# Comparison of VMAT craniospinal treatment delivery between Halcyon and Varian Clinac iX

Milena Teodosievska Dilindarski[1,*], Dushko Lukarski [1,2]

[1]*University Clinic for Radiotherapy and Oncology, Skopje, Macedonia*
[2]*Faculty of Medicine, Ss. Cyril and Methodius University, Skopje, Macedonia*

*Corresponding author: teodosi_soul@hotmail.com

## Introduction

Meduloblastomas are pediatric tumors that require irradiation of the entire craniospinal axis (CSI) which can be up to 80 cm in length for older pediatric patients. This presents some unique challenges in the treatment planning and radiotherapy delivery for these cases. Traditionally, in the classical 3D conformal radiotherapy with uniform intensity, this was solved by moving the junction of the adjacent fields so that the cold and hot parts of the target volume were not at the same place in the successive daily fractions [1]. As the technology evolved, new methods became available with modulated field intensities, which eliminated the need to move the field junctions [2]. Finally, with the introduction and development of the O-ring linac technology, which increased the speed and accuracy of the delivery, additional irradiation options became available for the CSI [3, 4].
In this work we evaluated the CSI on two different radiotherapy units at the University Clinic for Radiotherapy and Oncology in Skopje, a new Halcyion unit and an older Clinac iX, from a practical aspect of reducing the overall time the patient lies on the treatment couch during daily treatment, while maintaining the same quality of treatment plan and delivery.

## Materials and methods

Two Varian units with different performances are available for VMAT treatments at the clinic. The first one is a Halcyon unit, commissioned in 2022, with a maximum field size of 28x28 $cm^2$, MLC with an effective resolution of 5 mm and a flattening filter-free x-ray beam of 6 MV with a maximum dose rate of 800 MU/min. The second one is an older Clinac iX, commissioned in 2013, with a maximum field size of 40x40 $cm^2$, a Millennium 120 MLC collimator and maximum dose rate of 600 MU/min. The inner 20 cm of the Millennium 120 MLC have 5 mm, while the remaining 10 cm on each side of the isocenter have 1 cm resolution. The difference in the MLCs of the two different units also affects the width of the treatment field which can be up to 28 cm in the case of the Halcyon and 15 cm in the case of the iX unit. The treatment planning for both units was done using Eclipse 16.1 treatment planning system, using the Acuros XB algorithm for the Halcyon and the AAA algorithm for the Clinac iX.
Before planning and treating an actual clinical patient, a comparison was conducted on a publicly available patient CT taken from the Varian Medical Affairs web site [5]. Only after planning end evaluating the delivery of this test patient did we proceed with planning and delivery on our actual clinical patient. For both the test and the clinical patient a treatment plans for both units was created and optimized. In both cases the patients were in supine position with arms placed beside the body. The target structures and organs at risk were contoured by the responsible radiation oncologist at the clinic. The dose prescription for the CSI was 20 fractions with 1.8 Gy daily, followed by 10 fractions with 2 Gy daily for the boost target structure. Only the comparison for the entire CSI is reported in this abstract.

During the optimization process, beam entry through body parts not included in the CT (the arms) was avoided, with an additional margin of 5 mm. The length of the planning target volume (PTV) for the test patient was 72.5 cm, while for the clinical patient 66.5 cm. Each plan was considered to be clinically acceptable if the target coverage was $V_{95\%} \geq 97\%$, $D_{2\%} \leq 107\%$, $D_{max} \leq 109\%$ and the organs at risk were in accordance with the local limits based on QUANTEC. During planning, special attention was paid to adequate coverage of the part of the PTV near the eyes.

For the Halcyon plans, the plan offered on the Varian website uses five isocenters spaced 14 cm apart. The Halcyon unit allows organizing a maximum of two isocenters into one isocenter group for which the pre-treatment image verification of the patient positioning can be done with only one CBCT or MV-MV image set. In this comparison, it was assumed that MV-MV verification would be used on the Halcyon unit, due to the complicated treatment planning process of multiple isocenter treatment and the large CBCT dose that would remain unaccounted for in the treatment planning. Since this pre-treatment verification contributes significantly to the patient's overall treatment time, multiple plans were created to check if the number of isocenters or isocenter groups could be reduced, while maintaining plan quality at an acceptable level. Our treatment planning trials have shown that by increasing the distance between isocenters by more than 14 cm, the quality of the plan decreases significantly leading to lower target coverage or a higher low dose bath, which is especially important for pediatric patients. Therefore, for both patients, Varian's strategy of 14 cm isocenter spacing was adopted on the Halcyon unit.

Two arcs were used for each isocenter, one clockwise (CW) and another counterclockwise (CCW) with collimator angles of 0 and 90 degrees respectively. The only exception was the most cranial isocenter, where due to the presence of the eyes a greater modulation was required and therefore the placement of a third arc was necessary. The coordinates of the isocenters differed only in the cranio-caudal direction, and the positions were determined according to the different PTV lengths.

For the Clinac iX plans, many of the restrictions imposed by the Halcyon unit do not apply, so the planning process is a somewhat simpler and significantly faster. For both patients, plans of acceptable quality were achieved with 2 isocenters per patient and two arcs per isocenter (CW and CCW) with collimator angles 10º and 350º. The fields were opened up to 40 cm in the cranio-caudal direction (Y jaws) but limited to 15 cm X width of the jaws, due to the Millenium MLC120 design. Pretreatment image verification of patient positioning was assumed to be with paired kV-kV images.

**Results**

Figure 1 shows the sagittal views of the 4 plans depicting the isocenters and arcs. Figures 1 a) and c) show the plans for the Halcyon unit, where the plan for the test patient is given in a), while the plan for the clinical patient is given in c). In b) the Clinac iX plan for the test patient is shown, while in d) the corresponding plan for the clinical patient is given.

Table 1 shows a summary of the times required to perform various tasks during patient irradiation, for both patients and radiotherapy units. From measurements of phantom positioning and image verification, it was estimated that on the Halcyon unit the positioning and pre-treatment image verification ideally takes about 3.5 minutes per isocenter, while on the Clinac iX it takes about 5 minutes. As shown in Table 1, because the Halcyon plans have more isocenters, the total time required for the pre-treatment image verification of the patient positioning is about 8 minutes longer.

Again, due to the larger number of isocenters and significantly higher number of monitor units, the estimated exposure time itself is more than 3 minutes longer on the Halcyon and the

estimated clinical time it would take radiologic technologists to reposition the patient could be 5 minutes longer on the Halcyon and even more. Overall, it was estimated that the overall treatment time on the Halcyon unit could be 10–15 minutes longer, a significant increase compared to the Clinac iX, which is important especially for unsedated older children, as was the case with our clinical patient.

**Discussion**

The choice of treatment unit for a pediatric patient with medulloblastoma is not as straightforward as it may seem. Several questions need to be addressed if the treatment plan can be delivered with comparable quality, such as how many isocenters will provide good enough coverage, which machine will deliver the dose faster, how comfortable it is for the patient, etc. The issue of the number of isocenters is of great importance because it will dictate the number of verification images, and thus the number of entries of the radiation technologists in the treatment vault during the treatment, which will inevitably lead to greater disturbance of the patient. Furthermore, in the case of a pediatric patient, the patient's cooperation is always a question. Therefore, in this work we have tried to estimate the time the patient should remain lying on the treatment couch of the different machines that enable high-quality radiotherapy treatment of a complex case of irradiation of the entire craniospinal axis. We found that while a state-of-the-art machine like the Halcyon has a higher dose rate and allows for greater overall patient comfort under normal conditions, limiting field dimensions to 28 cm plays a critical role in cases where one dimension of the target volume is extremely large, such as is in this case.

**References:**


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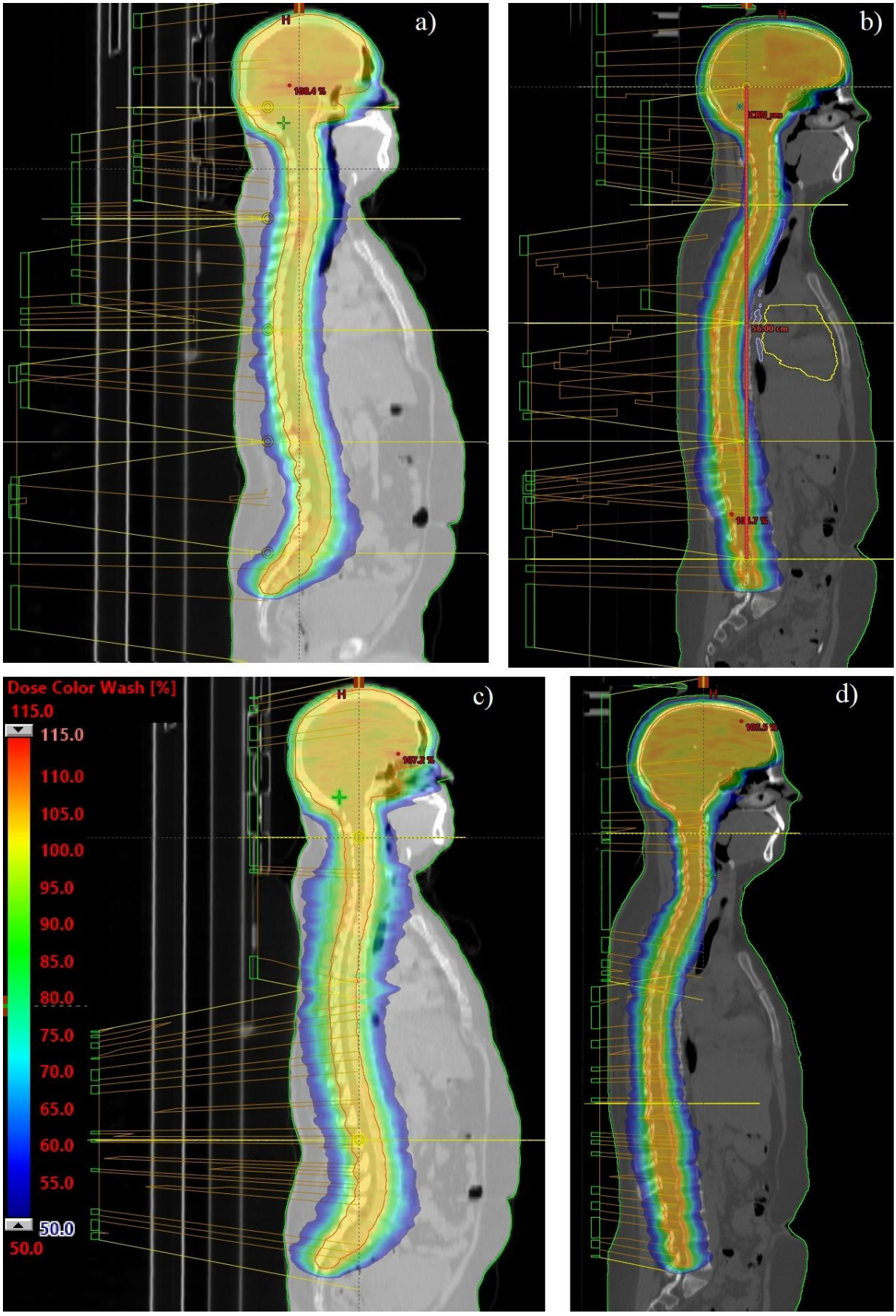


Fig.1 - Sagittal views of the 4 plans depicting the isocenters and arcs: a) test patient, Halcyon plan; b) clinical patient, Halcyon plan; c) test patient, Clinac iX plan; d) clinical patient, Clinac iX plan.

Table 1 - Summary of the times required to perform the different phases of irradiation

| | Test patient | | Clinical patient | |
|---|---|---|---|---|
| Radiotherapy unit | Halcyon | Clinac iX | Halcyon | Clinac iX |
| Number of isocenters used | 5 | 2 | 5 | 2 |
| Number of arcs | 11 | 4 | 11 | 4 |
| MU | 2116.9 | 851 | 1831.4 | 1140 |
| Estimation of the total time needed for pre-treatment image verification of the patient positioning (min) | 18-18.5 | 10-10.50 | 18-18.5 | 10-10.50 |
| Estimation of the irradiation time (min) | 9.10 | 6 | 9.8 | 6.4 |
| Estimation of the clinical time needed for patient repositioning (min) | 10-15 | 10 | 10-15 | 10 |
| Total time the patient spends lying at the treatment couch (min) | 37.1-42.3 | 26-26.5 | 37.8-43.3 | 26.4-27 |