Quantifying the Shift Uncertainty in Daily Image Guidance and Its Dosimetric Significance for Head and Neck IMRT

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Purpose/Objective

Uncertainty in image registration (or shift determination) is one of the key residual errors in image-guided radiotherapy (IGRT) for head and neck cancer. Our goal is to quantify the uncertainty in image-guided shift determination and evaluate its dosimetric significance.

Materials/Methods

Retrospective daily IGRT 2D matching setup processes were performed for ten patients using a commercial off-line review program. Four bony landmarks in three distinct regions for image registration were chosen: the sella turcica and the bony nasal septum, C2 and C5 vertebral bodies (Figure 1). The acquired daily kV radiographs were registered to DRR's based on each of the four landmarks. This led to three possible directional shifts from which we defined the uncertainty of the shift determination. The average of the uncertainty in daily shifts for each patient was calculated. Post-shift plans were generated by incorporating these uncertainty values. Comparison of these post-shift plans with the original plans demonstrates the dosimetric impact.

Figure 1: The four landmarks are bony nasal septum. sella turcica, dens/body of C2, and spinous process/body of C5 which represent three distinct geographical regions color-coded on both the AP and lateral films.

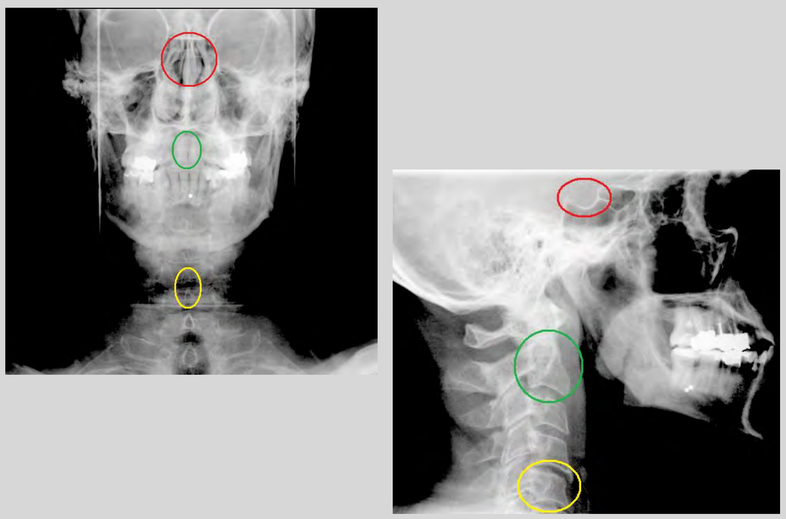
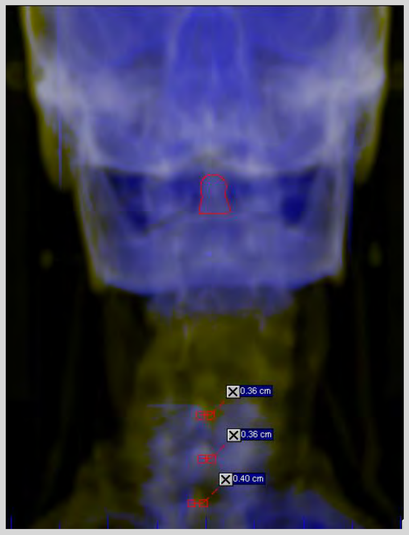
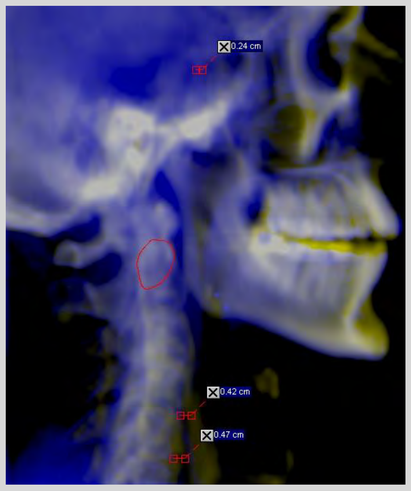


Figure 2: AP and Lateral kV films blended with DRR's for daily IGRT. The DRR is represented in yellow and the kV film is represented in blue. Measurements reveal registration errors due to image registration in a distinct geographic region.



AP Image: These blended images are registered to the dens, contoured in red. Note the lateral registration errors at multiple inferior cervical spinous processes.

Lateral Image: These blended images are registered to the body of C2, contoured in red. Note the anterior/posterior registration errors at the sella, the body of C5, and the body of C6.



Results

In seven out of the ten patients, the largest uncertainty is in the anterior/posterior direction (S_{AP}). Three patients have 3 mm or larger uncertainties. For all patients, the uncertainty in the superior/inferior direction (S_{SI}) are smaller than 1.0 mm. The median of $S_{AP,}$ S_{Lat} and S_{SI} are 2.5 mm, 2.0 mm and 0.4 mm respectively. These uncertainties translate to a deviation in dose to critical structures. The largest differential doses to the spinal cord and parotids are 5.5 Gy and 4.1 Gy respectively.

Table summarizing dosimetric impact of shift uncertainty

Dose Uncertainty (Gy)	Brainstem dose max	Spinal cord dose max	Parotids mean dose
Patient 1	9.1	5.5	3.6
Patient 2	0.7	1.0	4.0
Patient 3	0.9	2.3	1.2
Patient 4	3.5	3.5	0.7
Patient 5	1.1	1.1	0.4

Conclusions

We have quantified the shift uncertainty in daily image guidance when using different bony landmarks. Our results confirm the dosimetric impact on head and neck IMRT. This uncertainty can be larger than any other factors of residual error, such as mechanical stability of the on board imager (OBI) and intra-fractional patient motion. These positional variations should be considered when designing treatment margins and when choosing bony landmarks for daily image-guided shifts.

References

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Supported, in part, from a generous gift by the William Moss-Kenneth Stevens Resident Research Fund