Tumor Volume Delineation: a Comparison of Imaging Protocols for Lung Tumors

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Purpose

Stereotactic body radiation therapy (SBRT) is an efficient way of treating stage I/II non-small-cell lung cancer. During treatment planning, small margins are added to the tumors in order to decrease the volume of healthy tissue irradiated to such lethal doses and reduce the toxicity of surrounding critical structures. Hypofractionation involves highly focal doses and consequently requires accurate target delineation for treatment planning.

In this study, we investigated the impact of imaging protocols on tumor volume delineation by comparing the differences in tumor contours delineated on the free breathing (FB), four dimensional (4D), maximum intensity projection (MIP), average intensity projection (AIP), and slow-CT (SCT) images.

Methods and Materials

Data from ten patients who underwent SBRT of lung cancers were retrospectively investigated. For each patient, a FB CT and a 4D CT scan was acquired during simulation. Following the scan, MIP and AIP images were reconstructed. Since the 4D CT scan was acquired at a low pitch, a slow-CT scan was also reconstructed. These scans were repeated prior to each treatment, resulting in 48 CT data sets. The gross target volume (GTV) was delineated on FB, MIP, AIP, and SCT images and was compared with the internal target volume (ITV), which comprised the union of GTVs delineated on each phase of the 4DCT. To minimize contouring uncertainties, the same window level was used for each CT image.

Three evaluation metrics were used for contour comparison: GTV volume, overlap index (OI), and root-mean-squared (RMS) distance. OI measures the overlap ratio between two volumes. An OI of 1 indicates perfect overlap while an OI of 0 indicates no overlap. RMS distance describes how close two surfaces are. It measures the average squared distance of mismatches between two surfaces A and B along the radial line emanating from the center of mass of the volume encompassed by one of the surfaces. The smaller the RMS is, the closer the two surfaces are.

Results

Figure 1 shows the differences between the GTV_{FB}, ITV, GTV_{MIP}, GTV_{AIP}, and GTV_{SCT} superimposed on the FB CT for a representative patient with transverse, sagittal, and coronal views. The differences are observed predominately in the superior-inferior (SI) direction, a direction at which the tumor motion is the greatest in this case.

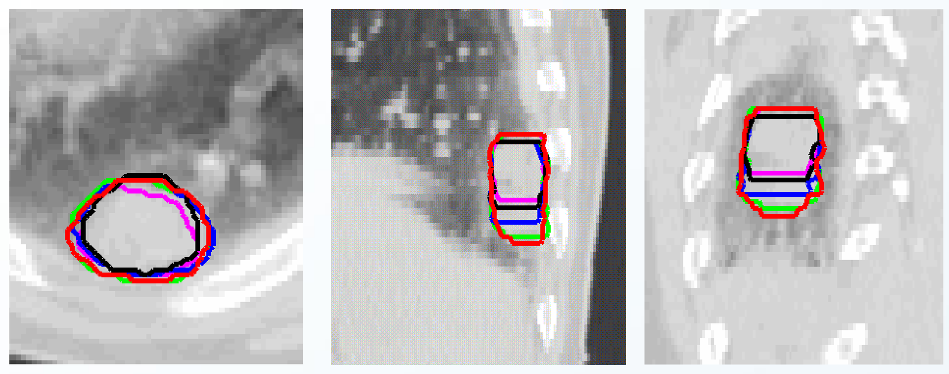

Fig. 1 GTV_{FB} (green), ITV (red), GTV_{MIP} (blue), GTV_{AIP} (purple), and GTV_{SCT} (black) shown on the FB CT for a representative patient with transverse (left), sagittal (middle) and coronal (right) views.

Figure 2 shows the variation of the normalized volumes of the GTV_{FB}, GTV_{MIP}, GTV_{AIP}, and GTV_{SCT} with respect to that of the ITV over the 48 sets of scans. In majority of the cases, GTV_{FB}, GTV_{AIP}, and GTV_{SCT} are at least 80% smaller than those of the ITV. On average GTV_{FB}, GTV_{MIP}, GTV_{AIP}, and GTV_{SCT} are 0.66 ± 0.13 ($p < 0.01$), 0.88 ± 0.08 ($p < 0.01$), 0.64 ± 0.13 ($p < 0.01$), and 0.64 ± 0.12 ($p < 0.01$) times smaller than ITV respectively. The difference between the ITV and each of the GTV_{FB}, GTV_{MIP}, GTV_{AIP}, and GTV_{SCT} are statistically significant.

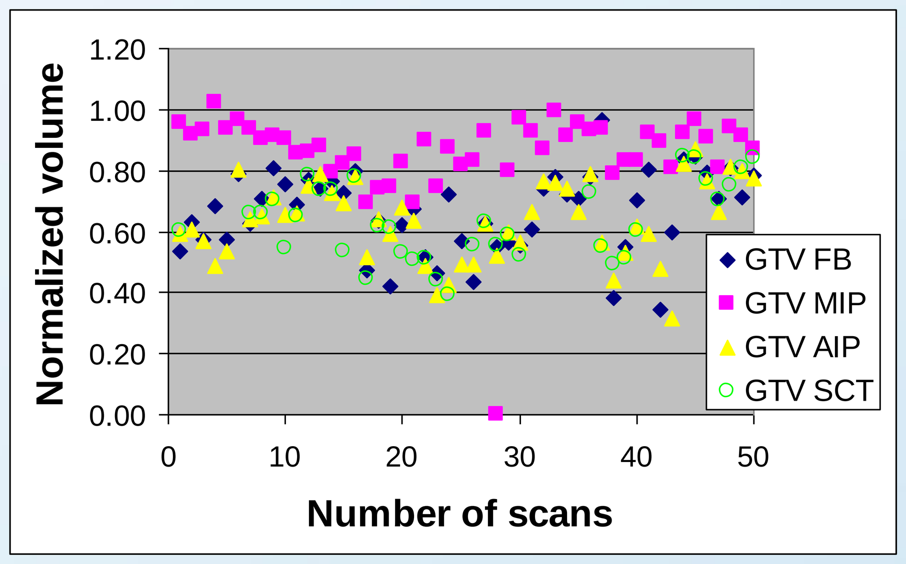

Fig. 2 Variation of the normalized volumes of the GTVFB, GTVMIP, GTVAIP, and GTVSCT with respect to that of the ITV over the 48 sets of scans

Results

Table I lists the OI between contour pairs of each combination of GTVFB, ITV, GTVMIP, GTVAIP, and GTVSCT averaged over 48 cases. OI was always near or below 80%. Table II lists the corresponding RMS distance of each combination of contour pairs. This distance is always near or above 0.3 cm.

Table I Overlap index between contour pairs averaged over the 48 cases

	GTV_{FB}	GTV_{MIP}	GTV_{AIP}	GTV_{SCT}
ITV	0.60±0.13	0.81±0.07	0.64±0.13	0.61±0.14
GTV_{FB}		0.62±0.14	0.71±0.43	0.68±0.15
GTV_{MIP}			0.67±0.12	0.65±0.14
GTV_{AIP}				0.80±0.11

Table II RMS distance (cm) between contour pairs averaged over the 48 cases

	GTV_{FB}	GTV_{MIP}	GTV_{AIP}	GTV_{SCT}
ITV	0.44±0.13	0.30±0.07	0.40±0.12	0.45±0.13
GTV_{FB}		0.34±0.06	0.35±0.09	0.36±0.10
GTV_{MIP}			0.39±0.17	0.41±0.11
GTV_{AIP}				0.28±0.04

Discussions

This study investigated the differences between contours delineated on various CT scans. GTV_{FB}, GTV_{AIP}, and GTV_{SCT} are statistically smaller than ITV. And most surprisingly, GTV_{MIP} is also statistically smaller than ITV. In our previous study, the intra-observer contouring uncertainty was found to be 82.2 ± 6.3% in OI, and 0.26 ± 0.03 cm in RMS distance.1 In this study, the OI between any contour pairs is less then the contouring uncertainty, at the same time, the RMS distance between any contour pairs is greater than the contouring uncertainty. Therefore contouring uncertainty itself cannot account for all mismatches among GTV_{FB}, ITV, GTV_{MIP}, GTV_{AIP}, and GTV_{SCT}.

Dependent on the protocol of each institution, either GTV_{FB}, or ITV, or GTV_{MIP} is frequently used to define the tumor size and shape for treatment planning. Since the difference between these structures is large, the corresponding treatment plans would also be different.

Conclusions

ITV is statistically larger than GTVMIP, and they are both larger than GTVFB, GTVAIP and GTVSCT. Even though GTVFB, GTVAIP and GTVSCT have similar size, the surface mismatch among them is still distinguishable.

References

1. J Wu, *et al*, "Do tumors in the lung deform during normal respiration? - An image registration investigation," *Int. J. Radiat. Oncol., Biol., Phys.* (in press)

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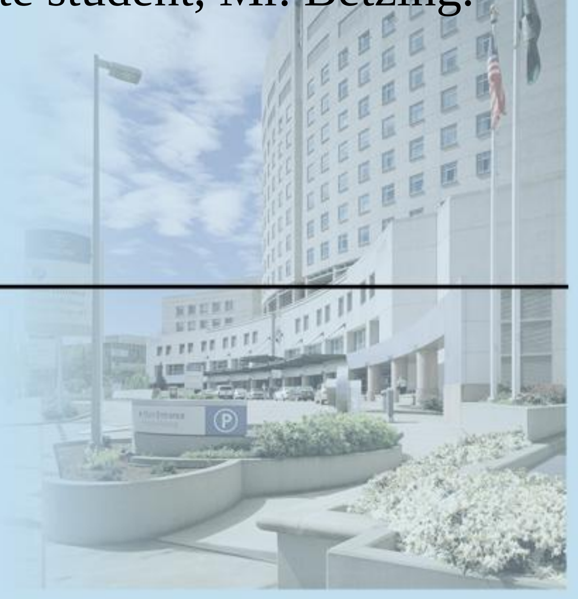

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