Assessment of Interfraction Patient Setup for head-and-neck cancer Intensity modulated radiotherapy using multiple CT based image-guidance

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Abstract

Purposes: Image-guided radiotherapy is routinely used in conjunction with head-and-neck (H&N) IMRT. The purpose of this work is to assess interfraction patient localization using KV cone beam CT (KVCBCT), MV cone beam CT (MVCBCT) and MV fan beam CT (MVCT) for H&N cancer radiation.

Methods and Materials: Three CT-based IGRT modalities used for H&N IMRT were considered in this study: kV cone-beam (Synergy, Elekta), MV cone beam (MVision, Siemens), and MV fan beam (TomoTherapy). The daily variations in medialateral, craniocaudal and anteroposterior dimension were measured. The CTV-to-PTV margins were calculated using $2.0\sum +0.7\sigma$, where $\sum$ and σ were systematic and random positioning errors, respectively. The influence of patient characteristics (i.e., weight, weight loss) on interfraction patient setup was also investigated.

Results: A total of 3302 CT scans for 117 patients were retrospectively analyzed. Average inter-fraction displacements (±standard deviation) in the medialateral, craniocaudal and anteroposterior direction were 0.5±1.5, -0.3±2.0, 0.3±1.7 mm for KVCBCT, 0.2±1.9, -0.2±2.4 and 0.0±1.7 mm for MVCT and 0.0±1.8, 0.5±1.7 and 0.8±3.0 mm for MVCBCT. For MVCBCT, 30.2% of the patients had displacements greater than 3 mm in one translational direction, compared to 11.4% and 3.4% for MVCT and KVCBCT, respectively. On average, both systematic (in lateral and vertical direction) and random setup errors for MVCBCT were larger than KVCBCT and MVCT. Maximal uniform CTV-to-PTV margins were 3.0, 4.6 and 7.4 mm for KVCBCT, MVCT, and MVCBCT. No statistically significant difference of setup error with respect to translational direction was observed for the evaluated characteristics as well as during early, middle and late treatment courses.

Conclusion: CTV-to-PTV margin in H&N IMRT may be a function of the imaging modality. These data indicate that larger uniform margins of 5 and 7 mm may be appropriate for MVCT and MVCBCT, respectively, compared to a smaller margin of 3 mm for KVCBCT.

Keywords— Head-and-neck cancer, Image-guided radiotherapy (IGRT), KV cone beam CT (KVCBCT), MVCT (MVCT), MV cone beam CT (MVCBCT)

I. Introduction

Image guided radiotherapy is becoming a standard treatment for head-and-neck (H&N) cancer. However, the rapid dose falloff of IMRT plans generally requires accurate treatment delivery so accurate margins and patient immobilization are paramount. Image-guided radiotherapy (IGRT) has been developed and used to ensure accurate inter-fractional patient setup and dose delivery. The in-room x-ray imaging strategy and technology for IGRT include the use of kilovoltage (kV) or megavoltage (MV) cone-beam tomography (such as KVCBCT and MVCBCT) and fan-beam (such as MVFBCT). The purpose of this work is to analyze the daily localization using multiple IGRT techniques including Elekta KV cone beam CT (KVCBCT), Siemens MV cone beam CT (MVCBCT) and TomoTherapy MV fan beam CT (MVCT) for head-and-neck cancer radiation. A total of 3302 CT scans for 117 patients were retrospectively analyzed.

II. Methods and Materials

Three CT based IGRT modalities, including KVCBCT, MVCBCT and MVCT, were investigated in this study for 117 patients. A total of 3302 pre-treatment scans for H&N on a TomoTherapy, an Elekta Synergy accelerator or a Siemens accelerator respectively were investigated. For most of the H&N patients, the prescription is in the range of 45-66 Gy with fraction size of 1.8-2.2 Gy. Patient demographics are shown in Table 1. The influence of patient characteristics (i.e., weight, weight loss) on interfraction patient setup was also investigated.

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CTV-to-PTV margin

The derived setup deviations and internal organ motions were used to calculate the population-based CTV-to-PTV margin using the following equation: margin $2\Sigma + 0.7\sigma$ [1], where the systematic variation Σ is the standard deviation of the average set-up deviations per patient in the group of patients and the random variation σ the standard deviation of the day-to-day set-up positions, averaged over all patients in the group. A uniform margin, defined as the maximal deviations in the three directions (L/R, S/I and A/P), was considered in the calculation.

Table 1 Patient demographics.

Total patients (n)	117
KVCBCT (n1)	29
MVCT (n2)	35
MVCBCT (n3)	53

MVCBCT patients (n3)	53
Gender	
Male	30
Female	23
Age (yr)	
Range	22-93
Mean	58.8
Initial weight (lbs)	
Range	87.4-278.6
Mean	169.0
Weight change (%)	
Range	1.6-22.7
Mean	7.9

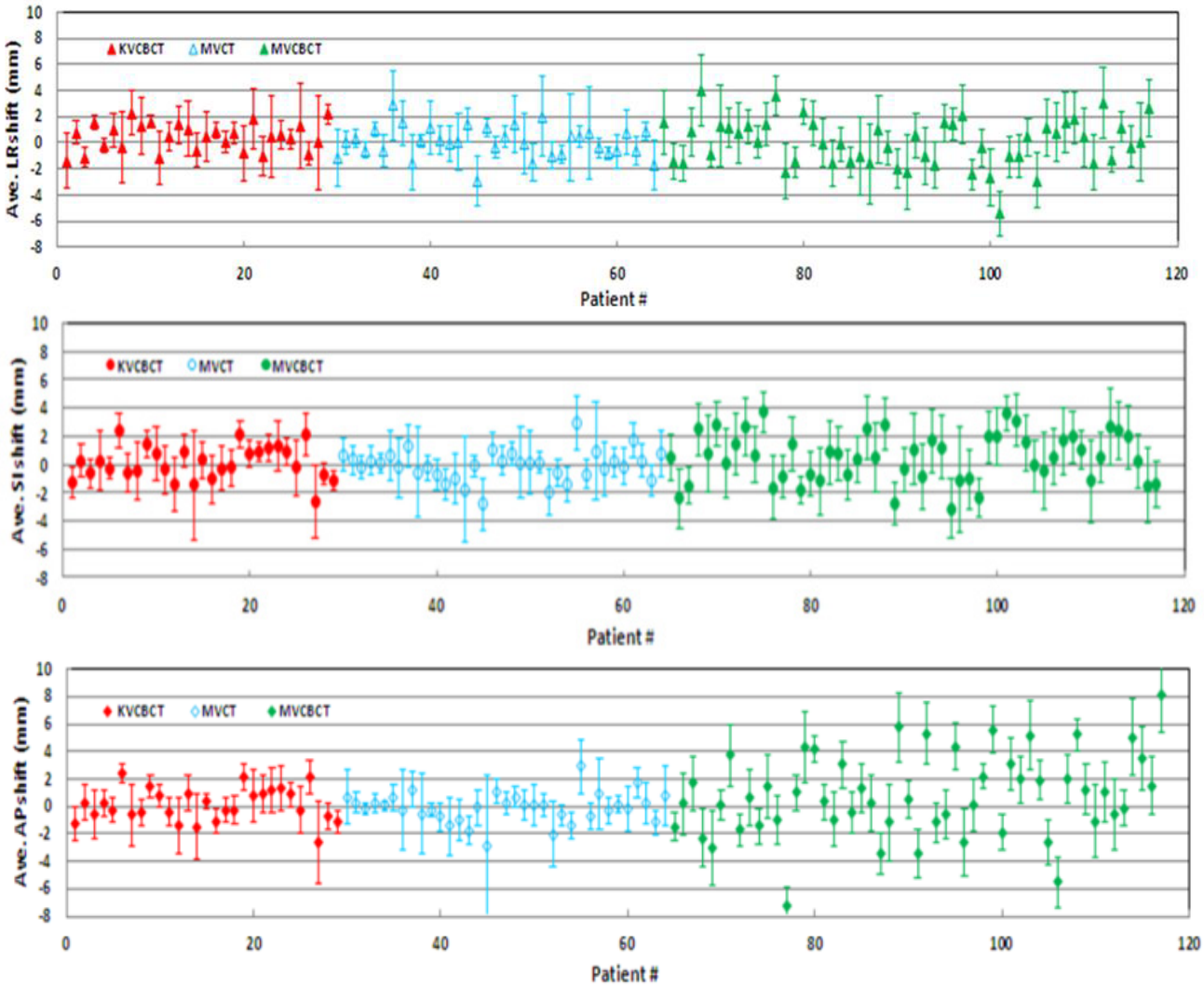
III. RESULTS

Table 2 Systematic variation (Σ), random variation (σ) and calculated CTV-to-PTV margin in medialateral (L/R), craniocaudal (S/I), and anteroposterior (A/P) directions. The rotational deviations were ignored in the margin calculation.

	KVCBCT			MVCT			MVCBCT		
Direction	Σ (mm)	σ (mm)	Margin* (mm)	Σ (mm)	σ (mm)	Margin* (mm)	Σ (mm)	σ (mm)	Margin* (mm)
L/R	1.0	1.0	2.8	1.0	1.4	3.1	1.9	1.9	5.1
S/I	1.5	1.3	3.0	1.8	1.4	4.6	1.8	2.0	4.9
A/P	1.1	1.2	3.0	1.0	1.2	2.9	3.0	1.9	7.3

*The calculated CTV-to-PTV margin using the equation: margin $2\Sigma + 0.7\sigma$ [1], where the systematic variation Σ is defined as the standard deviation of the average set-up deviations per patient in the group of patients and the random variation σ characterizing a certain patient group is then defined as the standard deviation of the day-to-day set-up positions, averaged over all patients in the group. A uniform margin, defined as the maximal deviations in the three directions (L/R, S/I and A/P) was considered in the calculation.

Figure 1 Average shifts and standard deviations in L/R, S/I and A/P direction using KVCBCT, MVCT and MVCBCT for head-and-neck patients. #1-29 were scanned with KVCBCT, #30- 64 were scanned with MVCT and #65-117 were scanned with MVCBCT.



IV. Conclusions

CTV-to-PTV margin in H&N IMRT may be a function of the imaging modality. These data indicate that larger uniform margins of 5 and 7 mm may be appropriate for MVCT and MVCBCT, respectively, compared to a smaller margin of 3 mm for KVCBCT.

References

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