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Scientific Article

Craniospinal Irradiation: A Dosimetric Comparison Between O-Ring Linac and Conventional C-arm Linac

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Abstract

Purpose: The aim of this study was to perform a dosimetric evaluation between craniospinal irradiation volumetric modulated arc therapy plans designed for an O-Ring and a conventional C-arm Linac.

Methods and Materials: Two adult patients were selected for this study. Two plans were designed one for a TrueBeam Edge and one for Halcyon O-ring Linac for each patient. The evaluation of the plans was conducted in terms of dose volume histogram analysis of the target volume and organs at risk (OARs) along with total plan monitor units and beam-on time. Paired sample *t* test was performed to compare D_{max} and D_{mean} of OARs for each plan's comparison. The delivery of volumetric modulated arc therapy plans was evaluated using Octavius 4D phantom.

Results: All plans demonstrated dose distributions with sufficient planned target volume conformity and homogeneity. The Homogeneity Index and Conformity Index for all plans were found comparable. The paired sample *t* test did not demonstrate significant difference in terms of D_{max} and D_{mean} of OARs between plans for both patients. All plans met the threshold of 90%, with Halcyon plans having higher gamma passing rates.

Conclusions: Craniospinal irradiation plans generated for Halcyon and Edge are equivalent in terms of plan quality and dose sparing at OARs. The small variations may have originated from the differences in beam profile or mean energy, the degree of the modulation for each plan and characteristics of multi leaf collimators for each treatment unit. Halcyon is able to deliver a distinctly faster treatment, but Edge provides an automatic rotational correction for patient positioning.

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Research data

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Introduction

Craniospinal irradiation (CSI) is considered to be an effective treatment of tumors involved in the entire central nervous system. Common malignant neoplasms indicated for CSI include posterior fossa tumors (eg, medulloblastoma) and ependymomas.[1-8]

Radiation-induced side effects from CSI might be neurocognitive defects, hypothyroidism, cardiac toxicity, pneumonitis, fertility issues, bone growth-related abnormalities, and secondary cancers.[2,8,9]

Until recently, the most widespread technique for treating such patients was 3-dimensional conformal radiation therapy (3D-CRT). Because of the extensive length of the planned target volume (PTV), multiple isocenters (2 or 3) are implemented.[1,7,10]

3D-CRT involves 2 lateral opposed photon beams for the brain and one or more posterior fields for the spine. The matching of the diverging fields is performed by rotating the couch and the collimator.[2-4,9,11,12] The prone position is the most appropriate modality of patient positioning. This set-up provides clear confirmation of the field junctions.[6]

Nonetheless, the prone position has some drawbacks that need to be taken into consideration. First, this position is uncomfortable, more difficult to reproduce daily and requires patient's cooperation during setup and treatment. In addition, the prone position is unreliable for pediatric cases, where anesthesia is demanded because of the position of the head being nonconducive to immobilization.[5]

The optimal placement of the junctions is essential, to avoid hot or cold spots. Thus, many institutions apply feathering (a moving junction) between fields with different isocenters, minimizing the over or underdosage of the target.[1,5,13,14]

In recent years, modern radiation techniques have been introduced, such as intensity modulated radiation therapy (IMRT) and volumetric-modulated arc therapy (VMAT). These sophisticated techniques are more efficient in terms of dose homogeneity, dose conformity and dose sparing in organs at risk (OARs).[2-4,6,8,15] The implementation of IMRT or VMAT to treat CSI patients reduces toxicity.[16]

Moreover, modern techniques offer 2 additional advantages. First, the patient position is supine, which is more comfortable and reproducible.[9,17] Second, these techniques provide junction free treatments.[1,3,8]

Nevertheless, intensity modulated modalities produce a larger amount of monitor units (MU) compared with 3D-CRT. Therefore, the low dose bath volume is increased because of the higher amount of scattered dose. This may result in a greater probability for the incidence of secondary malignancies.[12]

The scope of this study was to perform a dosimetric evaluation between CSI VMAT plans designed for an O-Ring Linac and a conventional C-arm Linac. The evaluation was performed regarding PTV coverage, dose conformity, dose homogeneity and dose sparing to OARs. Also, beam-on time and the number of MUs for each machine were recorded.

Methods and Materials

CT simulation

In this study, CT images of 2 adult patients, one with leptomeningeal metastases (patient 1) and one with ependymoma (patient 2) were acquired with a Toshiba Aquilion 16 LB. The slice thickness was defined at 2 mm, To achieve the optimal immobilization and reproducibility of the patient set-up, a 3-point thermoplastic head mask, a vacuum bag with a headrest and a knee-feet fixation were used.

Contouring

The total volume of the target was split in 2 structures, CTV_Brain, including the whole brain and CTV_Spinal, including the entire spinal canal. PTV_Brain and PTV_Spinal were generated from CTVs using a 5 mm outer margin. The total length of PTV for patients 1 and 2 was 68 cm and 71 cm, respectively. In the case of leptomeningeal metastases, the dose prescription was 36 Gy in 20 fractions while for ependymoma the prescribed dose was 20 Gy in 10 fractions. Outlined OARs included: eyes, lenses, oral cavity, mandible, parotids, larynx, esophagus, thyroid, heart, liver, stomach, kidneys, and small bowel. Finally, total normal tissue volume was created, with the subtraction of PTV from the body, to evaluate the dose to nontarget tissue.

Planning

Three RapidArc (VMAT) plans, were generated for each patient with Eclipse treatment planning system (Eclipse TPS v15.6, Varian Medical Systems Inc, Palo Alto, CA), using photon optimizer and the anisotropic analytical algorithm with dose calculation grid size of 2.5 mm.

Plans were designed for a Varian TrueBeam Edge and a Varian Halcyon 3.0. A 6 MV flattening-filter-free (FFF) plan was generated for Halcyon (Plan_Hal) and 2 plans for Edge, one 6 MV plan with flattening-filter (Plan_TB_6X) and one 6 MV FFF plan (Plan_TB_6FFF), for each patient. The geometry of Edge plans was identical.

Table 1 presents the parameters of the fields of each plan. The avoidance sectors were applied to avoid the entrance of the beam from the eyes, shoulders, and arms; for the reason that the arm is a structure with a

Table 1 The parameters of the fields of each plan

	Patient 1		Patient 2	
	Plan Halcyon	**Plans EDGE**	**Plan Halcyon**	**Plans EDGE**
No. of isocenters	3	4	3	4
No. of full arcs	3	4	3	4
Avoidance sectors for each full arc	330-30 degrees (Hal_Iso1) 120-70 degrees and 290-240 degrees (Hal_Iso2) 240-275 degrees and 85-130 degrees (Hal_Is03)	330-30 degrees (TB_Iso1) 110-70 degrees and 290-270 degrees (TB_Iso2) 240-295 degrees and 70-120 degrees (TB_Iso3) 120-87 degrees and 275-240 degrees (TB_Iso4)	330-30 degrees (Hal_Iso1) 120-60 degrees and 300-240 degrees (Hal_Iso2) 255-290 degrees and 70-105 degrees (Hal_Is03)	330-30 degrees (TB_Iso1) 115-55 degrees and 315-255 degrees (TB_Iso2) 240-295 degrees and 60-110 degrees (TB_Iso3) 110-70 degrees and 290-250 degrees (TB_Iso4)
Overlap region	≈5 cm	≈3 cm	≈4 cm	≈4 cm
Collimator rotation (degree)	0	0	0	0
Dose rate (MU/min)	800	600 (6X) 1400 (6FFF)	800	600 (6X) 1400 (6FFF)

Hal_Iso1 is located at the brain region, Hal_Iso2 is located at the thoracic spine region, and Hal_Iso3 is located at the abdomen region. TB_Iso1 is located at the brain region, TB_Iso2 is located at the thoracic spine region, TB_Iso3 is located at the abdomen region, and TB_Iso4 is located at the lumbar spine region.

challenging reproducibility, which can introduce dosimetric uncertainties. Because the maximum multi leaf collimator (MLC)-defined fields of the 2 treatment units are different, with Halcyon having a bigger one, the plans generated in Edge had one more isocenter, to cover the target length. The beam arrangement is presented in Fig. 1. The isocenter of each field was placed so that the isocenters differed only in the longitudinal axis. It is noteworthy to mention that in treatment delivery, the multiple-isocenter plans need to be split, each plan including one of the original plan's isocenters. Hence, each plan will be delivered individually and the total of the plans delivered will be equal to the initial multiple-isocenter plan. Therefore, the patient is repositioned and new imaging is acquired before each plan. This approach was implemented in this study. The minimum dose coverage of treatment volume was defined so that 95% of the PTVs receive 95% of the prescribed dose. The dose to OARs was reduced as much as possible.

Plan evaluation

For each patient, we compared Plan_TB_6X versus Plan_Hal, and Plan_TB_6FFF versus Plan_Hal. The dosimetric evaluation of the plans was conducted in terms of dose-volume histogram analysis of the target volume and OARs along with total plan MUs and beam-on time.

For the PTVs, the recorded dosimetric parameters of clinical interest were the volume of the target receiving 95% ($V_{95\%}$) of the prescribed dose, the dose covering 98% of the target volume ($D_{98\%}$) and the dose covering 2% of the target volume ($D_{2\%}$).

PTVs' dose conformity was calculated according to Paddick's formula[18]:

$$CI = \frac{TV_{RI}^2}{TV \cdot V_{RI}},$$

where CI is the conformity index (CI), TV_{RI} is the target volume covered by the reference isodose (95%), TV is the target volume, and V_{RI} is the volume of the reference isodose. CI varies from 0 to 1, where 1 is the optimal value.

PTVs heterogeneity was determined with homogeneity index (HI), according to ICRU 83[19]:

$$HI = \frac{D_{2\%} - D_{98\%}}{D_{50\%}}$$

A HI close to zero indicates that the absorbed-dose distribution is almost homogeneous.

For the various aforementioned OARs, body and total normal tissue volume the maximum and mean doses

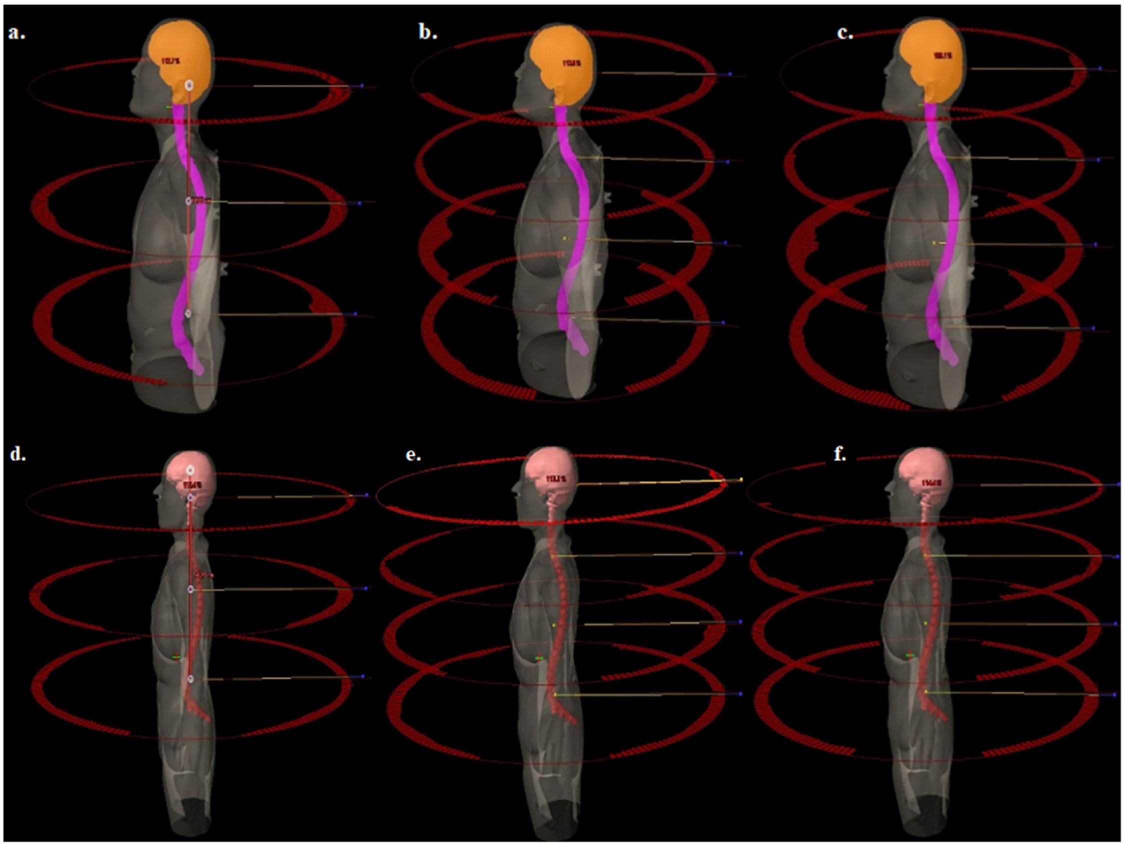

Figure 1 The beam arrangement of the plans a) Plan_Hal, b) Plan_TB_6X and c) Plan_TB_6FFF (Patient_1) and d) Plan_Hal, e) Plan_TB_6X and f) Plan_TB_6FFF (Patient_2).

(D_{max} and D_{mean}, respectively) were acquired for dosimetric comparison.

Paired sample *t* test was carried out to compare D_{max} and D_{mean} of OARs for each plan comparison. A level of $P < .05$ was defined as statistically significant. Four different statistical analyses were performed. The first statistical analysis was carried out between Plan_HAL and Plan_TB_6X of Patient_1 to investigate whether the treatment unit (Halcyon vs TrueBeam Edge) affects the plan dosimetrically in terms of D_{max} and D_{mean} of the patient's OARs. The second statistical analysis was carried out as above between Plan_Hal and Plan_TB_6FFF of Patient_1. Both statistical analyses were also applied for Patient_2. The statistical analysis was performed using the SPSS statistical analysis software package, Version 25.0 (SPSS Inc, Chicago, IL).

The delivery of VMAT plans was evaluated using Octavius 4D cylindrical phantom with the detector array 1500 (PTW, Freiburg, Germany). Gamma passing rate was applied with 3%/2 mm acceptance criteria, 90% passing rate and a 10% low dose threshold according to TG 218.[20] Each multiple-isocenter plan was divided into separate plans according to the number of the isocenters. For every single-isocenter plan, a verification plan was created and delivered individually. The gamma-passing rates are the mean values of the gamma-passing rates of the single-isocenter plans for each multiple-isocenter plan. For all measurements, the device was set up isocentrically. The Octavius 4D was aligned to lasers on the virtual isocenter and after that, the shift toward treatment isocenter was performed automatically.

Results

HI, CI, and dose coverage to PTVs

All plans demonstrated dose distributions with sufficient PTV conformity and homogeneity. The dose distributions of the plans are illustrated in Fig. 2. Each plan achieved clinically acceptable PTV coverage for both patients in this study. The PTVs dosimetric parameters ($V_{95\%}$, $D_{2\%}$, $D_{98\%}$, CI and HI) are presented in Table 2.

The HI values for all plans were noticed to be close to zero and were similar to one another. The most remarkable difference was found for patient 1 PTV_Brain, where the lowest HI value was 0.08 for Plan_TB_6X compared with 0.14 and 0.16 for Plan_Hal and Plan_TB_6FFF, respectively. The CI values for all plans were found to be almost the same. The most significant difference was found for patient 1 PTV_Brain where the highest CI value

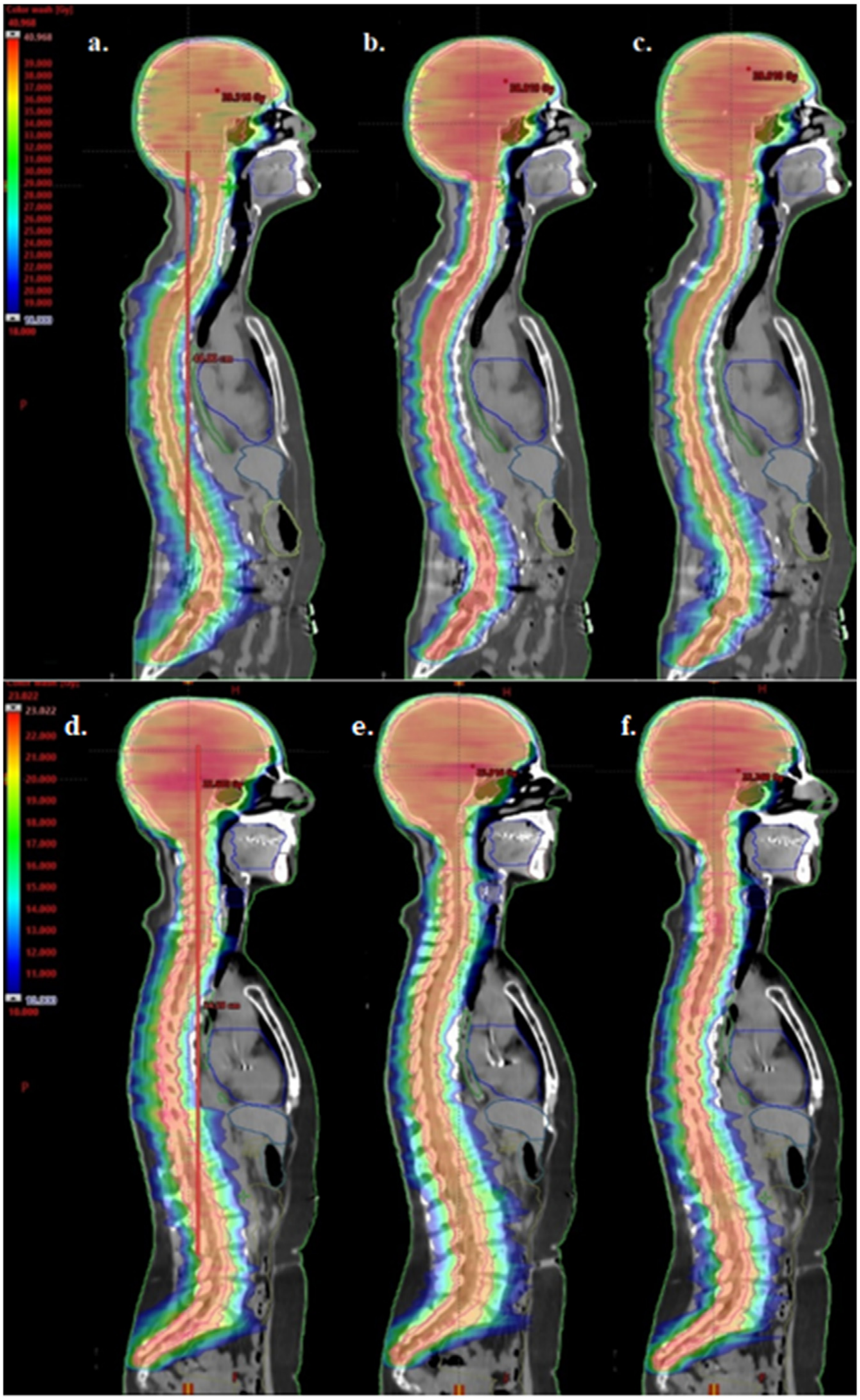

Figure 2 The beam arrangement of the plans a) Plan_Hal, b) Plan_TB_6X and c) Plan_TB_6FFF (Patient_1) and e) Plan_Hal, e) Plan_TB_6X and f) Plan_TB_6FFF (Patient_2).

was 0.83 for Plan_TB_6X and for Plan_Hal and Plan_TB_6FFF was 0.79 and 0.80, respectively. For both Patients, no notable variation was observed in terms of, $V_{95\%}$ $D_{98\%}$, and $D_{2\%}$.

Table 3 demonstrates the number of MUs, the total beam-on time and the beam-on time per arc for each plan for both patients. As it was expected, the beam-on time in Halcyon was shorter than Edge's.

Dose to OARs

Table 4 demonstrates the D_{max} and D_{mean} of each OAR from the 3 plans of Plan_Hal, Plan_TB_6X, and Plan_TB_6FFF, for both patient 1 and patient 2. The paired sample *t* test did not demonstrate any significant difference in terms of D_{max} and D_{mean} neither for Plan_Hal - Plan_TB_6X comparison nor for Plan_Hal–Plan_TB_6FFF

Table 2 The dosimetric parameters of each treatment plan

	Patient 1			Patient 2		
PTV_Brain	**Plan_Hal**	**Plan_TB_6X**	**Plan_TB_6FFF**	**Plan_Hal**	**Plan_TB_6X**	**Plan_TB_6FFF**
$V_{95\%}$	95.4	95.5	95.1	95.2	95.4	95.1
$D_{98\%}$	33.4	35.5	33.2	18.6	18.6	18.4
$D_{2\%}$	38.5	38.4	39	21.9	21.1	21.8
CI	0.79	0.83	0.8	0.84	0.87	0.84
HI	0.14	0.08	0.16	0.16	0.12	0.17
PTV_Spine						
$V_{95\%}$	97.7	97.3	97.8	97.5	97.8	98.5
$D_{98\%}$	34.1	33.9	34.1	18.9	19	19.2
$D_{2\%}$	37.9	37.4	37.5	21	20.4	21.1
CI	0.7	0.72	0.72	0.63	0.67	0.66
HI	0.10	0.10	0.09	0.1	0.07	0.09

Abbreviations: CI = confidence interval; HI = homogeneity index.

comparison. Therefore, from the point of dose sparing, all plans provide similar dosimetric outcomes. Table 5 presents the results of the statistical analysis.

In case of D_{mean} statistical analysis for Plan_Hal − Plan_TB_6X for patient 2, the *P* value was .05, but the 95% confidence interval of the difference includes the zero. Consequently, this result cannot be considered as statistically significant.

VMAT QA

All plans met the threshold of 90%. More specifically for plans: Plan_Hal, Plan_TB_6X and Plan_TB_6FFF regarding patient 1 the gamma passing rates were 98.1%, 96.3%, and 96.4%, respectively and regarding patient 2 they were 99.4%, 94.4% and 97.2%, respectively.

Discussion

In this study, CSI VMAT plans that were designed for Halcyon and TrueBeam Edge were evaluated and compared in terms of plan quality, dose sparing at OARs and beam-on time. First, we compared plans with the default energies that are used for CSI treatment plans in our institution, which are 6 MV with FF and 6 MV FFF for Edge and Halcyon, respectively. Second, we generated a plan with 6 MV FFF in Edge to compare it with a 6 MV FFF plan in Halcyon, in terms of the same energy conditions. It should be noted that for each individual plan we aimed for the best achievable dosimetric outcome between dose constraints at OARs and PTVs coverage.

Edge is equipped with the High-Definition Millennium HD120 MLCs. There are 32 leaf pairs with 2.5 mm resolution at isocenter for the inner 8 cm field and 28 leaf pairs of 5 mm for the outer field. The maximum MLC-defined field size is 22 × 32 cm^2 at isocenter.

Halcyon is equipped with jawless dual-layered stacked MLC that project to a maximum field size of 28 cm^2 × 28 cm^2 at isocenter. There are 29 proximal leaf pairs (upper bank), 28 distal leaf pairs (lower bank), and 2 outboard leaves on distal banks only. Each leaf's projection corresponds to a 1cm leaf width at the isocenter plane. The upper leaf pairs (proximal) are offset from the lower leaf pairs (distal) by 5 mm, so that the upper leaf gaps fall on

Table 3 MU and beam-on time for each plan

	Patient 1			Patient 2		
	Plan_Hal	**Plan_TB_6X**	**Plan_TB_6FFF**	**Plan_Hal**	**Plan_TB_6X**	**Plan_TB_6FFF**
MU	1581.7	1327.3	1708.1	1165.9	1372.2	1663
Beam on time	2 min 04 s	4 min 10 s	4 min 09 s	1 min 35 s	3 min 08 s	3 min 09 s
Beam on time per arc	0 min 41.3 s	1 min 2.5 s	1 min 2.25 s	0 min 31.6 s	1 min 2 s	1 min 2.25 s

Abbreviation: MU = monitor unit

Table 4 OARs D_{max} and D_{mean} of each plan

	Patient 1						Patient 2					
	Plan_Hal		Plan_TB_6X		Plan_TB_6FFF		Plan_Hal		Plan_TB_6X		Plan_TB_6FFF	
OARs	D_{max} (Gy)	D_{mean} (Gy)	D_{max} (Gy)	D_{mean} (Gy)	D_{max} (Gy)	D_{mean} (Gy)	D_{max} (Gy)	D_{mean} (Gy)	D_{max} (Gy)	D_{mean} (Gy)	D_{max} (Gy)	D_{mean} (Gy)
Lens L	8.3	5.6	8.6	7.4	6.7	5.3	4.5	4.1	4.5	3.1	4.7	3.3
Lens R	7.9	5.2	9.0	7.1	9.7	8.3	5.1	3.4	4.7	3.8	4.4	3.5
Eye L	20.9	8.4	26.4	12.6	25.3	10.9	14.2	6.9	15.5	6.9	15.3	6.7
Eye R	23.8	9.4	28.7	13.4	27.9	13.6	15.6	7.5	15.8	7.7	15.7	8.2
Mandible	32.2	8.9	27.9	9.1	31.8	9.8	19.9	3.3	16.4	4.6	15.4	4.3
Oral cavity	17.8	6.9	11.4	6.1	12.6	5.7	8.2	2.5	7.5	3.3	7.4	2.8
Parotid L	17.9	6.5	15.0	7.5	15.9	7.0	8.9	3.7	8.1	4.4	7.7	3.7
Parotid R	12.1	5.8	19.6	7.8	27.4	8.9	8.8	3.8	12.3	4.9	12.0	4.6
Thyroid	19.4	8.4	20.8	9.2	18.6	8.4	12.5	4.2	13.4	8.6	13.7	7.9
Larynx	8.8	3.9	16.2	4.9	15.1	4.9	7.2	2.8	13.0	5.8	11.7	5.7
Esophagus	25.2	11.5	22.4	10.1	20.9	9.3	16.1	6.0	15.5	7.5	14.1	6.3
Heart	19.2	6.3	13.7	5.4	14.0	5.2	8.9	2.9	7.9	3.3	7.9	2.9
Liver	20.0	5.3	23.3	5.7	19.1	5.1	14.3	3.6	13.4	3.9	14.0	3.9
Kidney L	19.6	5.2	15.2	3.6	12.8	3.8	10.4	2.3	9.8	2.2	9.4	2.2
Kidney R	16.8	3.9	15.5	2.6	13.2	2.7	11.9	3.0	13.2	3.0	14.3	3.1
Stomach	16.5	7.2	12.8	6.3	13.4	6.2	10.6	3.9	9.1	4.7	8.6	4.4
Bowel	23.7	7.9	19.8	6.3	18.7	6.3	18.4	4.9	17.2	4.6	17.2	4.7
Body	41.2	7.9	39.3	7.9	41.0	7.9	22.8	3.4	22.6	3.4	22.8	3.4
TNTV (body-PTV)	40.9	6.4	39.0	6.3	40.9	6.3	21.8	2.7	21.2	2.7	22.4	2.7

Abbreviations: L = left; PTV = planning target volume; R = right; TNTV = total normal tissue volume.

Table 5 The result of statistical analysis of each comparison

Comparisons		Paired differences for D_{max}			Paired differences for D_{mean}		
		95% confidence interval of the difference			95% confidence interval of the difference		
		Lower	Upper	Significance (2-tailed)	Lower	Upper	Significance (2-tailed)
Patient 1	Plan_Hal vs Plan_TB_6X	−1.6987	2.5092	0.69	−1.29	0.3847	0.271
	Plan_Hal vsPlan_TB_6FFF	−2.1215	2.911	0.746	−1.0782	0.6677	0.627
Patient 2	Plan_Hal vsPlan_TB_6X	−2.5293	0.7188	0.257	−1.2219	0.0008	0.05
	Plan_Hal vsPlan_TB_6FFF	−0.8048	1.2259	0.668	−0.9923	0.1418	0.137

the center of the lower leaves. As a result, this significantly reduces transmitted radiation beyond MLCs.

Our results show that the plan quality, in terms of HI and CI, was similar between generated plans of the 2 treatment units for both patients. However, it was noticed that the Plan_TB_6X for both patients had marginally better CI and HI values than Plan_Hal, although the $V_{95\%}$ $D_{98\%}$ and $D_{2\%}$ were very close in all cases. This may be originating from differences in beam profiles or mean energy. Our outcome concurs with Michiels et al,[21] who compared head and neck plans that were designed for Halcyon and TrueBeam with VMAT technique, as they found a slightly better dose homogeneity in TrueBeam plans. One more parameter, which can affect the plan quality is the modulation of the plan. Petroccia et al[22] evaluated spine SBRT plans between TrueBeam with Millennium MLCs and Halcyon. They also found better plan quality in TrueBeam. In addition, they calculated that the modulation complexity score (MCS) in TrueBeam was lower than Halcyon. A lower MCS means higher modulation. This reduction of MCS in TrueBeam reflects the improvement in plan quality compared with Halcyon.

MCS has also an effect on the plan delivery. More specifically, according to Agnew et al[23] and Quintero et al,[24] there is a correlation between MCS and gamma passing rate. In our case, the Edge plans tended to have lower Gamma passing rate in comparison to the Halcyon ones. This may be due to the different MLC architecture between treatment machines because the smaller aperture of the HD120 MLCs renders the plans more complicated with a higher possibility of inaccuracies in the delivery.

The paired sample *t* test did not show any significant difference in terms of dose sparing in OARs between Halcyon and Edge Plans. The same result was found in other studies,[21,25,26] which compared VMAT plans that were generated for Halcyon and TrueBeam in different anatomic regions (eg, head and neck, breast, prostate).

One possible explanation for this is that Halcyon can be both superior and inferior to Truebeam Edge regarding MLC related aspects. On the one hand, the architecture of Halcyon MLCs offers a lower transmission factor,[26] resulting in less dose to the OARs.[27] Besides, Halcyon MLCs provide full traveling, a fact that maybe enhances the dose sparing. On the other hand, the width of dual-layer stacked-staggered MLCs is 1 cm (projected at isocenter). Therefore, their dose conformity is not as good as the HD120 MLCs of Truebeam Edge, leading to more irradiation of the OARs.[22,26] Moreover, it is expected that the plans, which are generated in Halcyon have slightly more MUs with VMAT technique compared with the ones generated in TrueBeam Edge with 6 MV FF beam,[25,26] thus producing more scattered radiation to the normal tissue.

The facts do not allow the derivation of a conclusion that dose sparing is improved with Halcyon because it is a factor that depends on more than one aspect of the MLCs and their advantages can be offset by some of their technical properties.

Although Halcyon gantry can rotate 4 times faster than Edge's, the rotation speed during VMAT plans is limited to 2 times faster than Edge because the velocity of Halcyon MLCs is twice as much as the velocity of Edge's (5 cm/s against 2.5 cm/s for Halcyon and Edge, respectively). This evidence can explain the fact that the beam-on time for Edge plans was almost double the beam-on time found for Halcyon Plans.

Furthermore, the plans in Halcyon need one less isocenter than Edge for CSI, there is no need to insert and retract the imaging acquisition devices and there is an increased number of automated steps, in contrast to Edge. These 3 facts suggest that the overall treatment time in Halcyon is expected to be reduced.

The effect of treatment time reduction may improve the workflow efficiency as the delivery of the plans can be considered more accurate because of the decreased number of potential setup errors due to patient movements during treatment. In addition, patients feel more comfortable because of the shorter treatment time. Finally, it could also be advantageous for the clinic because a greater number of patients could be treated during the shift.

It should be mentioned that the Halcyon couch is not provided with the implementation of the rotational correction. On the contrary, Edge couch has 6 degrees of freedom. This means that Edge can provide an automatic yaw correction for patient positioning, and it is not necessary for the therapists to re-enter the treatment room to reposition the patient, if the image registration between kVCBCT and CT-SIM is not satisfying.[22]

Because any statistically significant difference was not detected, in terms of received dose in OARs and PTV coverage for each patient between Halcyon and TrueBeam Edge, the patients were treated in Halcyon treatment unit because of the less isocenters and reduced delivery time. The verification of the shifts from virtual to treatment isocenter (including delta-couch shifts) was performed with kVCBCT for every single isocenter plan.

Conclusions

This study demonstrates that Halcyon and TrueBeam Edge can generate CSI treatment plans with VMAT technique with almost identical plan quality and dose sparing at normal tissues, in terms of the standard energies that are used for CSI treatment plans in our institution (6FFF MV and 6 MV FF, for Halcyon and Edge, respectively). The small variations may originate from the differences in beam profile or mean energy, the degree of the modulation for each plan, the architecture and the characteristics of MLCs for each treatment unit. On the one hand, Halcyon dominates against Edge regarding the treatment time. On the other hand, Edge provides an automatic rotational correction for patient positioning. One limitation of this study is the small sample of cases. Therefore, there is a need for further investigation and research.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.adro.2022.101139.

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