Dosimetric Impact of Five Tumor Delineation Strategies in Stereotactic Body Radiation Therapy for Lung Cancer

Jianzhou Wu[1,2], PhD, Christopher Betzing[2], Apiaradee Srisuthep[2], MD, Martin Fuss[2], MD
[1]Department of Radiation Oncology, Swedish Cancer Institute, Seattle, WA 98104
[2]Department of Radiation Medicine, Oregon Health and Science University, Portland, OR 97239

Purpose

The hypofractionated nature of Stereotactic body radiation therapy (SBRT) is such that it necessitates highly accurate tumor volume delineation. Traditionally the gross target volume (GTV) has been delineated on the free breathing (FB) CT. However, this contour does not reveal tumor motion information. On the other hand, contouring on the 4DCT image sets can reveal the extent of tumor motion over a respiration cycle. Unfortunately, this is very time consuming. Recently new post-processing techniques have been introduced into clinic use. One can synthesize maximum intensity projection (MIP), average intensity projection (AIP), and slow-CT (SCT) images from the 4DCT scans. Contouring on these synthetic CT images has become a common practice in radiation therapy.

In this study, we retrospectively investigated target dose coverage of five lung SBRT treatment plans. The tumor contour was delineated either on FB CT, 4DCT, MIP CT, AIP CT, or SCT images. Our purpose was to investigate which plan has appropriate tumor dose coverage when tumor motion is fully considered.

Methods and Materials

Seven patients who had previously undergone SBRT for lung cancer were retrospectively investigated. For each patient, a free breathing (FB) CT and a 4DCT were acquired. Based on the 4DCT scans, three post-processing CT images were reconstructed: maximum intensity projection (MIP), average intensity projection (AIP), and slow-CT (SCT) images. The gross target volumes (GTVs) were delineated on the following CT image data sets: GTV_{FB} on FB CT, $GTV_{0\%}$, $GTV_{10\%}$, …, $GTV_{90\%}$ on 4DCT, GTV_{MIP} on MIP CT, GTV_{AIP} on AIP CT, and GTV_{SCT} on SCT. The GTVs delineated on the 4DCT were combined to create the internal target volume (ITV). To minimize contour uncertainties, the same window level was used for all tumor delineations.

Methods and Materials

Five treatment plans were created based on the GTVs obtained above. The corresponding planning target volumes (PTVs) were created by adding either a 0.5cm transverse margin plus a 1.0cm superior-inferior margin to the GTV_{FB}, GTV_{AIP}, and GTV_{SCT}, or a uniform 0.5cm margin to the ITV and GTV_{MIP}. All the plans were created on the FB CT with tissue homogeneity assumption (per the RTOG 0236 protocol). The prescribed dose is 20 Gy per fraction for a total 3 fractions. Plans were normalized such that 60 Gy was prescribed to the 85% isodose line.

For each plan, the corresponding 4D dose was calculated through deformable registration of the 4DCT images. The dose recalculation on each 4DCT images was performed with tissue heterogeneity correction. The 4D doses were analyzed and compared in terms of tumor D100 (minimum dose received by 100% of the tumor), tumor V60 (percent volume of the tumor receiving at least 60 Gy), lung V20, and mean lung dose (MLD).

Results

Table I lists information on tumor volumes, locations, and 3D motion amplitudes for the 7 cases used in this study. Figure 1 shows the target and PTV volumes used in each plan. All the volumes were normalized to the GTV_{FB} and PTV_{FB}. On average the volumes of the ITV, GTV_{MIP}, GTV_{AIP}, and GTV_{SCT} are 1.7 ± 0.5, 1.3 ± 0.3, 0.9 ± 0.2, and 0.9 ± 0.2 times that of GTV_{FB}. While the volumes of the PTV_{ITV} (PTV formed from ITV), PTV_{MIP}, PTV_{AIP}, and PTV_{SCT} are 1.1 ± 0.2, 0.9 ± 0.2, 0.9 ± 0.1, and 0.9 ± 0.1 times that of PTV_{FB}.

Figure 2 shows the tumor dose coverage in terms of D100 and V60 of the 5 plans over the 7 cases. all other cases have D100 over 60Gy for all the plans. Figure 3 shows the V20 of the ipsilateral lung and total lung of the 5 plans over the 7 cases. In most of the cases, either the ITV based plan or the GTV_{FB} based plan would deliver a higher lung dose.

Results

Table I Tumor volume at end-exhale ($GTV_{50\%}$), location, and 3D motion amplitude of the 7 cases.

	1	2	3	4	5	6	7
$GTV_{50\%}$ (cm^3)	15.1	3.9	9.5	10.1	4.1	0.9	1.9
Location	Left/sup	Right/mid	Left/inf	Right/inf	Left/sup	Right/mid	Left/inf
Motion (cm)	0.4	1.0	1.4	1.7	0.2	0.5	0.7

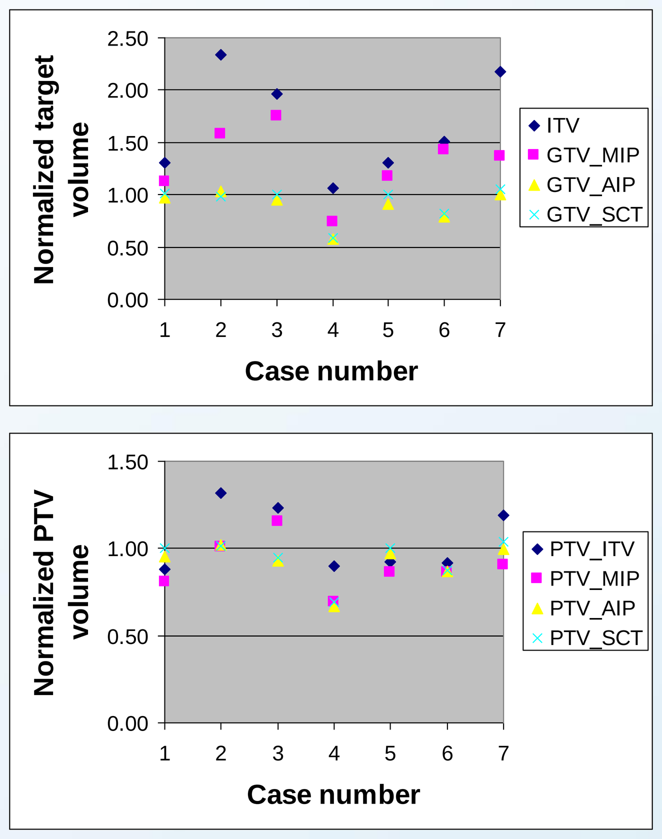

Fig. 1 Tumor (upper) and PTV (bottom) volumes normalized to those of the GTV_{FB} based plan for all plans over the 7 cases.

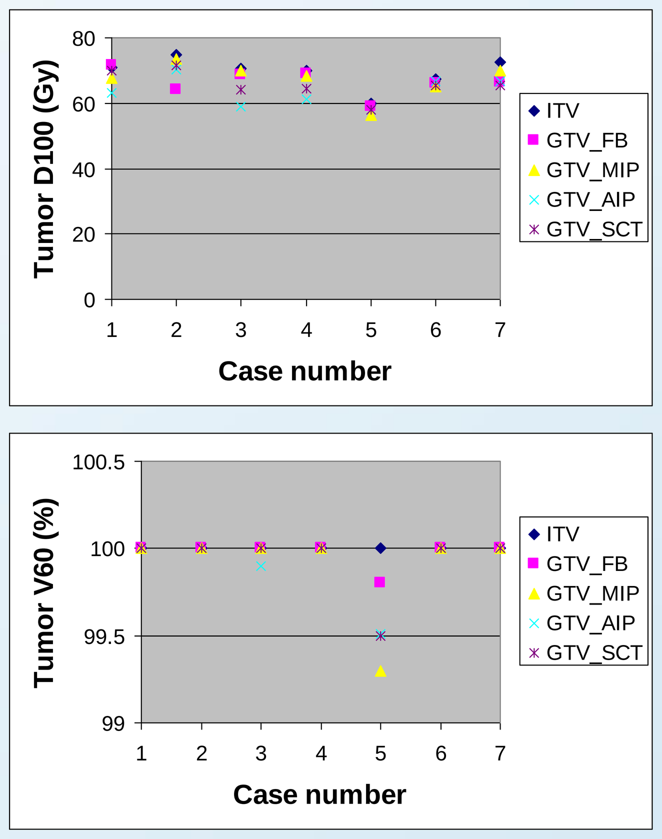

Fig. 2 Tumor D100 (upper) and tumor V60 (bottom) of the 5 plans over the 7 cases.

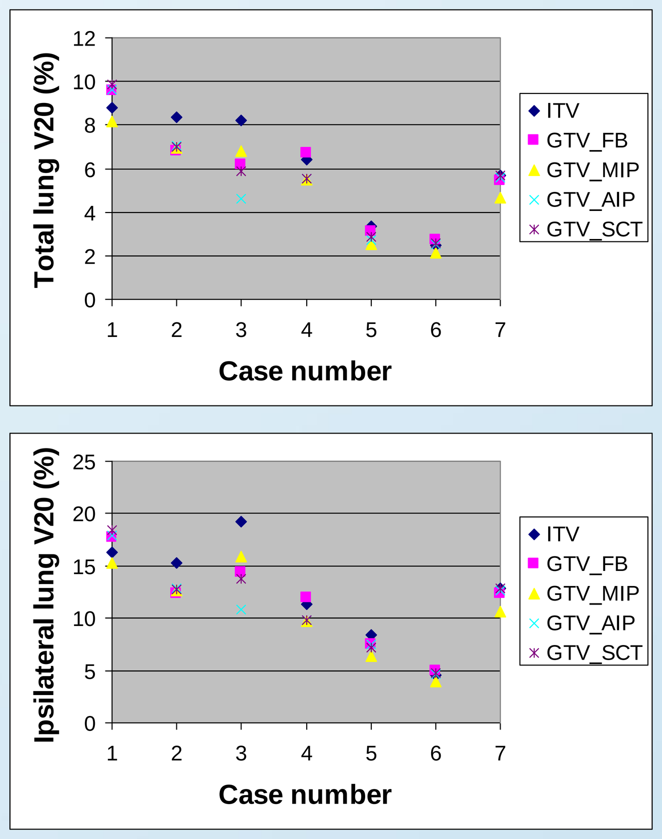

Fig. 3 Ipsi-lateral lung (upper) and total lung (bottom) V20 of the 5 plans over the 7 cases.

Discussions

Five plans created using different tumor volume delineation techniques were investigated retrospectively. 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.

In this study, the 4D dose was calculated on the CT images obtained at simulation. Which essentially assumed that tumor motion pattern is reproducible at each treatment and patient alignment is always perfect. However, in reality, these assumptions may not true. Fuss et al observed inter-fractional change in tumor motion pattern. As a result, the 4D dose distribution calculated on the daily 4DCT, if available, would be different from that calculated on the simulation 4DCT, which needs further investigation.

Conclusions

All plans can deliver equally well dose coverage to the tumor. The difference in lung dose among the five plans is also significantly small.

References

1. M. Fuss, et al., "Four-dimensional CT (4D-CT) image guidance for stereotactic body radiation therapy (SBRT)," Int. J. Radiat. Oncol., Biol., Phys. **72**, S440 (2008).

Acknowledgement

Thanks to a gift from Dick and Deanne Rubinstein for providing partial funding to the research undergraduate student, Mr. Betzing.

SWEDISH
CANCER INSTITUTE