Original Article

Craniospinal Irradiation by Volumetric Modulated Arc Therapy Technique on Halcyon

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Abstract

Aims: Craniospinal irradiation (CSI) is a challenging task on halcyon due to its field size constraint (28 cm × 28 cm). CSI was planned by volumetric modulated arc therapy (VMAT) technique on Halcyon (6MV) linac with no junction shift with multiple arcs and numerous isocenter depending on the length of the patients. **Methods and Materials:** Planning CSI was achieved on Eclipse treatment planning system version 15.6 with anisotropic analytical algorithm and was optimized using autofeathering technique. Positioning accuracy was ensured by obtaining daily kvCBCT before radiation which ensured accurate field placement and avoidance of junctional errors. Pretreatment portal dosimetry was done to ensure the dose distribution calculated by the treatment planning system matches the dose delivered to the patient. **Results:** All VMAT CSI plans produced outstanding planning target volume (PTV) coverage with V95% >98% and gave acceptable doses to organ at risk in all CSI cases. Furthermore, the dose distributions were highly uniform, with homogeneity index values ≤0.1 and target conformity was equally excellent with values more than 0.95. In portal dosimetry, all of the composite images of CSI plans were evaluated, yielding good passing criteria of >98%. **Conclusions:** The remedy was straightforward to plan and deliver, thanks to autofeathering optimization. CSI plan was created with no junction shift which resulted in homogeneous and conformal doses to the PTV. The gamma analysis in the portal dosimetry composite image, which was utilized as a pretreatment verification, met all of the requirements and revealed a homogeneous and uniform junction dose.

Keywords: *Autofeathering, craniospinal irradiation, multi-isocenter, no junction shift, portal dosimetry, volumetric modulated arc therapy*

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Introduction

Craniospinal irradiation (CSI) is a challenging task for both medical physicist and radiation oncologist. CSI has established the gold standard for treating primary tumors such as medulloblastoma, high-risk germ-cell tumors, and other central nervous system diseases. Patients with CSI were formerly treated with typical three-dimensional procedures including laterally opposed parallel beams for cranial fields and posterior fields to the spine,[1] which necessitated the matching of a large number of fields. The revolving couch and collimator matched both the cranial and spinal fields. The gap junction[2] approach was employed to apply the feathering technique, which resulted in a junction displacement[3] and a time-consuming and complicated treatment plan. Intensity-modulated radiation treatment (IMRT) and volumetric modulated arc therapy (VMAT) are two new approaches for treating CSI patient. Although VMAT[4] has more advantages than standard three-dimensional approaches, it still requires numerous isocenters and multiple arcs, which reduces entanglement. Coverage of target volume while limiting organ at risk (OAR) doses is a difficult challenge for CSI planning. CSI treatment

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planning has evolved throughout time as new machines and techniques have become available.

Halcyon, which is developed for IMRT and VMAT, can be used for CSI planning with no junction shift,[5] and it uses the autofeathering technique to avoid having to match the cranial and spinal fields. Halcyon 2.0 linear accelerator (Varian Medical Systems, Palo Alto, CA, USA) includes a ring-based gantry with 0.5 cm MLC-multi leaf collimator (MLC) (virtual) and a field size of 28 cm × 28 cm. Halcyon[6] offers the fastest delivery with 4RPM, an 800 MU/s dose rate, kV imaging capability, and a 6MV flattening filter-free beam. Halcyon has a maximum treatment length of 36 cm when using a dual isocenter (8 cm extension length of actual field size of 28 cm). This extended treatment field is useful in planning tumors with a length >28 cm but not more than 36 cm. Due to the field size constraint, it is challenging to plan for CSI and large tumors. The goal of this planning is to make CSI planning[7] with a conformal and uniform dose distribution to the planning target volume (PTV) as simple as possible.

Materials and Methods

Immobilization and computed tomography simulation

Patients were immobilized on a carbon fiber base plate in a head-first supine position.[8] A headrest was placed above a wedge to allow maximal neck extension and to flatten the spine, an indexable knee rest was inserted to decrease lumbar lordosis. To position the patient, thermoplastic molds were used: one over the head and neck and the other over the abdomen and thorax.

After the patient was properly immobilized, a computed tomography (CT) scan was performed from head to mid-thigh on a Siemens CT scanner with a 3 mm slice thickness. Three fiducial markers were placed on the thermoplastic cast. Images obtained were imported to the workstation after which radiation oncologist contoured, target volumes, and OAR on Eclipse Somavision version 15.6 (Varian Medical system Palo Alto, CA,USA).

Planning

Craniospinal radiation involves radiating a long segment of the entire spine and cranium. Typically, it stretches to 60–70 cm, depending on the height of the patient. Planning CSI was achieved on the Eclipse treatment planning system version 15.6 (Varian Medical Systems Inc., Palo Alto, CA, USA) with anisotropic analytical algorithm. CSI was given 36 Gy in 20 fractions, while the gross primary intracranial tumor was given 18 Gy in 9 fractions. The majority of the cases had three isocenters and two full arcs (clockwise [1810–1790] and anticlockwise [1790–1810]) at each isocenter [Figure 1], where the longitudinal Y coordinate was modified [Figure 2] and the X and Z coordinates were the same.

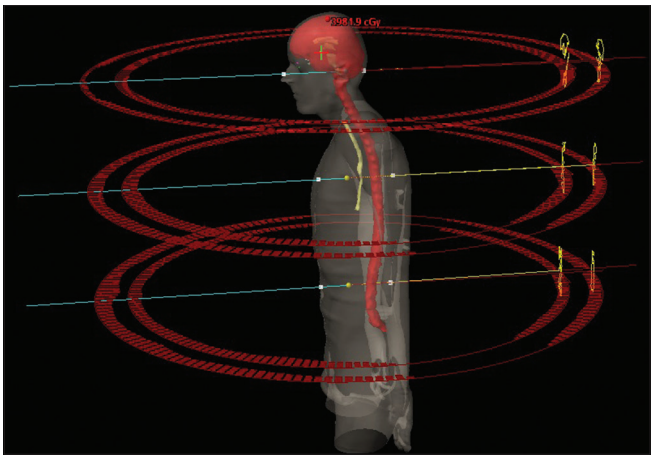

Figure 1: Image displaying multiple arcs for planning craniospinal irradiation patients

Due to the many arcs, optimization took a long time. The final plan was optimized using the autofeathering approach and dose calculation, resulting in a final plan [Figure 3] that delivered 95% of the dose to the target volume while also meeting the OAR dose. After completing the plan, all of the isocenters were divided into distinct plans (brain plan, upper spine plan, and lower spine plan) by assigning kvCBCT imaging to each plan, and then the sum plan was created to complete the treatment plan. Positioning accuracy was ensured by obtaining daily kvCBCT before radiation which ensured accurate field placement and avoidance of junctional errors.

Pretreatment portal dosimetry verification

In radiotherapy, the purpose of pretreatment portal dosimetry is to ensure that the dose distribution calculated by the treatment planning system matches the dose delivered to the patient. Pretreatment verification is a crucial measurement that identifies errors in planning before the patient's treatment; in this case, the portal dosimeter[9,10] is used to verify all IMRT and VMAT plans [Figure 4]. The findings of the predicted and measured photon fluence were compared using the gamma (γ)[11,12] method. 3% dose agreement within 3 mm distance to agreement (DTA) was set as the gamma index value DTA. The treatment plan included multi-isocenter volumetric arcs, each of which had its fluence measured and then put together to create a composite image. The composite image function in the portal dosimetry module of the ARIA version 15.6 software (Varian Medical Systems, Palo Alto, CA, USA) was utilized for this purpose and the composite image was evaluated using the gamma coefficient.

Group	Field ID	Gantry Rtn [deg]	Coll Rtn [deg]	X [cm]	Y [cm]	Z [cm]
I	kVCBCT	0.0	0.0	0.19	-30.85	-5.63
I	USpine1	180.1 CW 179.9	0.0	0.19	-30.85	-5.63
I	Uspin2	179.9 CCW 180.1	0.0	0.19	-30.85	-5.63
II	Brain1	181.0 CW 179.0	290.0	0.19	-4.68	-5.63
II	Brain2	179.0 CCW 181.0	20.0	0.19	-4.68	-5.63
III	Lspine1	181.0 CW 179.0	296.0	0.19	-58.19	-5.63
III	Lspine2	179.0 CCW 181.0	26.0	0.19	-58.19	-5.63

Figure 2: The longitudinal Y coordinate was modified and the X and Z coordinates were the same

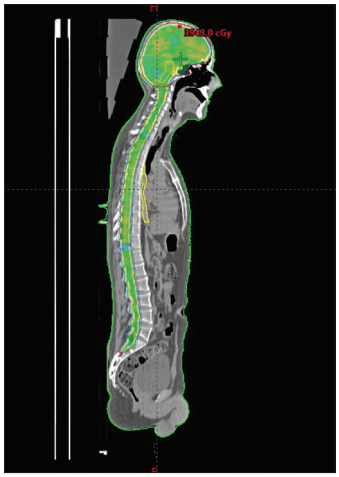

Figure 3: The final plan that delivered 95% of the dose to the target volume

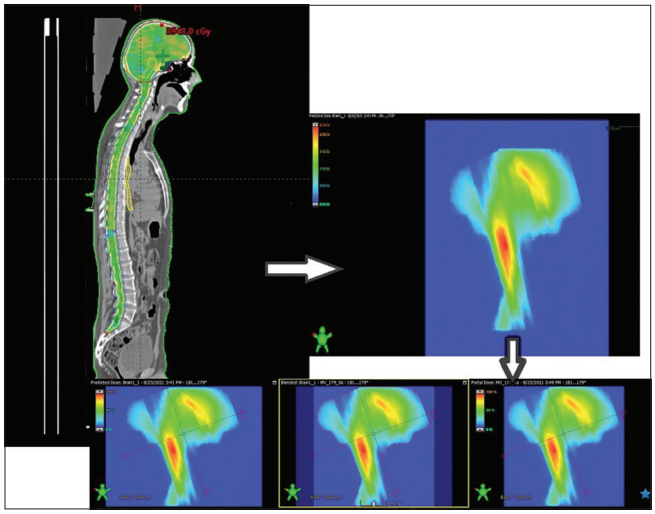

Figure 4: Portal dosimeter is used to verify volumetric modulated arc therapy plans

It was a time-consuming process to produce a composite image plan from numerous isocenter plans, which involved evaluating the portal dose image for each field and then creating a new plan by adding a new field image of the acquired portal dose image for the entire isocenter field. The portal dose prediction from the original portal dose verification plan was exported to notepad, where the X and Y offsets were modified to reflect the isocenter shift, and the corrected text files of all the fields were imported onto the new plan. These fields of the new plan were set unaligned, and the X and Y offsets of the obtained portal dosage image were altered for each field to match the isocenter shift. All of these fields were analyzed in a composite image.

Results

The CSI treatment plan was created using multiple isocenter VMAT and an autofeathering technique was used.

Plan evaluation

Target volume PTV coverage was indicated as the percent volume of PTV getting 95% of the recommended dose V95% in all cases. All VMAT CSI plans produced outstanding PTV coverage with V95% >98%. Furthermore, the homogeneity of the dose delivered to PTV was assessed using the homogeneity index (HI), with an HI of 0 indicating excellent planning. The dose distributions were highly uniform, with HI values ≤0.1. The conformity number (CN) was used to quantify planned dose conformity; ideal plans had a CN equal to 1. With values more than 0.95, target conformity was equally excellent. VMAT plans gave acceptable doses to OARs in all cases; OARs were appraised according to clinical criteria. The lung, kidney, heart, lens, and parotid dosages were 6–7 Gy, 5–6 Gy, 4–5 Gy, 3–4 Gy, and 12–13 Gy, respectively.

Dosimetric evaluation

The portal dosimetry verification plans were created. When performing portal dosimetry, the source to image distance was kept at 154 cm. To verify portal dosimetry, a global gamma analysis was performed with a threshold value of 10% (doses <10% of the maximum dose were ignored during gamma analysis). The gamma coefficient was defined in the form of values (D = 3%, DTA = 3 mm, 97%), and if this case passed, the gamma value was ≤1. The measured fluence from the electronic portal imaging device signal in portal dosimetry is compared to a calibration unit that is related to monitor units and dose. With portal dosimetry, all of the composite images [Figure 5] of CSI plans were evaluated, yielding good passing criteria of >98%.

In halcyon with the initial fraction therapy, we can verify and evaluate daily treatment [Figure 6]. On each

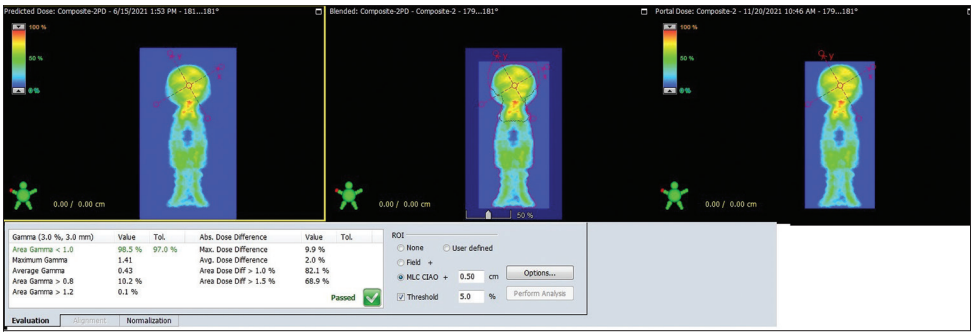

Figure 5: Portal dosimetry, all of the composite images of craniospinal irradiation plans were evaluated and yielding good passing criteria of >98%

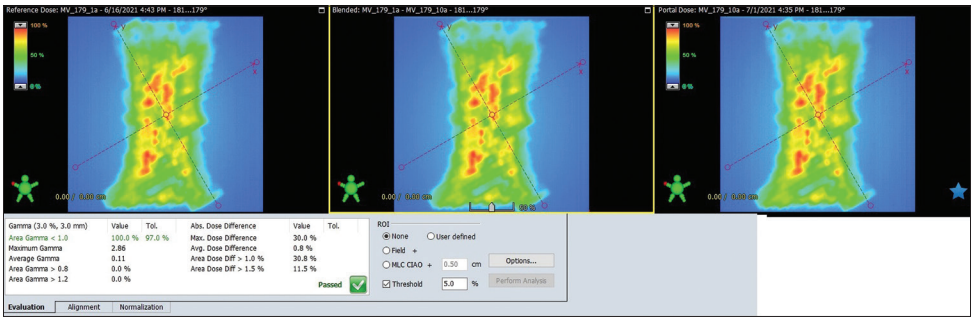

Figure 6: Evaluation of daily treatment with the first fraction treatment

fraction, the treatment field portal image was examined, and all fields were then combined to create a composite field. The image planar dose was compared to the first fraction (reference baseline) using gamma analysis, and it was found to pass with a gamma passing criteria of more than 98%.

Discussion

The quality of the treatment plan has improved as a result of new developments in treatment plans and techniques. The deployment of a VMAT CSI strategy was provided in this study, which needed no junction movement and facilitated CSI patient management. However, because of the smaller field size (28 cm × 28 cm) in Halcyon 2.0 compared to a C-arm linac (40 cm × 40 cm), we may use an extended field with multi-isocenter arcs and autofeathering optimization to provide a homogeneous and conformal plan that can be delivered in a matter of minutes. Using the autofeathering technique during optimization resulted in homogeneous and conformal doses to the PTV throughout the treatment field without causing excessive hot or cold spots near normal tissues.

Furthermore, pretreatment verification was demonstrated using portal dosimetry to assess dose distribution or fluence at the junction location. Portal dosimetry yielded a positive outcome, with field by field analysis yielding outstanding results for each field, and a composite image of all the fields being reviewed using the 3%/3 mm gamma analysis criteria with a 97% passing rate. Portal dosimetry also revealed the exit dose on a daily basis and compared it to the first treatment, revealing a high level of consistency and reducing setup errors. This demonstrates that physicists and oncologists can keep track of the patient, especially in the case of a complex treatment such as CSI or a huge tumor volume.

The VMAT CSI plan with multi-isocenter arcs in Halcyon 2.0 with no junction shift achieved the specified target volume while protecting the OARs, as demonstrated in this study.

Conclusions

CSI is a difficult treatment to plan and conduct from a technological standpoint. The remedy was straightforward to plan and deliver thanks to autofeathering optimization. CSI plan was created with no junction shift which resulted in homogeneous and conformal doses to the PTV. Daily treatment monitoring (which was done by comparing the daily fraction's fluence to the first fraction's fluence) was analyzed. The gamma analysis in the portal dosimetry composite image, which was utilized as a pretreatment verification, met all of the requirements and revealed a homogeneous and uniform junction dose.

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Conflicts of interest

There are no conflicts of interest.

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