Comparison of Lung Cancer Target Definition Strategies in Stereotactic Body Radiotherapy

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Purpose

Stereotactic body radiation therapy (SBRT) is an efficient way of treating early stage non-small-cell lung cancer. Due to the tight margins and rapid dose gradients, SBRT of the lung requires highly accurate tumor volume definition. In this study, we investigated various target definition strategies and their dosimetric impacts.

Methods and Materials

Seven patients who received SBRT for lung cancer were studied. For each patient, a free breathing (FB) CT and a 4D CT were acquired. Following the scans, a maximum intensity projection (MIP), an average intensity projection (AIP) and a slow CT (SCT) images were reconstructed. Gross target volumes (GTVs) delineated on the FB, MIP, AIP, and SCT images were compared with the internal target volume (ITV) produced with the union of GTVs delineated on the 4D CT. Three metrics were used for comparison: volume, overlap index (OI), and root mean squared distance (RMS). To further investigate the dosimetric impact of these contouring strategies, five SBRT plans were created on the FB CT based on the GTVs and ITV delineated above. Planning target volumes (PTVs) were created by adding either a 0.5 cm transverse plus a 1.0 cm superior inferior margin to the GTV_{FB}, GTV_{AIP}, and GTV_{SCT}, or a uniform 0.5 cm margin to the ITV and GTV_{MIP}. The prescribed dose was 60 Gy over 3 fractions to the 85% isodose line. For each plan, the corresponding 4D dose was calculated using deformable image registration. The 4D doses were analyzed and compared in terms of tumor D100 (minimum dose received by 100% of GTV) and lung V20 (volume receiving $\geqslant$ 20 Gy).

Results

On average the volumes of ITV, GTV_{MIP}, GTV_{AIP}, and GTV_{SCT} were 1.7 $\pm$ 0.5 (p = 0.03), 1.3 $\pm$ 0.3 (p = 0.43), 0.9 $\pm$ 0.2 (p = 0.28), and 0.9 $\pm$ 0.2 (p = 0.36) times that of GTV_{FB}. The volumes of the corresponding PTVs were 1.1 $\pm$ 0.2 (p = 0.89), 0.9 $\pm$ 0.2 (p = 0.21), 0.9 $\pm$ 0.1 (p = 0.20), and 0.9 $\pm$ 0.1 (p = 0.29) times that of PTV_{FB}. The corresponding OI and RMS were 57%, 57%, 58%, 60% and 0.4, 0.3, 0.4, 0.4 cm, respectively, with respect to GTV_{FB}.

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.

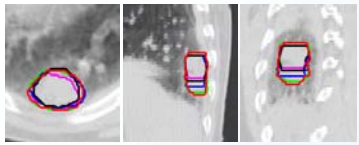

Fig. 1 GTV_{FB} (green), ITV (red), GTV_{MIP} (blue), GTV_{AIP} (purple), and GTV_{SCT} (black) shown on the FB CT for a representative patient with transverse (left), sagittal (middle) and coronal (right) views.

Figure 2 shows the normalized target volume and normalized PTV volume with respect to the GTV_{FB} and PTV_{FB} respectively for the 7 cases.

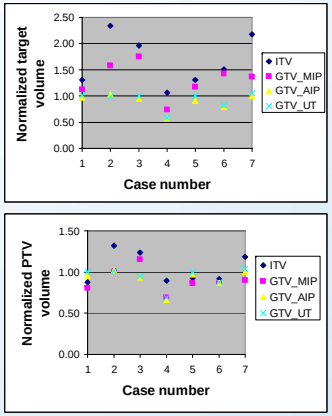

Fig. 2 Normalized target and PTV volumes with respect to GTV_{FB} and PTV_{FB} respectively.

Results

Figure 3 shows the tumor D100 (Gy) and V60 (%) of the 4D dose for the 7 cases. The tumor D100 of the ITV and GTV_{MIP} based plans was 3.0 $\pm$ 4.0 Gy (p = 0.09) and 0.9 $\pm$ 4.5 Gy (p = 0.61) above that of the GTV_{FB} based plan, while the tumor D100 of the GTV_{AIP} and GTV_{SCT} based plans was 2.8 $\pm$ 6.0 Gy (p = 0.26) and 0.8 $\pm$ 4.1 Gy (p = 0.61) below that of the GTV_{FB} based plan.

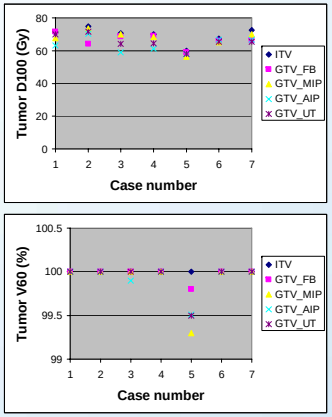

Fig. 3 Tumor D100 (Gy) and V60 (%).

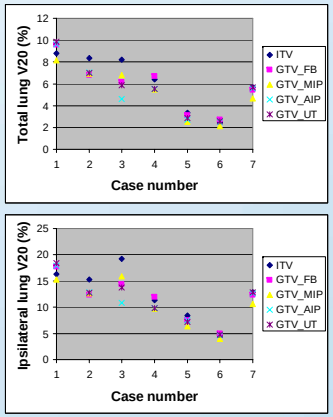

Fig. 4 Total lung and ipsilateral lung V20 (%).

Results

Figure 4 shows the total lung and ipsilateral lung V20 of the 7 cases. Compared with the GTV_{FB} based plan, the total lung V20 of the ITV based plan was 0.4 $\pm$ 1.0% (p = 0.36) absolute higher, while that of the GTV_{MIP}, GTV_{AIP}, and GTV_{SCT} based plans was 0.5 $\pm$ 0.7% (p = 0.09), 0.4 $\pm$ 0.7% (p = 0.17), and 0.2 $\pm$ 0.5% (p = 0.44) absolute lower.

Discussions

This study investigated the differences of various target definitions. GTV_{FB}, GTV_{AIP}, and GTV_{SCT} are statistically smaller than ITV and GTV_{MIP}. Even though only 5mm uniform margin, accounting for setup uncertainty, is added to the ITV when creating the PTV, on average, the PTV volume of the ITV based plan is still the biggest.

The 4D doses calculated for each plan showed that all plans could provide sufficient dose coverage for the tumor. As for the lung dose, either the ITV based plan or the GTV_{FB} based plan would deliver a higher dose, which is due to the relatively large PTV used in these two plans. However, the distinction in lung V20 among the five plans was statistically small.

Conclusions

Target volumes delineated with the knowledge of tumor motion (ITV, GTV_{MIP}) are larger than those delineated without that information (GTV_{FB}, GTV_{AIP}, GTV_{SCT}). However the margin used to create the PTV for the former cases is smaller than that used for the latter cases. Therefore, even though target definitions depend on imaging protocols, the difference in tumor and lung dose coverage is insignificant.

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