The effect of shoulder variation on IMRT and SmartArc for head and neck cancer

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Introduction

Patient positioning and immobilization is essential in radiation therapy, particularly with IMRT and VMAT which include sharp dose gradients to spare tissues surrounding the target. Although extensive effort is spent in positioning and immobilization the patient, this is almost exclusively limited to accurate isocenter setup; the position of the body away from isocenter is often ignored. Nevertheless, such distant body positions may also have an impact on the delivered dose distribution. For head and neck radiotherapy, or other treatments involving the low neck, the position of the shoulders may be of particular concern. Their position is generally not considered when setting up the patient each day. However, without any displacement of isocenter, the shoulders can still be in a position different from the one in the treatment plan.

Purpose

First, to determine an average and maximum displacement of the shoulder relative to isocenter over the course of treatment. Second, to establish the dosimetric effect of shoulder displacements relative to correct isocenter alignment on the dose delivered to the target and the surrounding structures for head and neck cancer patients.

Methods

The frequency of shoulder shifts of various magnitudes relative to isocenter was assessed for 10 patients using CT on rails images. Patients were immobilized with a 5-point thermoplastic mask (Orfit). The location of the center of the right and left humeral head relative to isocenter (usually C2) was found daily, and was compared to the location of the humeral heads relative to isocenter on the initial simulation CT.

Methods – con't

Three Baseline head and neck IMRT and SmartArc plans were generated in Pinnacle [3] (Phillips, Fitchburg, WI) based on simulation CTs. The CT datasets (external contour and boney structures) were then modified to represent shifts of the shoulder (relative to isocenter) between 3 mm and 15 mm in the SI, AP, and LR directions (Figure 1). The initial plans were recalculated on the image sets with shifted shoulders. The dose changes to CTVs and critical structures were evaluated, and a set of daily shoulder shifts (Figure 2) were applied to the treatment plans to find the clinical effect of the shoulder variability.

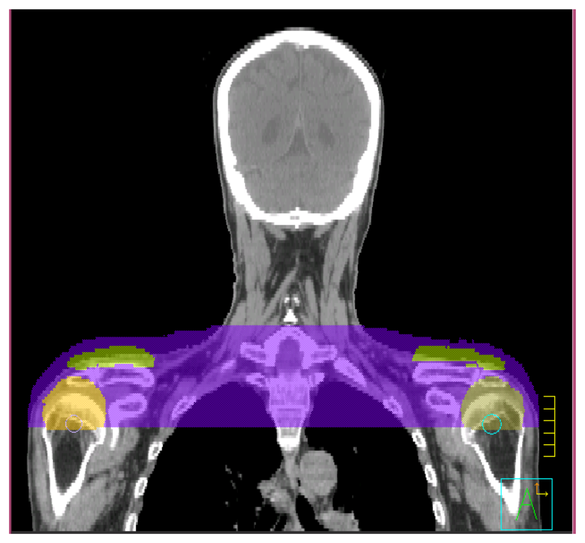

Figure 1: 15 mm superior shoulder shift. The body (purple) was shifted 15 mm superior as well as both humeral heads (orange and gold) and the shoulder bones (yellow). Areas where tissue has moved outside the CT image were forced to density 1.

Average shoulder shifts (cm)	RL	AP	SI	Net
Right Shoulder	0.26	0.38	0.31	0.55
Left Shoulder	0.26	0.38	0.31	0.55
Average Net				0.55

Table 1: Average shoulder shifts. The average shoulder shift in each direction for each shoulder, the average net 3D displacement for each shoulder, and an average 3D displacement for both shoulders.

Results

- The average shoulder shifts observed were 0.2-0.4 mm (Table 1). Maximum shifts could be as much as 2 cm.
- Eighty five percent of the observed shifts were less than 0.6 cm. Large shifts, greater than 1 cm, were observed in all directions except RL (Figure 3).

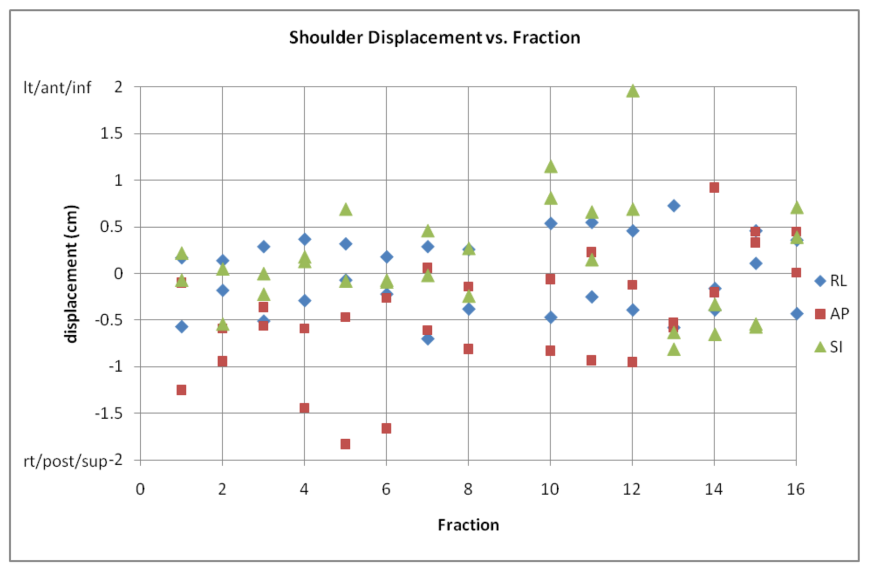

Figure 2: Shoulder Displacement vs. Fraction for each direction for a single patient. This patient's shifts were applied to clinical treatment plans to find the dosimetric effect of observed shoulder shifts.

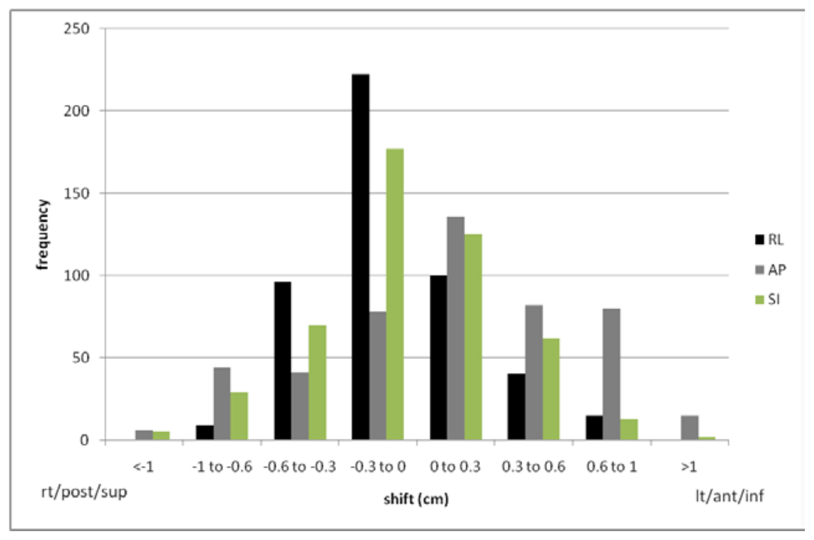

Figure 3: Total distribution of shifts in all 3 directions. 85% of shifts were less than 0.6 cm. The largest shifts greater than 1 cm were seen in the SI and AP directions.

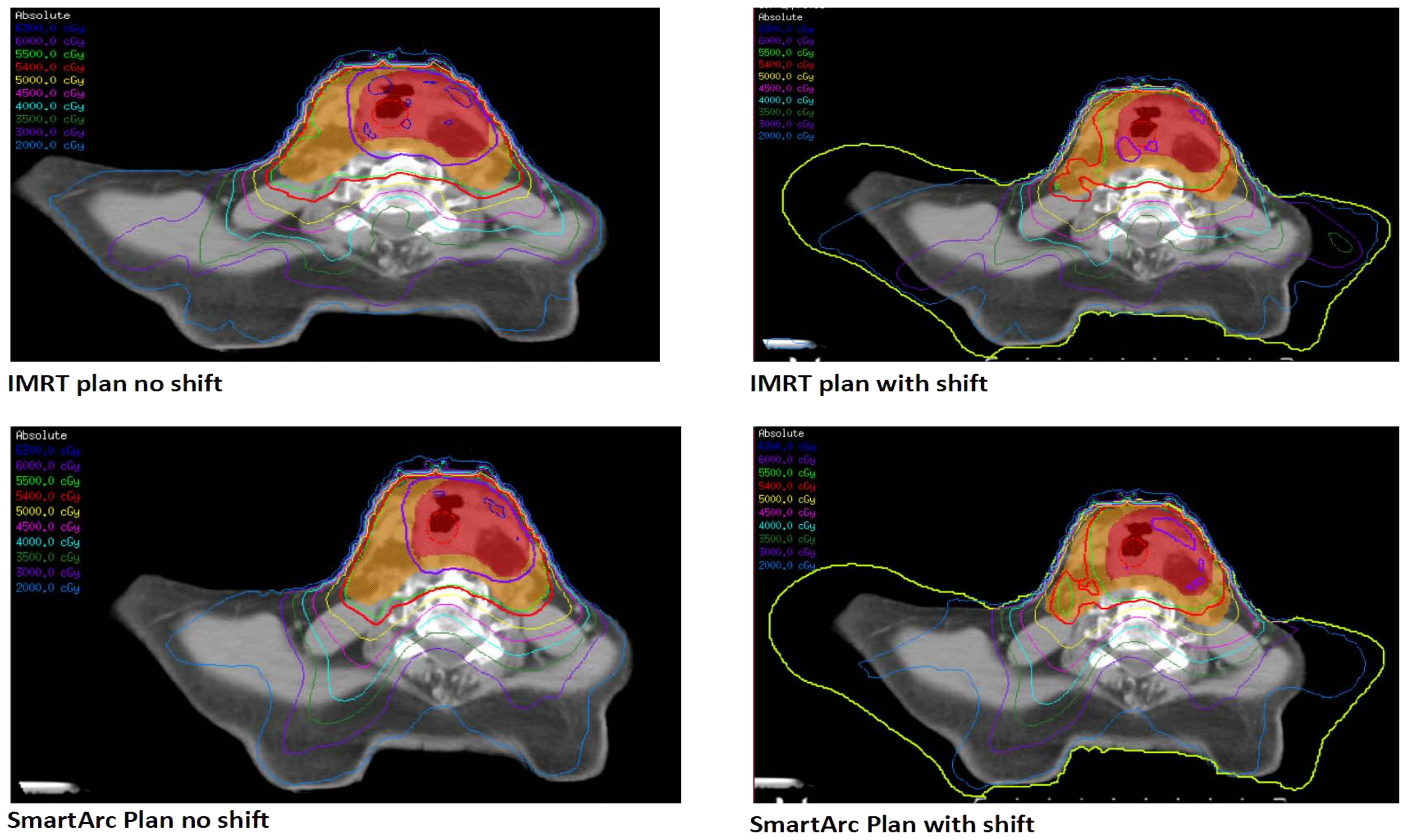

Figure 4: Isodose distributions before and after a 15 mm superior shoulder shift for IMRT (top) and SmartArc (bottom). Before the shift is on the left and after the shift is on the right. After the shift, the 60 Gy target (red) is no longer covered by the 60 Gy line (purple), which has all but disappeared. The 54 Gy target (orange) is covered by the 50 Gy line (thin yellow).

- Superior shifts resulted in the greatest loss of CTV volume coverage in lower neck targets. Large superior shifts resulted in loss of coverage by the 95% isodose line (Figure 4).
- Inferior shifts did not result in an increase in target coverage, but did show increased brachial plexus dose by 2 Gy (Table 2).
- Posterior shifts caused a loss of lower neck target coverage for IMRT plans but not VMAT.
- Large, anterior shifts did not cause an equal increase in coverage, however, they also caused an increase in brachial plexus dose by1 Gy (Table 2).
- When the set of observed shifts were applied to the treatment plans, the worst dose loss observed to 99% of a lower neck CTV was ~1 Gy.
- For the same set of shifts, the worst dose increase to 0.1 cc of the brachial plexus was 72 cGy.

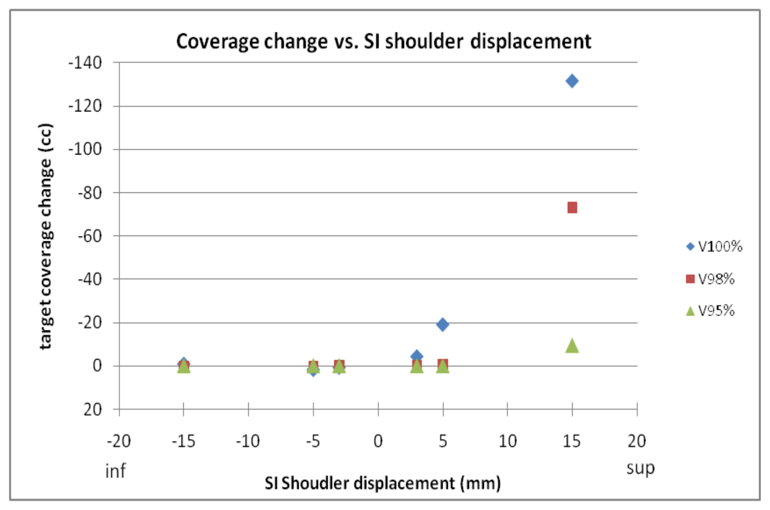

Figure 5: Target coverage change vs. shoulder displacement. Superior shifts (right side) show a large decrease in target coverage but inferior shifts (left side) do not show a gain in coverage. The effect does not average out.

Discussion

It is important to note that the coverage loss from superior and posterior shifts was not compensated for by an equivalent increase in coverage from inferior or anterior shifts. That is, the effect of the shift does not average out over treatment (Figure 5). The position of the shoulder each day has an impact on coverage. Table 3 shows the frequency of shoulder shifts required to cause important dose losses to low neck targets.

Brachial Plexus Dose Change							
Shift		*Patient 1*		*Patient 2*		*Patient 3*	
		IMRT	*Arc*	*IMRT*	*Arc*	*IMRT*	*Arc*
3 mm inferior	*max DVH dose (cGy)*	-1	-3	116	12	45	-29
	max 0.1 cc (cGy)	0	40	100	45	40	-90
5 mm inferior	*max DVH dose (cGy)*	5	-4	143	23	91	121
	max 0.1 cc (cGy)	0	40	130	60	90	97
15 mm inferior	*max DVH dose (cGy)*	49	372	203	186	218	259
	max 0.1 cc (cGy)	60	410	205	195	210	240
15 mm anterior	*max DVH dose (cGy)*	-1	1	125	10	109	-64
	max 0.1 cc (cGy)	0	0	100	0	100	-70
		red = increase greater than 50 cGy					

Table 2: Brachial plexus dose change. The maximum DVH dose and maximum dose to 0.1 cc of the brachial plexus is shown. Increases in dose over 50 cGy are highlighted in red.

		Frequency for losses of:		
SHIFT	*dose lost per fx*	*1 Gy*	*2 Gy*	*3 Gy*
5 mm sup	-3 cGy	33	--	--
15 mm sup	-11cGy	9	18	27
15 mm post	-5 cGy	20	--	--
5 mm sup + 15 post	-8 cGy	13	25	--
15 mm sup + 15 mm post	-16 cGy	6	13	19

Table 3: Dose losses per 2 Gy fraction for specified shifts and the frequency of shifts required to lose 1, 2 or 3 Gy to 99% of a lower neck CTV.

Conclusions

Large, superior shifts can lead to underdosing of lower neck targets if they occur frequently. Because up to 1 Gy can be lost from shoulder variation over the course of treatment, it may be necessary to include shoulder position in daily set up procedures for head and neck patients with lower neck targets. The losses demonstrated in this study may be particularly important for hypofractionated or single fraction treatments, therefore the position of the shoulder is of particular concern in these instances.

The 72 cGy increase in dose to 0.1 cc of the brachial plexus is not likely to cause harm because the max dose to the brachial plexus is not always in the same location within the structure, depending on shoulder position. The daily increase in brachial plexus dose was a few cGy, therefore the dose escalation required to receive a TD5/5 dose of over 60 Gy (3) on a single day was not observed.

References

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2. Court, Laurence E. et al. Clinical experience of the importance of daily portal imaging for head and neck IMRT treatments. *JACMP* 2008;9(3):26-33.
3. Chen, A.M. et al. Intensity-modulated radiotherapy increases dose to the brachial plexus compared with conventional radiotherapy for head and neck cancer. *Br J Radiol.* 2011 Jan;84(997):58-63.

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