TRANSMISSION COMPARISON FOR TWO DIFFERENT ELECTRON BLOCK MATERIALS

Sonja Petkovska[1], Dushko Lukarski[1], Margarita Ginovska[2]

[1] University Clinic for Radiotherapy and Oncology, Vodnjanska 17 Skopje, R. Macedonia, pet.sonja@gmail.com

[2] Faculty of Electrical Engineering and Information Technologies, Ss Cyril and Metodius University, Skopje, R. Macedonia

***Abstract* – The purpose of this work is to compare electron beam transmission, under two different block materials. The first one, cerrobend, consists of 10% cadmium and the second one is cadmium free. Percentage depth doses for open and block fields for all electron energies are measured. Measurements were performed with a plan-parallel ionization chamber over a range of depth from water surface to a depth of 160mm. The fields were defined using a 15x15 electron applicator mounted on linear accelerator. Depth dose curves beyond two alloys are matched and compared. Regarding the results, the percentage depth doses behind blocks correspond very well. The difference between the two alloy curves does not exceed 0.12%. The conclusion of the article is that a coincidence in transmission is acceptable.**

***Keywords* – cerrobend, block material, transmission**

1. INTRODUCTION

As a result of the photon behavior, the external beam radiotherapy (EBRT) is in some way limited by the inability to deliver adequate doses of irradiation, because of the dose tolerance limits of organ at risk (small bowel, spinal cord, kidney, lenses etc). In treating shallow tumors where a rapid drop off is desired beyond the depth of the tumor (e.g. head&neck lymph nodes over spinal cord, chestwall, skin cancers, other superficial tumors) it is highly recommended to use electron beams. Electrons have an abrupt fall off. They provide a high dose delivered close to the surface and a minimal dose delivered to the deep tissues. Because of their nature, there are some limitations (constrains) in their using such as: the field should always be perpendicular to the beam; dose goes to areas beyond geometrical field; the lower electron isodose lines bulge out below the surface- ballooning or mushrooming [1].

The electron beams can be delivered with a range of applicator sizes and field apertures (cut-outs), depending on the volume which should be treated. The shielding material used in our hospital for modeling blocks was cadmium and lead based shielding alloy (cerrobend). Cerrobend blocks are widely used to protect normal tissues and its characteristics are very well known [2]. Cadmium has been recognized as a source of environmental pollution and a poisonous cadmium gas is emitted during fabrication of the material into custom blocks. However, the potential for exposure to hazardous levels is extremely low if the recommended safe practices are followed, cadmium-free shielding alloy is decided to be used. The alloy, here referred as Rossen, same as the other Cd-free alloys contains a higher concentration of lead and melt at a higher temperature [3, 4].

In this work we compare transmission when an electron beam passes through selected alloys.

2. MATERIALS AND METHODS

Available electron energies are: 4MeV, 6MeV, 9MeV, 12Mev, 16MeV and 20MeV. Electron Pencil Beam Algorithm needs measured dose distribution obtain through open and fully blocked field for reference applicator.

Firstly, we deal with Lipowitz's metal, also called cerrobend alloy, whose melting point is 70 °C. It has a composition of 50% bismuth, 26.7% lead, 13.3% tin and 10% cadmium. Second one is cadmium free alloy, called Rossen, which consists of 0.3% cadmium. Its melting point is 106 °C. Full blocks (for applicator 15) from the two alloys are prepared in the mold-room.

Using a PPC-40 plan-parallel ionization chamber, a Blue water phantom and a 15x15 electron applicator mounted on Varian clinac, we measured the percentage depth doses for open and block fields, for all electron energies. OmniPro software allows us to see the depth dose curves, match them and compare them.

3. RESULTS

Depth dose curves comparison for all available electron energies is performed. As it is presented in other studies [5], the maximum dose under a blocked electron beam (for both alloys) occurs on the central axis closer to the surface than it does for the open beam. To be able to interpret the results of the transmission differences, we should know the depth dose distribution for open field (Table 1) and the block transmission factors for available electron energies (Table 2).

Table 1. Depths (mm) in water for selected open field percentage doses

Dose (%)	20	10	5	2	1
d_{4MeV}	14.3	15.4	16.2	17.0	17.4
d_{6MeV}	26	27.8	29.2	30.7	31.7
d_{9MeV}	39.5	42	43.9	46.3	48.5
d_{12MeV}	55.1	58.6	61.4	66.3	
d_{16MeV}	73.8	78.7	83.5	94	
d_{20MeV}	94.2	100.8	112		

Table 2. Transmission factors for electron beams

Energy (MeV)	4	6	9	12	16	20
T (%)	0.2	0.4	0.9	2.2	4.2	7.4

The electron beam transmissions under blocks made from different alloys, are presented through percentage depth doses. The percentage depth dose differences are converted into real dose differences using a transmission factor. Results are as it follows.

On the figures below, the red curve represents the cerrobend alloy and the green curve is the new alloy (Cd-free). The transmission curves are normalized to 100% (Dmax=100%). In reality this corresponds to transmission of 0.2%; 0.4%; 0.9%; 2.2%; 4.2% and 7.4% respectively for energies from 4MeV to 20MeV (Tab 2). Comparisons show highest discrepancies for 4MeV electron energy. This OmniPro graph is presented below (Fig. 1).

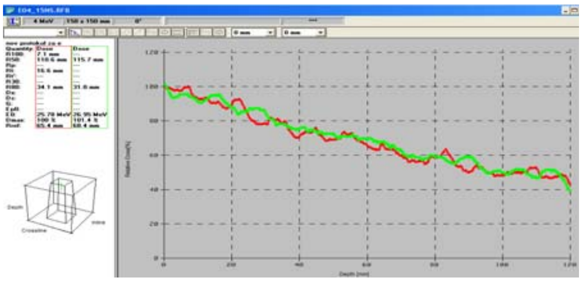

Fig. 1 – 4 MeV percentage depth dose differences

Coincidences between two curves are much better for the rest electron energies. Almost ideal coordination in transmission through two blocks is found for the most frequently used electron energy (Fig. 2)

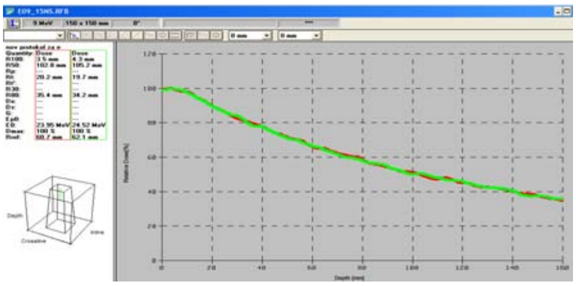

Fig. 2 – 9 MeV percentage depth dose differences

In order to discuss about 4MeV transmission comparison, we should take into account that results beyond 20mm depth are negligible because the dose drops off rapidly. In 3mm depth (from 14.3 to 17.4) the percentage dose falls from 20% to 1% (Table 1). Only the depths related to high discrepancies are shown below (Table 3),

Table 3. 4 MeV percentage depth dose differences

d(mm)	2.7	6.4	15	22
Δ Δ∗T	-5.4 -0.011	-5 -0.01	4.3 0.009	-9.5 -0.019

where, $\Delta\ (\%) = D_{Rossen}\ (\%) - D_{Cerrobend}\ (\%)$ (1)

The transmitted dose difference goes up to 9.5%, but even that, the real dose difference is less than 0.02%.

For the rest of the electron energies, the results presented below (Table 3) show good adjustment between block transmissions on selected depths.

Table 4. Percentage depth dose differences

d(mm)	10	20	40	60
Δ *6MeV* Δ∗T	-1.7 0.007	-2.3 0.009	1.5 0.006	2.5 0.01
Δ *9MeV* Δ∗T	-0.3 0.003	-0.6 0.005	-1.2 0.011	0.3 0.003
Δ *12MeV* Δ∗T	-0.9 -0.02	-1.1 -0.024	-1.8 -0.04	-1 -0.022
Δ *16MeV* Δ∗T	0.1 -0.004	-0.5 -0.021	-0.2 0.008	-0.5 -0.021
Δ *20MeV* Δ∗T	-1.5 -0.111	-1.5 -0.111	-1.4 -0.104	-1.4 -0.104

The first line in each row shows differences when the maximal values of the transmission curves are normalized to 100%. The second line shows these differences when corresponded transmission factors are taken into account.

4. CONCLUSION

Regarding the results, the percentage depth doses behind blocks correspond very well. The difference between the two alloy curves does not exceed 0.12%. As the coincidence between transmissions is obviously acceptable, the cerrobend alloy can be replaced with a new one. We should take into account that the cerrobend replacement does not mean that the problem with the alloy will disappear. The Cadmium-free alloy has a little bit lower transmission than the Lipowitz's metal, primarily due to the higher content of lead and bismuth, and it also has a higher melting point. While cadmium-free alloy was designed to eliminate cadmium from the workplace, it does not eliminate the potential problem of *lead*. Based on all current studies and published reports, it would appear that the alloy fumes do not present a real problem when following certain safety procedures. The potential problem of cadmium is minimized to the extent that it is difficult to make a valid argument supporting the use of a higher temperature, especially since the elevated pouring temperature creates a greater potential for serious burns.

A good solution for the future is a new material with higher attenuation, easy to fabricate and friendly to the environment [6, 7, 8], used as a substitute of lead.

5. REFERENCES

[1] Elizabeth Small B.S.R.T(T) *RTT 321, Dose Distribution*, catalog.umflint.acalog.com.

[2] Taherchani at al: *Evaluation of the physical caracteristics of Cerrobend blocks used for radiation therapy*, Iran J. Radiat, 8(2), 2010, 93-101

[3] Blackwell CR and Amundson KD, *Cadmium-free lead alloy for reusable radiotherapy shielding*, Medical Dosimetry, 15(3), 1990, 127-9.

[4] Kamal M et al., *Newton's metal as a new home-made shielding material*, Radiation Effects and Defects in Solids 162(1), 2007, 53– 57.

[5] Wojcicka JB, *Technical Note: On Cerrobend shielding for MeV 18–22 electron beams,* Med. Phys. 35(10), 2008, 4625-9.

[6] Tajiri M et al., *New shielding materials for clinical electron beams*, Radiotherapy & Oncology, 2008, 80(3), 391-393.

[7] Tajiri M et al., *New shielding materials for radiation tterapy* Med. Phys. 31, 2004, 3022-3023.

[8] Buckey C et al., *Evaluation of a commercially-available block for spatially fractionated radiation therapy*, Journal of Applied Clinical Medical Physics, 11(3) 2010.