PTV Margin for Reduced Normal Tissue Dose VMAT Cranionspinal Irradiation

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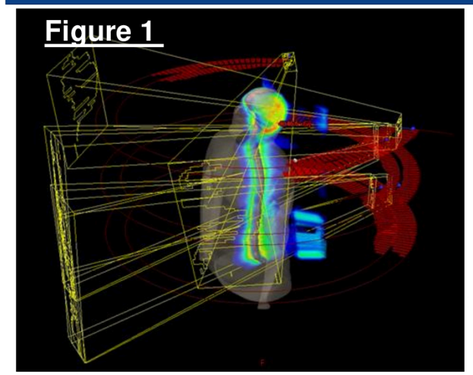
Introduction



Patients receiving craniospinal irradiation (CSI) often present with weakness or pain. The long treatment time of conventional CSI or CBCT guided VMAT-CSI increases the likelihood of motion and compromises treatment quality. We developed a 3-isocenter VMAT CSI technique with kV-image-guided setup with the aim to improve the plan quality and shorten the treatment time. We determined the required planning-target-volume (PTV) margins for future setups based on analysis of the kV images from the first treatments.

Materials & Methods

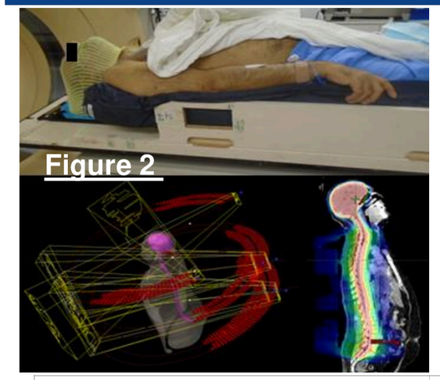
Ten patients treated with kV-image guided VMAT CSI were recruited. Patient setup began with kV images to straighten spine as needed. kV images were acquired at each isocenter, starting from the lower spine. In order to preserve the dose gradient at the matched region, no rotational adjustments were allowed. The daily kV images were analyzed to derive the inter-fractional shifts as systematic(Σ) and random(σ) errors in the antero-posterior(AP), lateral(LR), and superior-inferior(SI) directions. PTV margins were calculated for a minimum CTV dose of 95% for 90% of patients. The treatment time was analyzed and compared with previous conventional 3D CSI treatments.

Patient Setup

Figure 2 illustrates the patient setup and arc arrangement. Patient was setup in supine position and immobilized with a 3-point mask to secure the head position and a vacuum bag inside a body frame to secure the spine. Two butterfly arcs are employed for brain through cervical spine region; two posterior partial arcs are employed at each of the upper and lower spine isocenters. The arcs of each isocenter overlap in the superior inferior direction to optimize the dose gradient at the junction area and achieve a smooth, robust dose distribution.
Table 1 summarize the arc arrangements of VMAT CSI-planning.

Isocenter	Arc Angle	Collimator Angle	Avoidance Sector	Note
Brain	130-230, CCW	10	70-280	Y2 jaw extends about 1.5 cm from PTV superior border Y1 jaw set above shoulder
	230-130, CW	350	280-70	
Upper Spine	179-181, CCW	10	120-240	Y2 & Y1 jaw set to 18 cm
	181-179, CW	350	240-120	
Lower Spine	179-181, CCW	10	120-240	Y2 jaw set to 18 cm Y1 jaw extends at least 1.5 cm from PTV inferior border
	181-179, CW	350	240-120	

Results and Discussion



Setup Error at Individual Isocenters: Figure 3 shows the frequency of residual setup error after the initial couch shift made using the kV-image-guidance. The immobilization device and daily kV-image guidance achieved average setup error <1 mm for all isocenters and directions. However, the frequency, direction and the magnitude of the residual setup errors appeared to be isocenter-specific. Brain isocenter has smaller residual setup error than spine isocenters. This is due to the 3-point head immobilization mask. For the spine isocenters, the setup error in LR direction is more commonly seen and 26%/15% cases exhibited more than 2 mm lateral shifts in upper/lower spine isocenters, respectively.

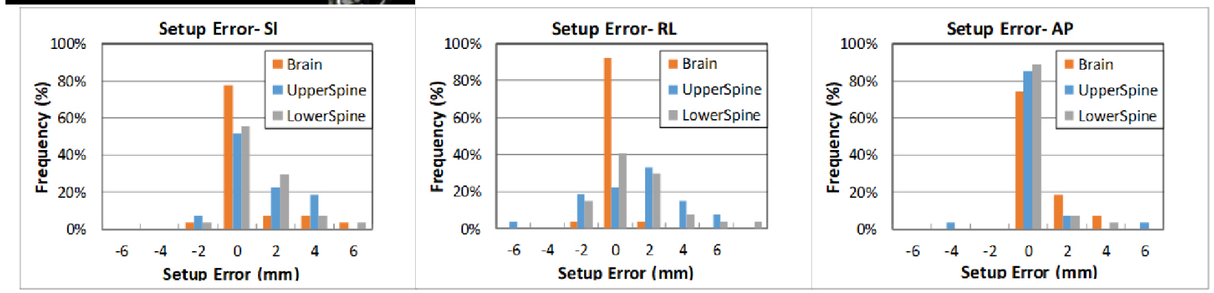


Figure 3

PTV Margin: Table 2 summarizes the parameters of margin calculation based on the Van Herk's method:
PTV Margin = $2{\cdot}5\sum + 0{\cdot}7\sigma$.
where $\sum$ and σ represents the systematic error and random error, respectively. The margins are asymmetric and isocenter specific (range 0.7-2.2 mm).

Table 2

	Brain			Upper Spine			Lower Spine		
	SI	RL	AP	SI	RL	AP	SI	RL	AP
M(mm)	0.4	-0.1	0.4	0.6	0.5	0.1	0.5	0.7	0.1
∑ (mm)	0.5	0.2	0.5	0.7	0.5	0.4	0.4	0.3	0.1
σ(mm)	0.6	0.3	0.6	0.8	1.4	1.1	0.8	1.2	0.6
Margin (mm)	**1.7**	**0.8**	**1.7**	**2.2**	**2.2**	**1.7**	**1.5**	**1.6**	**0.7**

Treatment Time: Comparing to conventional 3D CSI treatment, the kV-image-guided VMAT CSI ***reduced the treatment time by 45% for the first fraction***, which requires imaging at all isocenters for both methods, and by ***12% for the subsequent fractions***, despite the VMAT CSI imaging all isocenters while the conventional method only imaged the brain isocenter. By applying the PTV margins determined in this work, we expect to reduce the requirement of kV images on all isocenters to only the lower spine isocenter for non-initial fractions, shortening their treatment time by a total of 25%.

Conclusions

kV-image-guided VMAT CSI was shown to be more efficient. kV-image acquisition and patient alignment starting from the lower spine isocenter is more efficient since this area is relatively more unstable than the brain isocenter. Potentially, only the lower spine needs to be imaged after initial setup, further reducing on table time. Exact PTV margins derived allow refining the optimization to spare more normal tissue.