Bangladesh, China, Indonesia, Kazakhstan, Korea, Malaysia, Mongolia, Philippines, Thailand and Vietnam. Radiation oncology project is one of ten projects, and conducting multicenter cooperative clinical trials on radiotherapy for common cancers in Asia have been carried out since 1994. The object of this joint group is to establish safe and effective, technically feasible and economically reasonable treatment in Asian countries. [U+3010]Objective[U+3011] We have been conducted clinical trial of hypofractionated radiotherapy for post-operative breast cancer since 2013. The aim of this protocol is to prove that hypofractionated whole breast irradiation (HF-WBI) in breast conserving thrapy (BCT) and hypofractionated post mastectomy regional radiothetapy (HF- PMRT) are as safe and as effective as conventionally fractionated radiotherapy and superior in terms of convenience. If the hypofractionated radiotherapy is equally useful for Asian patients, more patients will be able to receive radiotherapy in radiotherapy resource-poor countries. [U+3010]Methods[U+3011] The eligibility criteria for HF-WBI are patients who have undergone breast conserving surgery and have been histopathologically confirmed to have breast cancer, tumor size is either Tis, T1 or T2, undergone a lymph node dissection (including sentinel lymph node biopsy) and has been histopathologically confirmed to have 3 positive lymph nodes or less. The eligibility criteria for HF-PMRT are patients who have undergone mastectomy and have been histopathologically confirmed to have breast cancer, without positive margin, undergone a lymph node dissection (including sentinel lymph node biopsy) and has been histopathologically confirmed to have less than 8 positive lymph nodes. Patients with parasternal lympnode metastasia are excluded. Radiotherapy consisted of 2.7 Gy per fraction, 16 times, up to the total dose of 43.2 Gy to conserving breast on HF-WBI, or chest wall and supraclavicular fossa on HF-PMRT. The patients who have high grade factors, which are age less than 50, positive axillary lymph node metastasis, lymph vascular invasion, positive surgical margin are added 3 times boost irradiation to the tumor bed up to the total dose of 51.3 Gy. The accumulation number of cases was set as 200 cases in both arms. [U+3010]Results[U+3011]From February 2013 to October 2016, 184 cases of HF-WBI and 131 cases of HF-PMRT were registered. In HF-WBI arm, the median age was 50 years old (range, 24–79). The clinical stage was 0 in 21 patients (11%), 1A in 100 (54%),
1B in 2 (1%), 2A in 42 (23%), and 2B in 19 (10%), respectively. One hundred five patients with high risk factors received boost radiotherapy to tumor bed. The median treatment duration was 26 days (range, 18–54). Acute dermatitis of grade 2 or more have been observed in 30 patients (17%) and grade 2 acute subcutaneous toxicity in 6 patients (3%). In regards to the late toxicity, grade 2 lung toxicity was observed in 2 patients, grade 2 skin toxicity in 1, grade 2 subcutaneous toxicity in 1, grade 1 heart toxicity in 5, and grade 2 heart toxicity in 2. One loco-regional recurrence, 2 distant metastases and 1 breast cancer death have been observed. In HF-PMRT arm, the median age was 48 years old (range, 24–74). The clinical stage was 2A in 50 patients (38%), 2B in 50 (38%), 3A in 27 (21%), 3B in 3 (2%), and 3C in 1 (1%), respectively. The median treatment duration was 21 days (range, 19–49). Acute dermatitis of grade 2 or more have been observed in 6 patients (5%) and grade 2 acute subcutaneous toxicity has been observed in one patient (1%). Acute grade 1 heart toxicity has been observed in 15 patients (11%) and late grade 1 heart toxicity in 6 patients (5%). Three loco-regional recurrence, 7 distant metastases and 3 breast cancer deaths have been observed. [U+3010]Conclusion[U+3011]In the intermediate analysis, HF-WBI and HF-PMRT have almost the same effectiveness and safety as conventional fractionation. Additional registration and longer follow up must be needed to obtain final results.

Session 11b - Quality in Radiotherapy: various dimensions **/** 325

Quality of radiotherapy services in post-soviet countries: an IAEA survey

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Background The fall of the “iron curtain” and dissolution of the Soviet Union represented a dramatic turning point for the countries involved. In the area of radiotherapy services, it is convenient to discuss the Soviet era as opposed to the post-Soviet/ modern era. The emphasis in the Soviet Union was on providing universally available free medical care, and this appears to have been achieved to a large extent. The post-Soviet countries had inherited the Soviet Semashko system of health care but, despite its achievements, many expressed discontent with what they saw as its poor quality, inefficiency and lack of responsiveness. There have been calls for change by national authorities, but they were less clear about how to address it, especially at a time of severe fiscal constraints and lack of personnel trained in concepts of modern medicine. Methods This Project was organized as a systematic gathering of information on the present status of radiotherapy practice in countries in Eastern Europe/Central Asia. The countries included in this study were: Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Republic of Moldova, Russian Federation, Tajikistan, Ukraine and Uzbekistan. Uzbekistan provided only general data on infrastructure, but did not participate in the survey. No reliable data on Turkmenistan could be obtained. Objectives of the Project were: 1to assess the current radiotherapy infrastructure in a group of 12 post-Soviet countries, [2]to assess the quality of radiotherapy services in these countries through the use of validated quality indicators(QI), and [3]identify nonstandard radiotherapy practices. The survey collated information on the country’s radiotherapy infrastructure as well as the quality of practice in each individual RT centre. It was based on two sets of validated QIs of structure and process in radiotherapy: the Australasian Clinical Indicator Report 2004-2011, and the Italian set validated and published by Cionini et al.(R&O,2007). These sets were adapted to the practice in the region so that a few of the indicators were not used. Results The survey was sent to a total of 184 centres. 108 radiotherapy centres (59%) replied. The collection of data using the survey tool faced logistical obstacles in the Russian Federation. Of the total of 119 radiotherapy centres in the Russian Federation with available contact information, 80 acknowledged that they have received the survey, out of which 19 centres (16%) returned the requested data. Although the sample cannot be considered representative of this country, it gives an approximate idea of the realities and obstacles faced by Russian centres. From the quality of services viewpoint, the results showed that in many aspects of patient care and RT treatment chart management the indicators were up to international standards.

However, some issues in individual countries were identified. Waiting time for RT was found acceptable. 90-100% of patients sign informed consent for treatment. Most cases are discussed among various disciplines; however, these are either consecutive consultations or organized ad-hoc (“consiliums”) for difficult cases, and not well-established multidisciplinary tumour boards. Mean 42.5% of RT courses are planned using CT and the proportion of curative/palliative cases is 2.7. Only in AZB and GEO most patients are treated using an MLC. The ratio of unplanned maintenance downtime/planned maintenance in days was 3.4 for Co-60 units and 5 for LINACs (benchmark should be 1). Except for Georgia, all other countries practice mostly 2D-radiotherapy planning and delivery, but some had a significant fraction of patients treated with 3D-CRT and a few with IMRT. The mean number of fractions for curative courses was 31, for palliative 14, and overall 23 fractions/RT course. At the time of the survey, two countries lacked brachytherapy systems. Many brachytherapy units using large Co-60 sources are still in use. Split-course RT is routinely used in 9/10 countries studied. This is done to avoid toxicity and is required by the local treatment protocols in H&N, cervix, lung and prostate cancers. The naming and task profile of RT professions is different than in western countries. Training in radiation oncology tends to be much shorter and in the majority of countries not well-structured. The specialty of medical physicist is not recognized in 9/10, and the specialty of RTT is not recognized in all countries. Appropriate training programmes for medical physicists and RTTs are lacking. Conclusions Strengths and weaknesses of radiotherapy services were identified. Most countries need modernization of the RT infrastructure coupled with adequate staffing numbers and education programmes. Some radiotherapy practices are not in line with what is considered modern practice in other regions. More attention is required to the areas of quality systems and safety. Quality systems should include regular independent audits as well as the use of radiation oncology-specific quality indicators over time.

Session 10a - Breast and Cervix / 328

Multi-institutional clinical studies of chemoradiotherapy for cervical cancer among Asian countries under the framework of Forum for Nuclear Cooperation in Asia (FNCA)

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The Forum for Nuclear Cooperation in Asia is a Japan-led cooperation framework for peaceful and safe use of nuclear science and technology in Asia. Eleven Asian countries have been participating in the project. The purposes of the project are to establish safe and effective treatments for predominant cancers in Asia and to improve the treatment outcomes. Since 1995, four international clinical studies of radiotherapy and chemoradiotherapy for cervical cancer have been conducted in the project. At the first clinical study, there were many difficulties, including wide differences in the cultural and socio-economic status among countries, wide differences in cancer imaging, poor compliance with the protocol, and poor follow-up rate. With the dedicated efforts of the study group members, the recent clinical studies of chemoradiotherapy (the 3rd and 4th studies) were well-controlled, and favorable treatment outcomes were obtained from the studies.

Tuesday morning - Poster Presentations - Screen2 **/** 329

Radiotherapy in Hue: journey and effort

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With a population over 90 millions, the cancer incidence rate in Viet Nam is having more than 150,000 new cases diagnosed every year. National strategy has been implementing, including the development of breast and cervical cancer screening projects, in order to control the cancer growing trend. Initiatives on improving the mortality rate of cancer patients, like enhancing hospital's infrastructure on cancer treatment facility, allocating extra resources in training programs for medical professionals, are also in progress. Hue Central Hospital, a public regional hospital belonged to Ministry of Health located in central Vietnam providing oncology clinical services including radiotherapy to cancer patients. Oncology Center, formerly known as oncology department, was established in 1995, with just 30 beds. In the beginning, we had a Cobalt-60 radiation therapy machine which treating for about 30 cancer patients per day with 2D techniques. Over the time, the number of patients has been increasing, at peak time this machine (over 2 times of source replacement) covered the treatment for approximately 70 to 90 patients/day. Realizing the treatment overloading, and that the Cobalt-60 machine was becoming obsolete, which specially did not ensure the quality of treatment, we decided to invest a new machine. However, one problem that we had to face to was that the investment capital was limited. Although Hue Central Hospital is a public one, but then, in 2010, the government was not enough money to invest for the the upgrading. Our leaders decided to invest by the socializing model (a private company was responsible for machine installing and maintenance, hospital team was responsible for operation, 40- 60 ratio invesment income sharing). So we had got the Elekta Pricise machine for treatment.
Also in that year, the project of upgrading equipments for the oncology center was launched, with Looking back 20 years of developing cancer radiotherapy in Hue, we found a great effort of overc

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A simplified approach of measuring beam attenuation through treatment couch and immobilization devices using electronic portal imaging devices

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Introduction With the increasing concern to measure beam attenuation caused by treatment couch and immobilization devices [1, 2], the objective of this study is to propose a simple and fast method to measure beam attenuation using the current generation of clinically available amorphous silicon electronic portal imaging device (a-Si EPID) without complex procedures to convert the signal to dose. Method An aS500 EPID attached to a Varian linear accelerator (21iX) was irradiated with 100 MU using 6 MV and 600 MU/min with a distance of 150 cm between source and EPID. Exact and IGRT Varian couches were positioned at source to surface distance (SSD) 110 cm. Integrated images without and with treatment couch, belly board, and head and neck board were acquired for jaw defined fields at gantry angles of 0, 30, 60° . In addition, attenuation measurements throughthe exact couch were examined with a presence of 20 cm solid water phantom. Attenuated 2D images were assessed as the percentage differences between images without and with attenuation. The percentage of attenuation at the centre, mean and maximum of attenuated image were reported. To validate the proposed method a comparison of measurements was conducted using an ionization chamber. Results Comparisons bbetween beam attenuation measurements using an EPID and an ionization chamber agreed to within 0.1 to 1.4 (1 SD). Attenuation data are shown in Figure 1. The highest attenuation was observed with the combination of the couch and head and neck baseboard 9.8% 0.41. The attenuation through the Exact couch was more angular dependent compared to the IGRT couch. Interestingly, the magnitude of attenuation was reduced with the addition of the phantom by approximately 1.2% for a large field size 15x15 cm2, see Figure 2. Conclusion A simple tool that provides attenuation data for patient support and immobilisation devices has been demonstrated. Unlike the conventional approach, this approach is not time consuming and provides attenuation data in the center as well as the entire field. Data from this study characterised beam attenuation, and could also be useful to quantify the effect of attenuation when an EPID is used for transit dosimetry.

Session 8 – Education and Training **/** 348

IAEA Education and Training Activities in Radiotherapy

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Introduction
Radiotherapy is instrumental in achieving cancer control. In order to be effective, radiotherapy has to be delivered accurately and precisely and following comprehensive quality standards. The advances in technology have been striking in the last few years and have changed the way radiotherapy is delivered as well as its overall management. In this framework, the education and training of the different professionals working in radiotherapy is of particular importance, since competent and well trained professionals are the strongest link in the quality management chain, supporting and ensuring the safety and efficacy of radiotherapy treatments for the ultimate benefit of patients.

Methodology
The IAEA is committed to promote and support quality education and training in different scientific, technical and clinical areas of radiotherapy. This synopsis will highlight the Agency's support to education and training through publications, articles and on line material, training courses and workshops and support delivered to Member States.

Results/Content
Medical physicists play a crucial role in ensuring the customization, precision, quality, safety and effectiveness of radiotherapy treatments. They are one of the key professionals responsible for ensuring the quality and safety of the radiation treatment delivered to the patient and their role is fast changing, developing and adapting to new technologies. Despite its relevance, the medical physics profession is still facing lack of recognition in many countries, which represents a weakness in the radiotherapy chain of quality. The IAEA published the International Basic Safety Standards (BSS) defining the responsibilities of medical physicists for safety in radiation medicine and the Human Health Series No. 25, which further clarifies the role and responsibilities of the medical physicist in all sub specialties of radiation medicine. To further support harmonization worldwide, other relevant publications have been issued by the IAEA to offer guidelines to Member States in establishing postgraduate academic programmes and structured clinical training programmes, essential to prepare medical physicists for clinical practice. Comprehensive handbooks have been produced to set the theoretical basis and guidelines are constantly being prepared to support regular activities of radiotherapy medical physicists, addressing specific topics such as acceptance and commissioning procedures, as well as more general issues such as how to plan for and establish a radiotherapy department.

Radiation oncology and radiation biology are the disciplines underpinning the treatment of cancer patients with radiotherapy. The IAEA provides support in these areas with specific attention to countries where limited resources can affect the radiotherapy delivery and workflow. Several publications are available to provide guidance to Member States in these areas, together with specific material developed for radiation therapists (technologists). With the aim of overcoming the geographical barriers and providing opportunities to exchange professional knowledge and experience in radiation oncology, the IAEA developed a telemedicine pilot project in the Anglophone part of the African continent: AFRONET. Due to a limited number of radiotherapy centres and restricted number of professionals, many African countries face limited opportunities to offer professionals and residents access to international meetings, conferences and above all exchange of opinions and peer review. AFRONET provides participating centres with the opportunity to discuss clinical cases with international experts, through monthly online meetings acting like a multidisciplinary Virtual Tumour Board, thus enhancing treatment outcomes through improvement of the quality of decision making in radiotherapy.

The IAEA also directly responds to the requests of Member States, delivering customized support through the Technical Cooperation (TC) Programme. Human health, including radiotherapy, represents an important part of the relevant activities. Expert missions, workshops, training courses, long and short term fellowships are offered through this TC mechanism in support of human resource development. Promoting good radiotherapy practices, the IAEA supports the multidisciplinary

approach, strengthening all associated radiation oncology and medical physics components. Specific programmes are also developed in the area of education and training, for example for medical physics with the Joint ICTP, IAEA, University of Trieste Master in Medical Physics, which combines academic education with clinical training.

The IAEA also supports scientific research in every area of radiotherapy, through Coordinated Research Projects on topics of specific interest with the aim of expanding knowledge, strengthening research capabilities of Member States and creating scientific networks and partnerships.
Specialized online material for radiotherapy professionals is available on the IAEA Human Health Campus, a website containing topics related to human health including radiation oncology, medical physics, radiation biology and material for radiation therapists. The Human Health Campus also offers cost-free download of material such as e-learning, web based educational material and links to selected scientific articles and publications.

Conclusions

The IAEA supports the education and training of professionals working in radiotherapy. The education and training activities and materials offered to Member States cover different professional areas and offer a comprehensive multidisciplinary approach in the pursuit of quality and effectiveness for the benefit of radiotherapy patients.

Session 11b - Quality in Radiotherapy: various dimensions / 351

IAEA Experiences with QUATRO audits

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Independent external quality audits, forming part of a comprehensive QA programmes, are generally recognized as an effective way of verifying the quality of radiotherapy practices in a cancer centre. Quality audits include a range of types and levels of review, either of the entire radiotherapy process or of specific critical parts of it, such as radiotherapy dosimetry.

The IAEA has contributed to the quality of radiotherapy dosimetry across the world since 1969 when the IAEA/WHO postal dosimetry audit was first introduced. To-date over 2200 radiotherapy centres in 132 countries participated in the audits. Poor audit results were followed up to resolve dosimetry discrepancies including expert support where appropriate. The IAEA has also been requested to organize expert missions in response to problems found during the radiotherapy treatment planning process. While accurate radiation dosimetry and treatment planning are necessary conditions for quality radiotherapy, alone, they are not sufficient and the QA of the entire radiotherapy process must be taken into account. Errors and inaccuracies, which affect quality, can appear in the radiotherapy chain in several places. Given its long-time contribution to QA in radiotherapy, the IAEA started receiving numerous requests to conduct more comprehensive audits of radiotherapy clinics. In response, the Quality Assurance Team for Radiation Oncology (QUATRO) audit programme was developed in 2005.

QUATRO audits aim to help radiotherapy centres attain the best level of practice achievable in their economic circumstances. The operation of QUATRO is based on the use of three experts in the audit teams: a medical physicist, a radiation oncologist, and a radiotherapy technologist (radiotherapist or RTT). QUATRO experts have a broad experience in the field and receive specialized training in the auditing methodology. The audit process has a well-defined structure and is guided by 37 check lists that facilitate a consistent approach among the audit teams. QUATRO teams review the entire radiotherapy programme, including the organization, infrastructure, as well as clinical, medical physics and safety aspects of the radiotherapy process. It also includes reviewing the departmental professional competence, with a view for quality improvement. Auditors acknowledge strengths in radiotherapy practices and identify gaps in technology, human resources and procedures, allowing the audited centres to document areas for improvement.

To-date QUATRO has conducted 91 audits, on voluntary requests, in radiotherapy centres from the IAEA Europe Region (33 audit missions with 4 re-audits and 1 QUATRO physics audit), Asia (21 missions with 10 re-audits), Africa (9 missions) and Latin America (12 missions with 1 re-audit) supported by the IAEA Technical Cooperation Programme. Countries that have participated in QUATRO audits are shown in Figure 1.

There has been great interest in the QUATRO audits in the IAEA Europe Region. The results of 31 missions conducted in 2005-2014 in this region were analyzed in order to explore strengths and weaknesses in radiotherapy practices and to identify common issues that impact on the quality. Overall, 600 positive findings (commendations) and 759 recommendations were documented in 31 QUATRO reports. Positive comments were received on patient centredness, communications within and across disciplines, good quality facilities (except for radiotherapy equipment shortages), very good dosimetry and equipment quality control including radiation protection and safety. Recommendations were mostly issued for insufficient equipment availability and staff shortages, lacking professional development programmers, as well as shortcomings in documentation and quality management. Ten of 31 centres have been acknowledged for operating at a high level of competence (‘centres of competence’ or CC). The quantitative characteristics of CCs compared to other audited centres pertained to significant differences in the number of radiation treatment courses per professional. On average, courses per medical physicist and per RTT differed by a factor of two between CCs and other centres while the numbers of courses per radiation oncologist were quite comparable. Another distinctive characteristic of CCs was related to the availability of quality management programmes including adequate procedures and documentation, which were assessed deficient in the other centres.

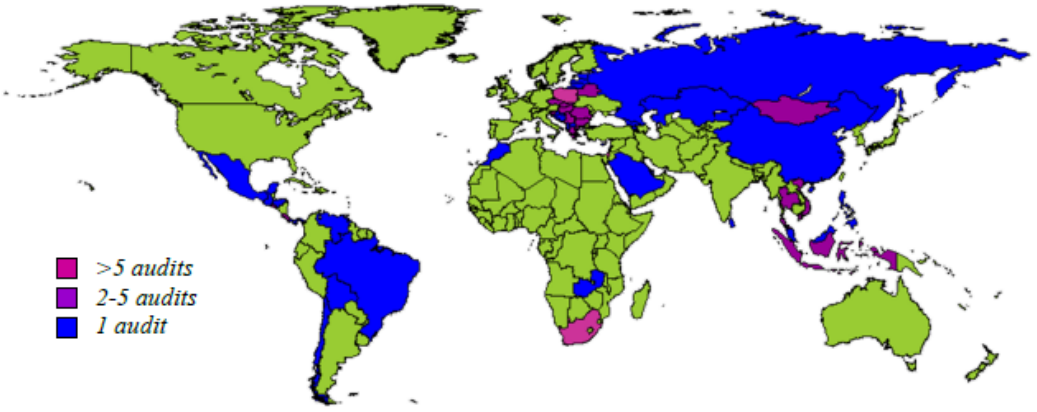

Fig. 1. Countries participating in QUATRO audits in 2005-2016.

In Latin America, the results of 12 audits were analyzed. One centre was designated 'centre of competence' by the audit team. In contrast to QUATRO findings in Europe, staff numbers in most centres were sufficient but equipment shortages were prevalent resulting in long waiting lists in over 50% centres. Local training programmes for medical physicists and RTTs were scarce. Only 4 of 12 centres offered academic education for radiation oncologists and medical physicists. There was a general absence of quality management programmes and several centres did not meet international requirements in radiation protection.

Analysis of QUATRO audit results in Asia and Africa are yet to be performed.

Overall, QUATRO audits documented various deficiencies and gaps in radiotherapy practices, identified areas for improvement and further development, as well as showed positive aspects of work and strengths in the audited centres. In general, follow-up audits recorded great progress in several centres.

QUATRO recommendations to the governmental bodies indicated that national policies for radiotherapy services are required in several countries involving significant investments in equipment and staffing infrastructure to enable the provision of radiotherapy services to the population at adequate levels.

Session 16b - QA from simulation to delivery / 352

Dosimetry audits in Radiotherapy: the IAEA perspective

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The postal dose audit service for radiotherapy dosimetry operated jointly by the IAEA and the World Health Organization (WHO) has been in existence for 48 years using mailed thermoluminescence dosimeters (TLD). Radiotherapy centres irradiate the dosimeters under well-defined conditions and return them to the IAEA for evaluation. To-date the calibration of over 12300 radiotherapy beams in 2300 hospitals in 132 countries has been audited. An important part of the process is the resolution of discrepancies in the beam calibration that have been identified in audits. The results with discrepancies are followed up by a new TLD irradiation and, in parallel, the centres are contacted to discuss the causes of discrepancies and resolve them.

Significant improvements have been observed in radiotherapy dosimetry across the world. In its early years, the IAEA/WHO postal audit programme recorded that approximately 50% audited centres had the adequate beam dosimetry. Since then, several radiotherapy centres have improved their practices, and the percentage of acceptable results has increased to more than 95% at present. However, some poor results remain uncorrected, mostly due to local problems. There exist practical limitations such as insufficient availability of qualified medical physics staff, lack of reference dosimetry systems, or obsolete radiotherapy equipment. These inadequacies have to be addressed locally, in order to improve dosimetry practices at the radiotherapy centres concerned and bring them to the level of other centres.

Overall, the IAEA/WHO audit results suggest that the calibration of high-energy X ray beams is more accurate than that of 60Co beams. There might be two reasons for inferior 60Co dosimetry: inadequate (or lack of) medical physics staffing and/or poor technical condition of some 60Co units caused by old machine age, inadequate maintenance and/or too low activity of 60Co sources. The IAEA also noted that larger centres having several radiotherapy machines generally perform better than single machine clinics. This might be related to more adequate physics infrastructure in larger centres. Also, the IAEA data suggest that regular participation in audits is associated with higher quality dosimetry than the first participation. Furthermore, the use of up-to-date ND,w based dosimetry codes of practice results in more accurate dosimetry than the use of obsolete NK or NX dosimetry protocols by some radiotherapy centres in a few countries.

For several years the IAEA has encouraged and supported the development of methodology and establishment of national TLD-based quality audit networks for radiotherapy dosimetry to extend the availability of radiotherapy dosimetry audits throughout the world. The IAEA programme of remote dosimetry audits at the national level involves several steps of audit that are implemented progressively, from simple to more complex conditions and geometries closer to the dose delivery to the patient. The recent project focuses on remote IMRT audits. It developed new methodologies for four audit steps: (i) remote verification of TPS calculation of small beam output factors (ii) dosimetry audit of MLC positional performance for IMRT using radiochromic film, (iii) film audit of single clinical IMRT field dose delivery and (iv) end-to-end dosimetry audit for IMRT techniques using TLDs and radiochromic films. New procedures and phantoms have been developed, tested through multinational pilot studies and implemented at national levels by the project participants. The first study compared TPS calculated beam outputs to the reference data sets published by the IROC-Houston QA Center. The results showed good agreement (within 1%) between the TPS output and the reference data for field sizes ≥ 4 × 4 cm2 and dose overestimation by TPSs by 2%−3% for field sizes ≤ 3 × 3 cm2. The second study evaluated MLC performance using picket fence tests and confirmed that most MLCs perform as expected. The third study compared gamma analysis techniques among centres using a single film irradiated with a complex field arrangement. Differences in gamma agreement were found, that were attributed to the differences in film scanners and calculation algorithms employed in gamma analysis software. The fourth step end-to-end IMRT audit gave generally acceptable results and highlighted the importance of accurate phantom positioning for the irradiation. The overall results of this project point to the challenges in TPS

commissioning for small field sizes, and the challenges for multicentre comparison of gamma analysis for complex dose distributions.
The IAEA end-to-end audit methodology for on-site dosimetry verification was initially developed for 3 D conformal radiotherapy in 2009. It reviewed dosimetry, imaging, treatment planning and radiotherapy dose delivery using the end-to-end approach, i.e. following the pathway similar to that of the patient. TPS calculated doses were compared with ion chamber measurements performed in the CIRS thorax phantom for a set of test cases. The audit was implemented with the IAEA assistance at national levels in 60 radiotherapy centres of eight European countries. In total, about 200 data sets (combination of TPS algorithm and beam quality) have been collected and reviewed. Discrepancies requiring interventions were discovered in about 10% of datasets. In addition, suboptimal beam modelling in TPSs occurred in several centres. This project has contributed to better understanding of the performance of TPSs and helped to resolve discrepancies related to imaging, dosimetry and treatment planning.

Currently, new end-to-end audit procedures for head and neck IMRT treatments are being developed. The objective is to review the overall clinical IMRT performance and to provide feedback to the radiotherapy centres regarding the quality of a typical clinical head and neck IMRT treatment. A dedicated anthropomorphic phantom manufactured by CIRS is used for this audit. A set of contours representing the target volumes and organs at risk are electronically imported and superimposed on the CT scans of the phantom. Dose prescriptions and normal tissue constraints are provided. Treatment plans are developed by audit participants, transferred to their linacs and the dose is delivered to the phantom. Ionization chamber measurements are done to determine the doses at specific points in the phantom and a 2D dose distribution in a coronal plane of the phantom is obtained using radiochromic films. Comparisons are made between the calculated and delivered doses. The results of a multicentre pilot study show that the IMRT audit methodology is feasible and the audits can be implemented at national levels similarly to the TPS audit.

The IAEA experiences demonstrate that quality audits improve the reference and clinical dosimetry. Audits also provide support and confidence when introducing new techniques and complex processes in radiotherapy. They strengthen the confidence of physicists and clinicians who are given assurance that their patients receive accurate doses. Due to evident benefits, all radiotherapy centres should be encouraged to participate in dosimetry audits.

Session 9b - Small field dosimetry / 355

The physics of small megavoltage photon beam dosimetry

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Developments in radiotherapy techniques led to a proliferation of the use of small megavoltage photon beams, paralleled with the development of specialized dedicated treatment units. Unfortunate accidents have occurred, however, in some radiotherapy centres that in most cases were related to the inappropriate use of dosimetry instrumentation and procedures intended for conventional radiotherapy dosimetry.

The last decade has witnessed a substantial interest in the development of dosimetry recommendations for small photon beams, a task led by a comprehensive IPEM report and followed by other organizations. Among them was a joint IAEA-AAPM project initiated in 2007 that has culminated with the publication of the international Code of Practice IAEA TRS-483. Its development included the early publication of a new dosimetry formalism for small and non-standard fields that has triggered considerable research by the scientific community. This research has led not only to the availability of different types of new data for combinations of machine and detector types, but also has contributed substantially to the enhancement of our understanding of the physics of small megavoltage photon beam dosimetry.

There are three general conditions to consider if a photon beam can be classified as small:

- There is a loss of lateral charged-particle equilibrium in a region of interest.
- There is a partial occlusion of the primary photon source by the beam collimating system, which is a machine-specific issue.
- There is a mismatch between the detector size and the field size, and perturbation effects much larger than in the case of conventional broad radiotherapy beams.

These conditions and the reasons for their incidence will be discussed in detail in the teaching lecture.

Session 11c - Toward a radical treatment of oligometasteses / 360

Imaging and treatment delivery from a medical physics perspective

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Metastatic progression is a common occurrence in patient's cancer. Published surgical series show that a subset of patients with oligometastatic disease to the lung or liver will survive for a long time with local treatments only. Data also show that only a minority of patients will present with limited number of metastases, and/or will be deemed suitable for surgical resection because of co-morbidities, cumulative toxicity of therapy or anatomical location of the tumors.

In primary and oligometastatic setting, stereotactic body radiotherapy (SBRT) has been reported to be an effective alternative therapy. It is minimally invasive, delivers high biological equivalent doses to the target, while minimizing the dose to the critical structures nearby. SBRT is also associated with high rates of local control (70>90%). The reported toxicity is generally low. The overall treatment time for SBRT is significantly shorter than conventional radiotherapy (1-2 weeks for stereotactic body radiotherapy versus 6-8 weeks for conventional radiotherapy). Therefore, this technique is uniquely suitable for patients who are not candidates for other more invasive treatment. The dose per fraction for SBRT is high. Because of this the treatment time for each fraction is long. This requires patient compliance for treatment delivery.

Oligometastatic patients are most likely to progress with additional metastases in the same organ, outside the target. Oligometastases can present themselves as single lesion in a single organ, multiple lesions in the same organ, or multiple lesions in different organs. Some of these patients with oligorecurrences might require re-irradiation in the same organ or in different organs. Therefore, in patients with multiple concurrent oligometastases and in patients with oligorecurrences following local ablative treatments some factors are essential when considering SBRT:

- Precise immobilization and localization with an accuracy between 1-3mm
- Good imaging capabilities for accurate visualization and localization of target
- Access to good CT simulation capabilities such as 4DCT for motion analysis of target and organ-at risk
- Special technology for planned treatment delivery
- Limiting dose to organs at risk to minimize toxicity
- Technologies that enable alignment of tumors, intracranial or extracranial, between planning CT and cone beam CT prior to treatment delivery
- For extracranial lesions, confirmation of oligometastatic status with careful evaluation with PET-CT within two months preceding treatment
- Knowledge of each target's as well as Organ's-at-risk (OAR's) motion and respiratory management
- Accurate target delineation
- Minimization of set-up errors
- Interpretation of composite plans
- In patients Resources to ideally use the same immobilization and respiratory management with oligo-recurrences previously treated with SBRT

This presentation will focus on the discussion of the items mentioned above.

Session 11c - Toward a radical treatment of oligometasteses / 361

Treatment delivery and clinical evidence for the treatment of oligometastases

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The term oligometastases was initially proposed by Hellman and Weischselbaum. Oligometastases describes a clinical entity where there are a limited number of metastatic sites of disease (classically <4 and in some descriptions <6). The clinical entity implies that cure may be possible because there are no viable micrometastases and that all the metastases that are present have declared themselves. Hence this is potentially an extension of locally advanced disease or an intermediate state between locoregional and widespread metastatic disease.

This talk cover the following areas:

- A brief background to oligometastases
- The various treatment options / techniques in oligometastatic cancer
- A discuss of the recommended radiotherapy dose for SABR in oligometastases
- The timing of SABR in oligometastatic disease with relationship to other treatments
- A short review of the recently completed and ongoing clinical trials in oligometastatic disease

Session 10b - Small field dosimetry / 363

Implementation of the IAEA-AAPM Code of Practice for the dosimetry of small static fields used in external beam radiotherapy

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The International Atomic Energy Agency (IAEA) and the American Association of Physicists in Medicine (AAPM) have jointly developed a new Code of Practice (CoP), IAEA TRS-483, for the dosimetry of small static photon fields. Procedures and data are provided for reference dosimetry in non-standard machine-specific reference (msr) fields. The CoP also provides consensus data on detector-specific correction factors that should be used in conjunction with measurements for relative dosimetry i.e., measurements of field output factors. This work presents the results of the initial experience of testing the recommendations of the CoP in the clinic.

Measurements were performed for the following:

i. Beam quality indices TPR20,10(10) and %dd(10)X in msr fields for a 6 MV beam based on measurements made in different field sizes in a TrueBeam™ STx machine;
ii. Polarity effect in a GammaKnife® PerfexionTM machine using 8 detectors for voltages ranging from ± 700 V to ± 10 V; and
iii. Reference and relative dosimetry (e.g., measurements of field output factors) in GammaKnife® IconTM, CyberKnife® M6TM with InciseTM MLC collimator and TrueBeam™ STx machines.

TRS483 has provided detailed recommendations on how to select detectors for such measurements. These recommendations were followed for the selection of detectors:

i. Three Exradin A16 micro chambers, one Exradin A1SL mini chamber and a Capintec PR-05P mini-chamber were used for reference dosimetry measurements in the GammaKnife Icon machine.
ii. Four PTW 30013 Farmer type ionization chambers and one Exradin A12 Farmer type ionization chamber were used for reference dosimetry measurements in the CyberKnife M6 and the TrueBeam STx machines.
iii. Seven diodes and two ionization chambers were used for relative dosimetry measurements. Field output factors were measured for 14 field sizes for the TrueBeam STx (0.5 cm x 0.5 cm to 10 cm x 10 cm), for the beams 6X, 6XFFF, 10X, and 10XFFF, and 12 cones for the CyberKnife (0.5 cm to 6.0 cm cones).

Where appropriate, results were compared with those obtained using the recommendations of the IAEA TRS-398 Code of Practice.

Beam quality indices TPR20,10(S) and %dd(10,S)x were measured for field sizes ranging from 3 cm x 3 cm to 10 cm x 10 cm and values of TPR20,10(10) and %dd(10,10)x were calculated from these measured values. These values were found to be in excellent agreement with those obtained from measurements made directly in a 10 cm x 10 cm field size.

Polarity effects were measured for eight different small volume ionization chambers in a 16 mm collimator GammaKnife beam for voltages ranging from +700 V to -700 V in steps of 50 V. All but one chamber exhibited a polarity correction factor $\leq$1.005 in the voltage regions where these chambers should be operated. For one of the PR05P chambers the polarity effect was found to be 1.007 at the recommended voltage range for the chamber.

For GammaKnife reference dosimetry, the dose rates in water determined according to TRS-483 were found to be approximately 2% higher than those determined using the recommendations of IAEA TRS-398 for the Exradin A16 ion chamber and 0.3% for the Exradin A1SL ion chamber. This

difference reflects the chamber-specific component correction factor that is included in the $k_{Q_{msr},Q_o}^{f_{msr},f_{ref}}$ correction factor of TRS-483, which is not included in TRS-398. For the determination of Dw using TRS-398, an ABS plastic-to-water scale factor of 1.1 was included in the dose calculation.

For CyberKnife reference dosimetry, the mean dose per monitor unit determined with five ionization chambers was 1.018 cGy/MU with a standard deviation of 0.4%. A maximum difference of 0.7% was observed when Dw/MU determined according to TRS-483 was compared with TRS-398.

For the reference dosimetry of the TrueBeam STx msr 6X beam, the standard deviation of the mean value of Dw/MU at zmax obtained with the four chambers was about 0.3% using both %dd(10,10)x and TPR20,10(10). The corresponding data for the 6XFFF and 10X beams were also about 0.3% for both beam quality indices, and increased up to about 0.4% for the 10XFFF beams. In general, the absorbed dose to water values using TPR20,10(10) or %dd(10,10)x were found to agree within 0.2%. When Dw/MU (TRS-483) was compared with Dw/MU (TRS-398) minor differences of around 0.1% were observed; these are consistent with the differences of the kQ values given in the two CoPs.

For the CyberKnife relative dosimetry, the mean values of the field output factors with all the detectors for all cone sizes differed from the mean values of the uncorrected measured detector readings by as much as 4% for the smallest cone size. For the TrueBeam STx, the corresponding difference was of 2% for the smallest field size of 0.5 cm x 0.5 cm. This demonstrates the importance of incorporating the field output correction factors recommended in TRS-483 for measurements of output factors, especially for very small field sizes.

From this initial testing of the implementation of TRS-483 in the clinic it is concluded that, (a) for the GammaKnife msr beam, the difference in reference dosimetry using TRS-483 or TRS-398 can be up to 2% depending on the ion chamber used; (b) for linac WFF and FFF beams, the values of Dw/MU following the new CoP are consistent within better than 1% with those obtained using TRS-398; and (c) the small field dosimetry of certain msr (reference) and most relative (using field output factors) beams can be significantly improved when the correction factors for different detectors included in TRS-483 are appropriately incorporated into their dosimetry.

Session 10b - Small field dosimetry / 364

Prescribing, Recording, and Reporting of Stereotactic Treatments with Small Photon Beams, ICRU Report 91

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On behalf of ICRU Small Field Report Committee with following members:
J. Seuntjens (co-chair), E. Lartigau (co-chair), S. Cora, G. Ding, I. El Naqa, S. Goetsch, J. Nuyttens and D. Roberge

Rapid developments in imaging and radiation-delivery technology have fueled the application of small photon beams in stereotactic radiation therapy (SRT). Historically, stereotaxy referred to the use of a three-dimensional coordinate system to localize intracranial targets (SRS) and has been more recently extensively developed in extracranial clinical situations (SBRT). SRT involves stereotactic localization techniques combined with the delivery of multiple small photon fields in a few high-dose fractions. In SRT, the therapeutic ratio is optimized through delivery of highly conformal absorbed dose distributions with steep dose fall-off ensuring optimal absorbed dose in the target volume combined with minimal normal-tissue irradiation. The ICRU Report 91 consists of seven sections and an appendix discussing clinical examples.

Section 2 of the Report concentrates on small field dosimetry. Three main features dominate the dosimetry of small beams from accelerators. Firstly, absorbed-dose distributions formed by small beams are characterized by a lack of charged-particle equilibrium over a much greater fraction of the treatment volume than for conventional radiotherapies. Secondly, in small beams, part of the source is often occluded by the collimation system, leading to beam-penumbra overlap and a drastic reduction in output fluence rate. Thirdly, the measurement of absorbed dose from small beams is highly dependent on the size and construction details of the detector used. None of the detectors currently available are ideal for small-field dosimetry. For reference dosimetry in a machine-specific reference field (msr) the IAEA-AAPM TRS-483 (2017) recommendations are recommended. In small fields, different detectors should be used to determine relative output factors and the measured data should be corrected with the type-specific $k_{Q_{clin},Q_{msr}}^{f_{clin},f_{msr}}$ correction factor data from the IAEA-AAPM TRS-483 report.

Consistent with previous ICRU Reports 50 (ICRU, 1993), 62, (ICRU, 1999), and 83, (ICRU, 2010), in Section 3, the Report recommends a strict definition of target volumes (GTV, CTV) by reviewing imaging modalities used in clinical practice. The GTV, CTV, and OAR correspond, respectively, to volumes of known (GTV), and/or suspected (CTV) tumor infiltration, and volumes of normal tissues that might be irradiated and affect the treatment prescription (OAR). In SRT there are peculiarities in how these volumes are designed and used such as, for example, cases for where there is no GTV or the GTV is not explicitly defined, but where the PTV is based directly on a CTV. Dose-volume constraints for OARs are mainly derived from retrospective clinical observations of treatment with “conventional fractionation.” This Report recommends an internal policy to record and evaluate observed toxicity within the treatment schedule, and recommends implementing or joining prospective multicenter studies.

In Section 4, dose calculation algorithms are discussed. In SRT, the accurate modeling of lateral electron scattering in heterogeneous regions with mass densities that differ significantly from water is critical. The impact of lateral electron scattering increases with increasing energy as the lateral range of the secondary electrons increases. Therefore, for treatment planning in SRT, advanced model based absorbed-dose-calculation algorithms such as Monte Carlo, or deterministic algorithms should be used to ensure that dose in tissue of heterogeneous density is accurately calculated.

Section 5 deals with the use of image guidance radiation therapy (IGRT) critical in the application of SRT where daily variations have a greater impact on the absorbed-dose distribution compared to conformal radiation therapy, due to the high gradients present in the absorbed-dose distribution delivered with small fields. Furthermore, a hypo-fractionated scheme is usually employed in SRT and, therefore, daily correction to match the original plan is required instead of averaging the dose delivery over many fractions. The verification of target location in all treatment positions during all fractions for the entire procedure should ideally be achieved at sub-millimeter precision. In order to take advantage of the steep dose gradients obtained with SRT, selection of the CTV-to-PTV margin is

critical. Continuing evaluation and management of intra-fraction target location is important since organ motion can affect the consistency between delivered dose and the planned dose in the PTV and PRVs. The likelihood of missing moving targets during the treatment could dramatically increase without IGRT.

Section 6 addresses fundamental elements of quality assurance in SRT. An institution embarking on radiation medicine using small beams should establish a comprehensive quality-assurance (QA) program. A QA program for radiation therapy using small beams consists of procedures that ensure that the prescribed absorbed-dose distribution is faithfully delivered to the intended target, and its success requires the involvement of the entire radiation-therapy professional team. For SRT treatments, execution of this mandate requires an extraordinary amount of vigilance and the Report recommends that a specialized and dedicated team be established.

Finally, in Section 7, the Report recommends a framework for prescribing, recording, and reporting stereotactic radiotherapy, and covers most of the pathologies eligible for stereotactic delivery (malignant and non-malignant). For dose reporting, the Report recommends the metrics:

1. D50 %, PTV median absorbed dose. As this Report recommends a CTV be defined for each case, the D50 % can be also reported for the CTV.
2. The SRT near-maximum dose, Dnear-max. For PTV volumes V larger than or equal to 2 cm3 the near-max volume represents 2 % of the PTV volume; for a PTV volume V of less than 2 cm3, near-max is an absolute volume of 35 mm3, in which case D35 mm is reported.
3. The SRT near-minimum dose, Dnear-min. For PTV volumes V larger than or equal to 2 cm3 the near-min volume represents 2 % of the PTV volume; for PTV volumes V of less than 2 cm3, near-min is an absolute volume of 35 mm3, in which case $D_{V-35\,\mathrm{mm}^3}$ is reported.

Session 19b - Telemedicine / 376

TELESYNERGY®

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Background: In the emerging era of telemedicine, the engineers and scientists at the Center for Information Technology (CIT)* of the National Institutes of Health created a unique system, TELESYNERGY®, to enable secure, highly sophisticated collaboration for cancer research. The Radiation Oncology Branch and the Radiation Research Program (RRP) of the National Cancer Institute were among the early and sustained users of this unique system. Among the successes are its uses in the very high technology environment of the NCI-All Ireland Cancer Consortium and the RRP's Cancer Disparities Research Partnership (CDRP) program. The system and technology have evolved along with the rapid changes in information technology and global interconnectivity so that it is appropriate to consider this program as a key infrastructure component of global cancer care and research.

Features: Among the key features is the ability to do synchronized viewing of high resolution images among collaborators. This helps meet the need for expertise in pathology, diagnostic imaging and radiation therapy treatment planning and delivery. Synchronized viewing allows for teleconference participants to individually manipulate images in order to point out areas of interest on images. This provides a "same room" experience to enhance education, training and mentoring. That "telepresence" feature and the emphasis on image quality provide features not available on other commonly used systems. There are a range of systems in use; benefits to TELESYNERGY® include:

- Interoperability with a variety of environments
    - Can be integrated with existing systems and databases
    - System consists of a Linux computer and a switch to connect devices
- Fully HIPAA compliant
- Affordable and flexible
- Minimum maintenance
    - No operators or technicians needed except for initial setup and installation
- Images viewable in multiple locations and on multiple devices
    - With specialized equipment, images can also be adjusted by collaborators

Future: Access to TELESYNERGY® is available from the NIH which provides support and ongoing development to adapt to the rapidly changing telemedicine and telecommunications environments. Further progress and innovation are based on collaboration between the NCI RRP and the Open Health Systems Laboratory*

*Notes:

- Presented on behalf of Kenneth Kempner, Biomedical Imaging and Visualization Section, Center for Information Technology, NIH (https://oir.cit.nih.gov/node/32) and Anil Srivastava and Amar Bhat, Open Health Systems Laboratory, Rockville, MD (www.ohsl.us).
- Views expressed are those of the presenter.
- No endorsement by NCI, NIH, ASPR, DHHS or any U.S. Government agencies has been given or inferred

Session 22a - Translational Radiation Biology / 382

Radiation Related Effects on the Heart (RRHD)

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For many decades, the heart was regarded as a radiation-resistant organ. This postulate was based on the fact that cardiomyocytes are post-mitotic and hence radiation tolerant cells, together with observations that under “normal” conditions, the proliferative activity of endothelial- and connective tissue cells is very low.

This view started to change slowly since the 1970s when reports on RRHD in long-term cancer survivors became available. Much of the data referred to survivors of Hodgkin’s lymphoma who had received “mantle field irradiation”, with local heart doses up to 40 Gy, as part of their cancer treatment, and to breast cancer survivors treated with radiotherapy after mastectomy. Early clinical data on late effects of thoracic radiotherapy suggested pericarditis as the only severe symptom. Later studies also report on radiation-related damage to other cardiac structures.

More recently, data from clinical studies with long term surviving radiotherapy patients and epidemiological studies on A-bomb survivors already showed long-term adverse effects on the heart at much lower thorax doses (doses less than 2 Gy) than previously expected. A striking example was the observation that patients with left-sided breast cancer had significantly higher risk of cardiac complications later in life than right-sided breast cancer patients.

It has now been recognized that the potential adverse effects of cardiac exposure to ionizing radiation are numerous and can include not only pericarditis but also, coronary artery disease (CAD), cardiomyopathy, valvular disease and conduction abnormalities. The severity of the effects appear to be related to radiation dose, exposed volume and dose-distribution within the heart. The manifestation of effects may be variable, ranging from subclinical abnormalities detected only following special screening tests, impairment of cardiac pump function up to lethal clinical events.

Animal models have long been used to understand the mechanisms underlying the development of RRHD. Until the 1970s, only a few papers on RRHD in preclinical models were published. Stewart and Fajardo were among the first investigators describing in detail the clinical symptoms and pathological changes after local heart irradiation using New Zealand rabbits as a model. In the 1980s and 1990s, a substantial number of investigations from different research groups on the effect of local cardiac irradiation, mainly using rodent models, became available. These studies highly improved the knowledge on the pathological and functional changes after selective exposure of the heart (and some of the surrounding lung tissue) to moderate and high doses of radiation. Large animal models were hardly used. Mouse models of RRHD were only described during recent years. Recently, functional endpoints are increasingly assessed with modern, high-precision imaging techniques, whereas molecular techniques and omics together with more “classic” techniques are used to elucidate potential mechanisms in RRHD.

Recent studies are aiming on:

The aetiology of radiation related heart disease (RRHD): (pericarditis, myocardial fibrosis/infarction, conduction defects, coronary artery disease and valvular insufficiency): early and late radiation-induced gene-expression and molecular alterations could explain the aetiology of the different aspects of RRHD. From the yet available data no “valid” conclusions can be drawn regarding gene expression and later occurring damage to cardiac structures.

A specific point of interest is the pathogenesis of early and late alterations in the micro-circulation of the heart and the role of radiation in the development of atherosclerosis in damaged vessels (CARDIORISK project; between 2008 and 2011): For this purpose genetically manipulated mice (ApoE (-/-) knockout mice), showing elevated serum cholesterol levels, were used. From these studies the following conclusions were drawn: (1) radiation at low doses does not per se induce atherosclerotic changes in arteries, (2) inflammation does not play an important role in radiation-induced cardiovascular disease (CVD), (3) no apparent relation between observed reduction in vascular density and changes in cardiac function.

Role of compensatory mechanisms in RRHD: Nervous system response; upregulation of adrenergic receptor densities and reduced norepinephrine (NE) concentrations in myocardial tissues; Renin-angiotensin system (RAS) (upregulation of mediators of RAS - increased Angiotensin II and aldosterone in myocardial tissue); Cardiac Natriuretic peptide hormones. Several studies show a relation between the radiation dose, and synthesis- and circulating levels of natriuretic peptides. It has been suggested that these peptides might be used as marker for RRHD, however, serum levels of these peptides will not give information on the type of damage.

Modulation of (late) radiation response: using (1) radio-protective drugs (such as Ethyol); (2) anti-fibrotic therapies (Pentoxifylline; TGF-beta antagonists); (3) ACE-inhibition (captopril); (4) anti-inflammatory strategies (early administration of dexamethasone, antiplatelet aspirin and clopidogrel). Combinations of these drugs or newly developed drugs could be effective, however, timing when to start with the treatment, which combination and the duration of the treatment is still a question..

It can be concluded that recent experimental models of local heart irradiation provided a deep insight into molecular alterations that could explain the aetiology of RRHD. Modifiers of endothelial injury, TGF-β, RAS, cardiac sensory nerves, and the endothelin system may potentially attenuate “certain” manifestations of RRHD. Nevertheless, many mechanisms of this disease may still be unknown. More research is needed to elucidate the exact mechanism of damage starting from the immediate effects after exposure and following the consequences throughout lifespan.

Session 21 - Quality and safety / 445

What more do we need to do in radiotherapy safety?

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First, we need to get the message across that radiotherapy is not as safe or of as high quality as it could be. All of us in the radiotherapy community have an obligation to our patients to acquaint ourselves with the growing body of knowledge in the area of radiotherapy safety and to implement those tools and strategies which are likely to prove most effective in our own local environments.

As part of this growing body of knowledge there have been many recommendations made by expert panels over recent years. In this presentation we will distil many of these recommendations down to those most frequently cited as being important for patient safety. The twelve most cited issues from 7 seminal documents are staffing/skills mix, training, documentation, learning from incidents, communication/questioning, check lists, QC/PM, dosimetric audit, accreditation, minimizing interruptions, prospective risk assessment and safety culture1. Thus, to make radiotherapy safer we need to be cognizant of these recommendations and consider their relevance to our own particular clinical operations. A previous study2 has suggested which of these issues are likely to be the most important in the context of Low and Middle Income countries. We will briefly estimate the possible resource implications for institution of each of these 12 factors strongly implicated in patient safety and suggest that many of them entail only very small budgetary impacts in terms of both capital and human resources.

However, budgets in all jurisdictions are necessarily restricted. Harnessing the power of the Web is an approach to enhancing quality and safety in radiotherapy with minimal if any cost to the user. Most of this presentation will comprise descriptions of 2 free, web-based tools specifically designed and developed to aid radiotherapy specialists enhance the quality and safety of their practice.

The AAPM's Safety Profile Assessment is freely available on the AAPM's website (spa.aapm.org). You don't even have to be a member of the AAPM to use this tool. Best completed by the multidisciplinary radiotherapy team, the tool allows you to self-assess the performance of your clinic against 92 dimensions. Your assessment is completely confidential and cannot be accessed by anyone other than your clinic's lead on the project who will have the electronic key to the clinic's data. The tool allows you to benchmark the performance of your clinic against others in the database (anonymously, of course) and monitor improvement over time. To assist with quality and safety enhancement, the tool will output a Quality Improvement Log with which you can track progress in the areas of safety chosen by you for action on the basis of your experience with the Safety Profile Assessment tool.

The second freely available resource is the IAEA's eLearning course on Quality and Safety in Radiotherapy (http://elearning.iaea.org/m2/course/view.php?id=392
). The course consists of 12 modules each with 3 or 4 sections. After providing an introduction to the topic of quality and safety in radiotherapy the course then progresses to discussions of such key topics as Root Cause Analysis, Incident Learning, Failure Modes and Effects Analysis and Fault Tree Analysis. Examples based on reported incidents are used to emphasize the relevance of such error management strategies to the modern radiotherapy clinic. Each module is accompanied by a short quiz and a Certificate of Completion can be awarded once all the quizzes have been completed. The course has been designed to benefit both seasoned practitioners as well as students and trainees. A time commitment in the region of 6 hours is required to complete the course.

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Session 25c - Clinical Research in Radiation Oncology / 456

Challenges in LMICs

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1 Professor, Department of Radiation Oncology,Tata Memorial Hospital, Mumbai, India

Background: Clinical research has an unequivocal role in improving treatment outcomes in cancer patients. International collaboration in clinical research not only allows faster recruitment of participants in large trials but also makes the trial more pragmatic. Collaborative research provides platform to introduce newer and effective treatment strategies quickly and smoothly in routine clinical practice in all participating countries. However, there are many challenges that are faced while conducting collaborative clinical research in Low and middle income countries (LMICs).

The cancer burden, types of cancer, stages at presentation in LMICs are different from High income countries (HICs) (1). LMICs form a heterogeneous population and clinical research in LMICs is posed by number of financial/logistic, ethical, scientific and regulatory challenges. Lack of infrastructure, paucity of trained human resources and expertise etc. form important barriers for conducting clinical trials in LMICs (2). There is also a need for financial and logistic support (Central as well as institutional) from both Governmental and Non-governmental sources especially for academic clinical trials (3). Data Safety and Monitoring Board (DSMB), Regulatory Authorities (RA) and Institutional Review Boards (IRB) etc. play a key role in regulation of clinical research but may be lacking or inefficient in many LMICs. In the recent past, rapid amendments in regulations at frequent intervals related to patient rights, compensation, and timelines in India have resulted in loss of enthusiasm for both the investigator-initiated and industry-sponsored trials (4). Lack of time for research, competing priorities and procedures for competent authorities are considered as major barriers among investigators (5). Cultural and social differences lead to additional logistic and ethical concerns in process of consenting, design and implementation of research protocols. Transforming trial results in to benefits (Post trial benefits) to the study population belonging to LMICs is also a major challenge.

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Session 9a - From GTV to PTV / 479

Revisiting ICRU volume definitions

Author(s): ROSENBLATT, Eduardo[1]

Introduction

The Applied Radiation Biology and Radiotherapy (ARBR) Section of the IAEA considers three-dimensional conformal radiotherapy (3D-CRT) as the standard technique for curative radiotherapy in all regions. The introduction and expansion of 3D-CRT in the 1980s brought with it the need to standardize the way radiotherapy was prescribed to tumour volumes, how these volumes were defined as targets or organs at risk, in summary; the need to speak a common language. The subsequent development and adoption of more sophisticated 3D techniques (IMRT, IGRT, SRT, SBRT) has magnified the need for volume definitions and contouring standards.
In modern radiotherapy, volumes need to be defined and then contoured. Volume definition is a clinical decision, in which the radiation oncologist makes a judgement on which volumes need be irradiated to which dose levels, based on the type of tumour and its clinically evident regional metastasis or potential metastatic routes. In a second stage, these volumes are then contoured or delineated.

The following volume definitions are based on three ICRU reports dealing with EBRT; ICRU Reports-50 (1993), -62 (1999) and -83 (2010). ICRU definitions are offered for the purpose of promoting conformity among radiotherapy centres when reporting their doses and comparing their treatment results. No specific dose prescription recommendations are made.

EXTERNAL BEAM RADIOTHERAPY
GTV – The Gross Tumour Volume is the gross palpable or visible/demonstrable extent and location of malignant growth.
CTV – The Clinical Target Volume is a tissue volume that contains a demonstrable GTV and/or subclinical/microscopic malignant disease which has to be eliminated.
PTV – The Planning Target Volume is a geometrical concept, and it is defined to select appropriate beam sizes and beam arrangements, taking into consideration the net effect of all the possible geometrical variations, in order to ensure that the prescribed dose is actually absorbed in the CTV. The PTV is thus a static, geometrical concept used for treatment planning.
TV – The Treated Volume is the volume enclosed by an isodose surface, selected and specified by the radiation oncologist as being appropriate to achieve the purpose of treatment (cure or palliation).
IV – The Irradiated Volume is the tissue volume which receives a dose that is considered significant in relation to normal tissue tolerance.
IM – The Internal Margin is a margin added to the CTV to compensate for expected physiologic movements and variations in size, shape and position of the CTV during therapy.
ITV – The Internal Target Volume is the volume that includes the CTV plus the IM.
OAR – Organs-at-Risk are normal tissues whose radiation sensitivity may significantly influence treatment planning and/or the prescribed dose.

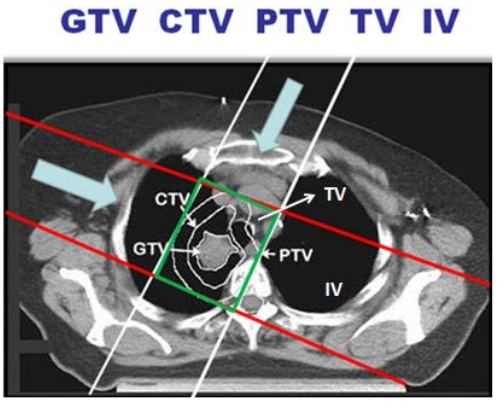

Fig 1.
The image shows in one plane, the various volumes defined in ICRU reports with the example of a lung tumour; GTV, CTV, PTV, TV and IV.

BRACHYTHERAPY

The comprehensive work done by the GEC-ESTRO group on 3D image-based brachytherapy planning is reflected in the recently published ICRU Report-89 "Prescribing, Recording and Reporting Brachytherapy for cancer of the Cervix." Here, the GTV is defined at the time of initial diagnosis (GTVinit) but also as a new GTV following an initial chemo-radiotherapy response (GTVres) that is, at the time of brachytherapy.

GTVinit – The Initial GTV represents the GTV at the time of initial diagnosis.

GTVres – Is the Residual GTV following initial therapy (at the time of brachytherapy).

CTV_{HR} – The High-risk CTV is defined as the CTV that includes the GTV, the whole cervix, and adjacent residual pathologic tissue, if present.

CTV_{IR} – The Intermediate-risk CTV represents the GTVinit as superimposed on the topography at the time of brachytherapy and a margin; that is, the CTV_{HR} and margins as appropriate.

CTV_{LR} – The Low-risk CTV represents compartments at risk for potential contiguous or non-contiguous *microscopic spread* from the primary tumor.

Session 16b - QA from simulation to delivery / 489

Effective and efficient radiotherapy dosimetry audit: Where to next?

Author(s): CLARK, Catharine[1]; GERSHKEVITSH, Eduard[1] ; TOMSEJ, Milan[1] ; JORNET, Nuria [1]

1 ESTRO

Dosimetry audit plays an important role in the quality and safety of radiotherapy both for established and new technologies and techniques. Audit also helps to reduce delivered dose variability and is mandatory in many multi-institutional trials. National and large scale audits are able to set, maintain and improve standards, as well as having the potential to identify issues which may cause harm to patients. A recent workshop was held by ESTRO on theme of 'Future techniques for dosimetry audit of advanced radiotherapy', with the goal of identifying what ESTRO can do to support and facilitate further audit of advanced radiotherapy in Europe.

We are faced with many challenges in setting up effective and efficient audit procedures. In addition the upcoming techniques and associated auditing further extend this challenge, as it is not yet clear what should be audited. When we think about audits for upcoming techniques it is important to ask 'What are the attributes of an ideal dosimetry audit' and 'How can we design and build equipment to facilitate this?' The requirements of anthropomorphic phantoms and how they can be used with advanced detector technology such as arrays, EPID and gel need extensive thought. In addition, there is a need to incorporate motion to audit 4D techniques in order to cover techniques such as gating, tracking and deep inspiration breath hold which are becoming widespread.

Dosimetry audits have traditionally either been performed by teams of auditors visiting the hospital or have been carried out by the physicists at the hospital, with phantoms and dosimeters sent by the auditing centre (postal audit). In order to reduce costs and make the audit available to all departments, methods which could be used to reduce, or avoid completely, the need for a physical visit to the hospital are being discussed. These incorporate both planning and delivery analysis, but most importantly how these relate to one another. Techniques to check plan quality and complexity might be able to isolate plans which may not deliver so well, in advance of any measurements taking place. Furthermore, the deliverability of the plan could be checked using log files, virtual phantoms or EPID measurements. For example the pre-treatment verification could be run on-site by the local physicists, while the results could be analysed remotely by the audit centre.

Finally, sharing the results in common platforms, once mutual recognition of the audit methodology is guaranteed, could increase audit efficiency. The work of both the IAEA and the Global Harmonisation Group for QA in Clinical Trials in streamlining audit through methods to better understand the practices and results of different groups, demonstrates how this could be undertaken.

It is clear that ESTRO could play a role to facilitate dosimetric audits through the drafting of guidelines, by sharing solutions developed by members and/or auditing structures, and also sharing the results of audits to set standards. Therefore, it has been decided that a task force will be created with the aim of further exploring how ESTRO could contribute to this important field.

Session 13b - The role of international organizations and professional societies - Part 1 / 500

SEAROG

Author(s): CHIN, Francis[1]

1 SEAROG

This talk is about efforts of the South East Asian Radiation Oncology Group (SEAROG) to promote radiation educational activities in SEA countries. SEAROG was inaugurated on May 12, 2007 composed of National Radiation Oncology Societies of member countries which share common geographical location, disease patterns, resources, and challenges. SEAROG founding members were IROS (Indonesia), MOS (Malaysia), PROS (Philippines), SRS (Singapore) and THASTRO (Thailand).

The mission of the society is to improve the quality of radiation oncology practice in the SEA region by enhance cooperation in education, research and QA initiatives.

A strategy of common consensus and shared activities like advancing good knowledge and practise of radiation oncology techniques, improving education standards with the aim of improving outcomes of cancer treatment through safe delivery of radiation.

It is acknowledge that cancer is becoming more prevalent and important health morbidity and mortality in SEA countries as the countries industrialise and modernise. Good radiation practises are often not optimised because of lack of radiation therapy machines, poor training, lack of visibility and misunderstanding about radiation.

One of the earliest initiatives is a collaboration with the ESTRO school to have a yearly series of workshops taught by ESTRO school experts in collaboration with local experts with the curriculum adapted to SEA important diseases. This follows normal ESTRO curriculum taught in Europe by brought to SEA for people unable to go to Europe because of costs or distance.

The fees are kept low and affordable (often less than 150 USD) without compromising on the quality of the teaching. These enabled Radiation practitioners in low resource countries to keep abreast with the lastest in radiation techniques and teachings. The courses appeals to trainee doctors, therapists, physicists and even experienced doctors seeking refreshers. It is estimated that over 1500 people participated and benefitted over the years. Each course being more successful than the previous and are being fully subscribed always.

Below is a list of course so far.

2009 – Bali, Indonesia; Evidence Based Radiation Oncology
2010 – Kuala Lumpur, Malaysia; Basic Clinical Biology
2011 – Singapore; Advanced Technologies
2012 – Bangkok, Thailand; Physics for Modern Radiotherapy
2013 – Bangkok, Thailand; Target Volume Determination
2014 – Yogyakarta, Indonesia; Combined Drug-Radiation Treatment
2015 – Manila, Philippines; Advanced Treatment Planning
2016 – Bangkok, Thailand; Paediatric Radiation Oncology
2017 – Singapore; Multidisciplinary Management of Head and Neck Oncology

Over time, SEAROG grew in membership and the number of national bodies included Brunei, Myanmar, Cambodia and Vietnam.

The joint and alternating system of organising at different countries in SEA, drew on the strength of each countries, choosing each ESTRO course, and enable greater fraternalisation and cooperation among the radiation practitioners in these SEA countries, as well as with the presidency being rotated.

Session 14b - The Role of professional societies and international organizations - 2 / 508

The International Cancer Expert Corps (ICEC) sponsored CERN workshop: Design Characteristics of a Novel Linear Accelerator for Challenging Environments

Author(s): COLEMAN, Norman[1]

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Background: The growing burden of cancer in Lower- middle income and Low-income countries (LMICs) requires investment in healthcare systems, physical infrastructure and expertise. The magnitude of the gap requires substantial and sustainable investment. ICEC has as its goals two "arrows" for progress - 1) Mentoring: Matching Experts to Needs and 2) Innovation: New Equipment Design. The overall progress and challenges for ICEC are presented at a symposium in the ICARO2 meeting. ICEC sponsored a meeting hosted in CERN (Geneva) in Novemeber 2016 on "Design characteristics of a novel linear accelerator for challenging environments".

Progress: The background for this effort includes the following:

- Arose from presentation at ICTR-PHE conference in 2014 presentation on global health and discussions regarding linear accelerator possibilities with Ugo Amaldi, Manjit Dosanjh and Jacques Bernier
- Following formal establishment of ICEC, 2015 and ICTR-PHE meeting in 2016 as well as early partnerships and discussion with MPWB, AAPM, ESTRO, ASTRO, ARRO and early pilot programs, CERN offered to host ICEC meeting in November 2016. David Pistenmaa and Manjit Dosanjh key organizers.
- Joined with alternative-technology/non-proliferation groups in 2016.
- Workshop over 70 participants representing universities, government, international organizations, industry, NGOs
- Three Task Forces formed. Core groups have met 3 or more times. Progress to be presented at this meeting.
    - Task Force 1 – Technical ("Bury the complexity")
    - Task Force 2 – Education, Training and Mentoring.
    - Task Force 3 – Global Connectivity and Development

Future: A meeting report of the November 2016 workshop is under review and provides further details on the future plans. The enormous scope of the need for effective global cancer care requires, in our opinion at ICEC, novel collaborative approaches including but also well beyond the current efforts. This is presented elsewhere in the ICARO2 meeting in the symposium on non-government organizations (NGOs).

*Note:

- Presented on behalf of participants at the workshop.
- No financial conflict of interest
- ICEC is a not-for-profit 501 (c) 3, NGO. Dr. Coleman serves as Senior Scientific Advisor. No compensation
- Views expressed are those of the presenter.
- No endorsement by NCI, NIH, ASPR, DHHS or any U.S. Government agencies has been given or inferred.

Session 25c - Clinical Research in Radiation Oncology / 521

How to develop your clinical research program in Radiation Oncology?

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In contrast to the phenomenal technological advances, the clinical research in Radiation Oncology has been sparse. Developing a clinical research program requires significant investments in manpower, resources and time. Clinical research warrants well drafted protocol and strict QA to be successful and meaningful. It is observed that compliance to protocols has significant impact on outcome. Research priorities are also determined by scientific opportunities which basically open avenues for significant improvements and benefits for patients and institutions.

The presentation will discuss the major issues facing when setting up such a research program at the national or regional level. Appropriate set-up is needed to develop, which can track and measure the performance and efficiency of clinical trials. Several countries have adopted such set-ups to mitigate the underlying issues related to the clinical trials.

The issues and needs are unique to Radiation Oncology research. It is required to develop an organizational structure and adopt some validated methods available to set research. Often the researchers are constrained by budget and find it difficult to maintain quality as well as cost. For a national level research program, it is important to spread the funding in such a way that many questions can be answered on issues being studied.

Systematic research capacity development would be desirable especially with LMICs and having a brief description of ways and means to leverage technology and collaboration and look at grant opportunities available. In most cases LMIC health care research capability has problems of strong demands and weak supplies. The quality of research that can be conducted is an important aspect to be considered. Thus, if the research cannot be conducted appropriately or ethically in a manner, which will answer the research question in the country then priority assigned is lesser. While ethical conduct of trial is of paramount importance in modern science, there are several challenges in LMIC nations in this regard. The LMIC should consider clinical research and prepare themselves for quality research to answer the issues related to them. The collaborative research will overcome several issues, those have been limitations for past. The post-graduate students and young scientists should initiate the process.

Session 25c - Clinical Research in Radiation Oncology / 522

QA in Clinical Trials – Benefits and how to organise it

Author(s): CLARK, Clark[1]

1 ESTRO

Clinical trial quality assurance (QA) has the primary purpose to ensure compliance with the trial protocol, but also to ensure consistency amongst the recruiting centres. These two purposes sometimes require different approaches and hence the processes which are put in place to ensure the quality need to be carefully designed for each trial. It is also of benefit to the trials if the QA is carried out by a group independent to the recruiting centres, so that the assessment is unbiased and impartial.
There is evidence to show that centres who successfully pass the QA exercises and who go on to recruit regularly to the trial have better outcomes than those who struggle to pass and who recruit infrequently [1]. Hence the exercises need to be pragmatically applied such that the centres do not find them burdensome in a way which inhibits them from completion. A further implication of the achieved pass rate for the QA is the role which the QA group plays in support and potential training for any centres who find that they are not initially able to achieve the standards required. It is for this reason that clinical trial QA groups play a role in driving up standards in radiotherapy which cascade into routine clinical practice.
The processes which are commonly used for assessing a centres ability to comply with the trial protocol can be divided into three categories:

- Baseline
    - Ensures centres have the equipment, expertise and ability to comply with trial protocol requirements
- Pre accrual
    - Confirms centres are able to deliver treatment accurately and consistently according to specific trial guidelines
- During accrual
    - Assures continued compliance and consistency of treatment delivery both within individual centres and across all recruiting centres throughout the trial

Each of these categories typically includes different exercises but some can be carried over between stages, depending on requirements and may also be repeated at different time points. In the baseline these include the initial facility questionnaire which documents equipment and processes, and a beam output audit which may have been measured on a regular basis independently of clinical trials. For pre accrual exercises it is important to assess how the volume delineation, planning and delivery will be undertaken. The delineation and planning may be carried out separately or in combination. A dosimetry audit may take place prior to or during the recruitment depending on the trial requirements and whether a previous dosimetry audit may give confidence in capability or not. Finally during accrual individual cases may be reviewed either in real time (ie before treatment starts) or at periodic intervals during the recruitment process. Treatment records may also be reviewed, sometimes including additional imaging data. These processes may be streamlined according to the requirements for other similar trials in the portfolio. They may also be set according to the complexity of the trial and whether radiotherapy form a key component in the trial endpoint question.

For rare cancers trials or other trials where recruitment needs to be quick or substantial, it is becoming more and more common to recruit from multiple centres in an international setting. This raises the issue of how the QA can be undertaken and by who. The Global Quality Assurance of Radiation Therapy Clinical Trials Harmonisation Group was set up to address this growing demand for collaboration between different groups conducting these trials to ensure adequate statistical power, which will work to broaden the acceptance of trial results therefore allowing these trials to have a meaningful impact in the clinical setting. The group consists of clinical trial quality assurance offices in existence around the world with the main objective to harmonise and improve the quality assurance of radiation therapy implemented worldwide as it pertains to multi-institutional cooperative clinical trials for the treatment of cancer. A further goal of this group is to ensure consistency between the QA groups as well as between the recruiting centres.

[1] Peters et al Critical impact of radiotherapy protocol compliance and quality in the treatment of advanced head and neck Cancer: Results from TROG 02.02 J Clin Oncol 29(19) 2010

Session 23 - Global Impact of Radiation in Oncology - GIRO / 546

Costs and needs of radiotherapy – a regional perspective

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This analysis presents the resources needed and costs at the present time globally and by region to give full access to RT. The variables and methodology were the same used by the GTFRCC. The GTFRCC reported the resources needed and costs to reach full access to RT in 2035 by income group, but not per region (Atun R et al. Expanding global access to radiotherapy. Lancet Oncol 2015; 16(10)).

The division in regions adopted by the IAEA was used: Africa (AF), North America (NA) only includes USA and Canada, Latin America and the Caribbean (LAC) includes Mexico, Asia-Pacific (AP) includes Australia, New Zealand, and the Pacific islands, and all the post-Soviet states are included in Europe (EU).

AP is bigger than all the other regions together in terms of population and also in terms of additional resources needed. The weighted GNI per capita is US$ 2,086 for AF, US$ 6,343 for AP, US$ 9,863 for LAC, US$ 25,225 for EU, and US$ 54,140 for NA. This is an important observation, as the scale of salaries and training costs used by the GTFRCC was fixed for each income group, but the reality shows that there are big differences between the same income group in different regions (Zubizarreta E et al. Analysis of global radiotherapy needs and costs by geographic region and income level. Clinical Oncology 2017, 29).

According to IAEA-DIRAC there are 13,133 megavoltage machines worldwide, of which cobalt machines represent 15%, and the total number required is 16,666, but NA has near the double of machines needed. Assuming working days of 12 hs. AF covers 34% of its needs, AP 61%, EU 92%, and LAC 88%. Globally, 73% of the needs are covered worldwide.

The table below summarises the main findings of the analysis.

Summary of actual status and total needs to provide full access to radiotherapy in the different regions of the world

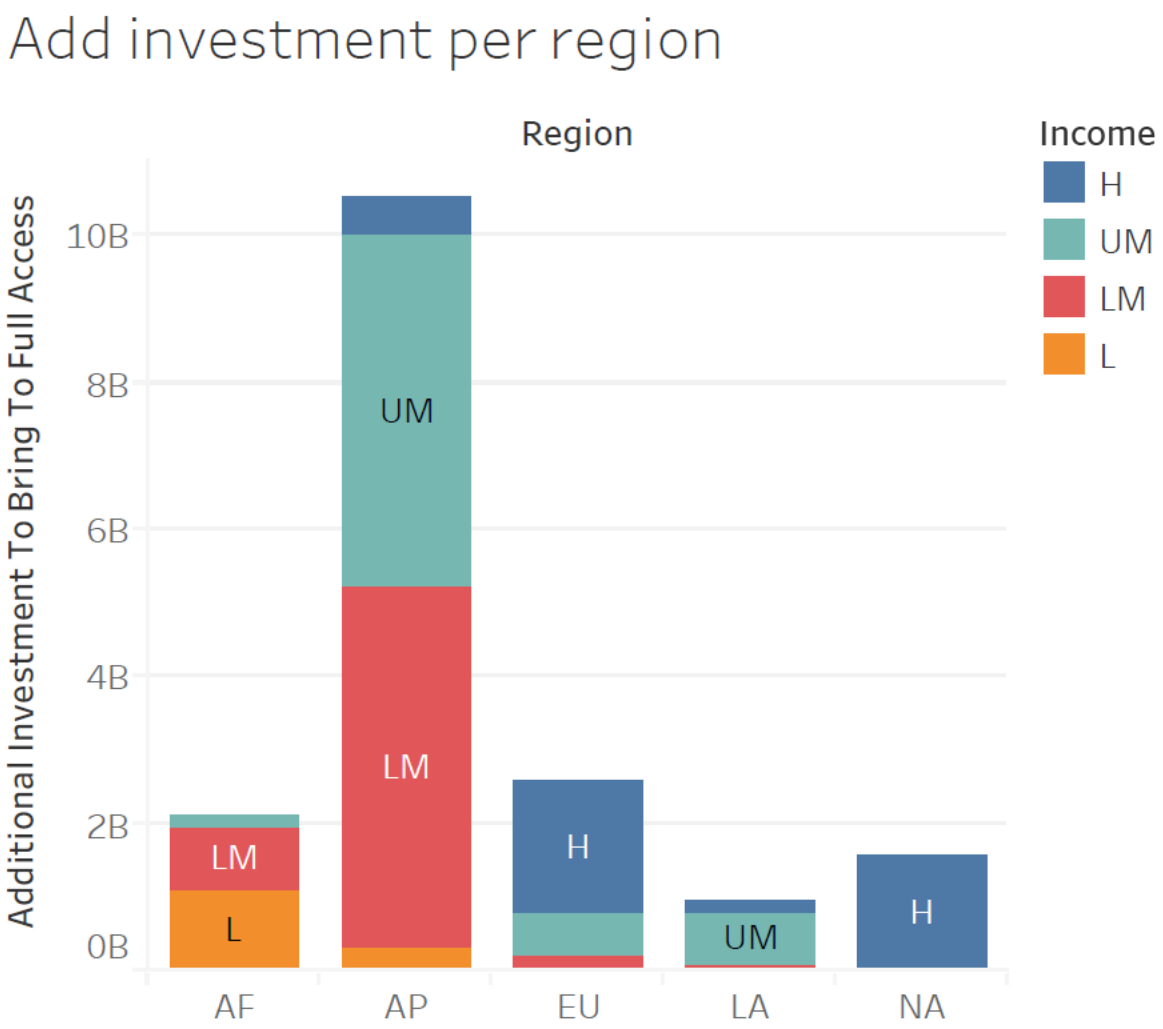
	Africa	Asia Pacific	Europe	Latin America	North America
Population and courses					
Population (million)	1070	4108	893	601	350
Actual radiotherapy courses	148 600	1 914 454	1 712 000	503 000	934 746
Total radiotherapy courses	437 624	3 277 387	1 884 893	573 385	934 746
Resources					
Actual radiotherapy centres	140	2585	1431	620	2787
Total radiotherapy centres needed for full access (working 12 h/day)	407	3503	1449	624	1200
Actual megavoltage machines	277	3894	3751	968	4243
Percentage cobalt machines	30.0%	19.8%	16.0%	30.1%	3.6%
Total megavoltage machines needed for full access (working 12 h/day)	813	6406	4098	1106	2175
Actual coverage of the needs	34%	61%	92%	88%	195%
Costs					
Capital + training costs needed to bring to full access (million US$)	2118	10 497	2573	918	1558
Actual operational costs/year (million US$)	182	4638	5868	975	6151
Total operational costs/year (million US$), assuming full access	571	6968	6573	1192	6588
Actual cost per radiotherapy course (US$)	1226	2423	3428	1939	6581
Total cost per radiotherapy course (US$), assuming full access	1306	2126	3487	2079	7048

Around 40,000 additional professionals would be needed if the additional equipment needed would be installed: 8,732 RO, 6,122 MP, 21,100 RTT, and 3,787 dosimetrists. 70.5% of these correspond to AP.

Operating costs will increase 23% globally, but the cost per patient will decrease 10%.

By region, AF requires 239% (percent extra needs) additional investment (new or upgraded Mv machines, staff), AP 54%, EU 13%, LAC 23%, and NA 6%.

The figure below shows the additional investment to obtain full access to RT in 2016, a total of US$ 17.6 billion. 12% correspond to AF, 59.4% to AP, 14.6% to EU, 5.2% to LAC, and 8.8% to NA.



The main conclusion is that an additional investment of 25% is needed today worldwide to obtain full access to RT, US$ 17.6 billion, and that a separate analysis of each region provides a clearer picture, as the situation is totally different in all of them.

Session 4 - DIrectory of RAdiotherapy Centres - DIRAC / 562

IAEA DIrectory of RAdiotherapy Centres (DIRAC)

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[1] *International Atomic Energy Agency (IAEA)*

INTRODUCTION

Radiation therapy is one of the most cost-effective forms of cancer therapy. Thanks to the long lifespan of radiation therapy machines, large numbers of patients can be treated over several years of operation. The availability of radiation therapy facilities and adequate access to radiation therapy are therefore important in the management of cancer and have major implications for the quality of cancer control programmes. Knowledge about and assessment of the geographical distribution of radiotherapy facilities in relation to population, cancer incidence, and economic level are essential for understanding the availability of radiotherapy in the different countries and regions of the world.

METHODS

The IAEA Directory of Radiotherapy Centres (DIRAC) is the first and only centralized database containing information on radiotherapy resources across the world. It comprises information about radiotherapy facilities, including data on teletherapy and brachytherapy machines used for the treatment of cancer. It also includes information on imaging and simulation equipment, treatment planning systems, dosimetry and ancillary equipment, and personnel, as well as patient workloads.
Each record of an individual radiotherapy centre includes the administrative information of the centre, the equipment details, staffing for radiotherapy, and number of patients treated. Teletherapy equipment is divided into clinical accelerators versus radionuclide units and includes information such as type of radiation, dose rate, energy and/or isotope, and date of installation. Brachytherapy equipment is divided into manual versus remote afterloading with additional information on isotope, source shape and strength, and date of installation.

The DIRAC database is available online and is continuously updated with information provided voluntarily by different organizations, radiotherapy centres and other institutions around the world. DIRAC data undergoes a process of review and verification to detect any inconsistencies and to ensure its integrity and completeness.

Most of the information included in the database is available to the general public. Users can access DIRAC data through predefined queries. The details of radiotherapy facilities, as well as summaries of the major data on equipment divided into countries and larger geographical regions are presented in the main directory. Recently, interactive maps have been added to illustrate the availability of radiation therapy facilities in certain parts of the world, countries or cities. Furthermore, there is a tool that can be used to compare regions or countries. The DIRAC data is also available for downloading.

RESULTS

The DIRAC database contains information on radiotherapy facilities in 139 different countries. It is estimated that the DIRAC database describes approximately 90% of the existing installations worldwide. Currently, it contains over 7000 radiotherapy centres with almost 14,000 teletherapy machines and more than 2500 brachytherapy units.

The substantial difference in radiotherapy resources by country is illustrated in Figure 1. While North America and countries in Western Europe, Japan, Australia, and New Zealand have more than 5 teletherapy machines per million (with more than 10 machines per million in North America), most countries in Africa and South Asia have less than one machine per million. Africa has the lowest number of available radiotherapy resources. Many countries, some of them with a large population, do not have any radiotherapy capacity. Of the 55 African countries registered in DIRAC, only 24 operate radiotherapy services with a total of 342 operational radiotherapy machines.

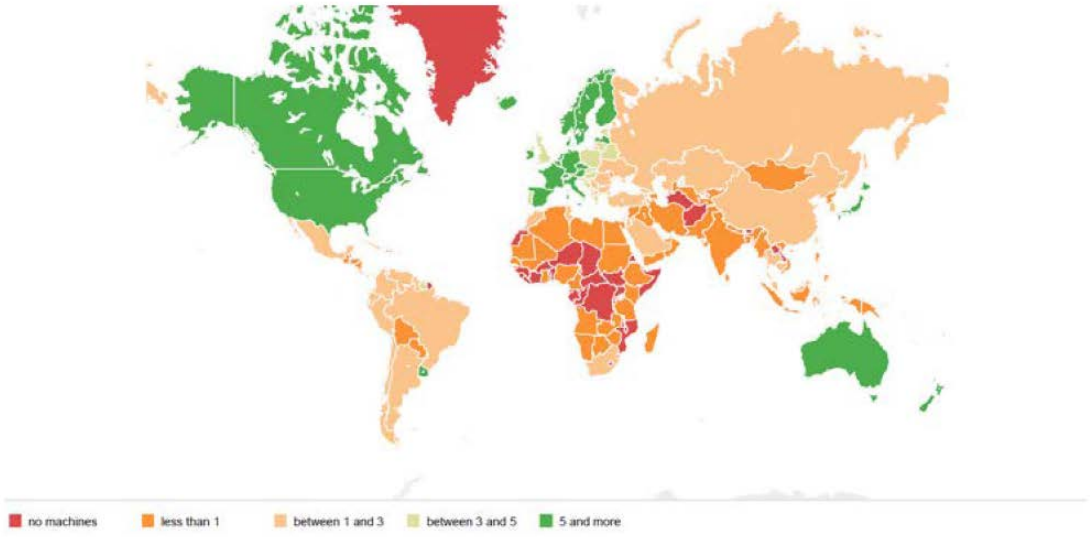

Fig 1. Number of teletherapy machines per million population (https://dirac.iaea.org/).

DIRAC information can be used for a wide range of applications. For example, the distribution of machines by the gross national income per capita (GNI) highlights the relationship between increased wealth and increased radiotherapy resources. Low and lower-middle income countries have less than 10% of teletherapy machines which serve almost 50% of the world population, whereas high income countries have over 60% of all teletherapy machines and 16% of the world population. When the number of machines is compared to the cancer incidence rate, the disparity with GNI and geography shows a similar trend to disparity versus population. The distribution of technology over the world shows that 83% of teletherapy units are linacs and 17% are Co-60 units. Most Co-60 units operate in low and middle income countries in Eastern Europe and Asia. Further analysis shows that the majority of new installations are linacs, and also that 370 radiotherapy machines still in use are more than three decades old. Also, the brachytherapy resources of a large number of lower income countries are insufficient to address high incidence of cervical cancer prevalent in these countries.

CONCLUSION

No centralized comprehensive database other than DIRAC is currently available describing the capacity for delivery of radiation therapy worldwide. Therefore, DIRAC constitutes an important source of information for the analysis and planning of the distribution of radiation therapy resources. In this context, DIRAC data may be used to draw the attention of national health authorities, decision makers, and international organizations to the weaknesses and needs of radiation therapy services at national, regional and global levels. The assessment of geographical distribution of radiotherapy facilities in relation to the various populations, cancer incidence and economy levels is essential for understanding the accessibility of radiotherapy in the different parts of the world, as well as for planning future radiation oncology services. The results of DIRAC data analysis highlight the disparities across geographic and economic grounds and indicate deficit of radiotherapy equipment needed for cancer treatment in low and middle income countries.

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- Abstract 320 - Image registration methodology to quantify ROIS’ volume transform accuracy

Other notes

The ICARO2 Team would like to point out that due to uploading problems during the process of the abstract submission, in a few cases tables, graphics or images could not be extracted from the INDICO system and therefore do not appear in this book.

In some other cases, the formulas were submitted as part of the text but not as an attachment at the time of submission. For this reason, there can be some some formulas missing and also some gaps in the texts.

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