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.

Table I lists the OI between contour pairs of each combination of GTV_{FB}, ITV, GTV_{MIP}, GTV_{AIP}, and GTV_{SCT} 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.

Discussions

This study investigated the differences between contours delineated on various CT scans. GTV_{FB}, GTV_{MIP}, and GTV_{AIP} 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. In this study, the OI between any contour pairs is less than 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}.

Conclusions

ITV is statistically larger than GTV_{MIP}, and they are both larger than GTV_{FB}, GTV_{AIP} and GTV_{SCT}. Even though GTV_{FB}, GTV_{AIP} and GTV_{SCT} have similar size, the surface mismatch among them is still distinguishable.

References


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