Treatment planning in stereotactic body radiation therapy of lung cancer: which image set is appropriate for dose calculation?

Jianzhou Wu[1,*], PhD, Christopher Betzing[2], Tony He[2], PhD, 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

Patients underwent stereotactic body radiation therapy (SBRT) of lung cancer are normally four-dimensional (4D) CT scanned. As such, a couple of CT image sets are reconstructed for each patient. For example, except the free-breathing (FB) CT image, an average intensity projection (AIP) CT image set and an untagged slow-scan CT (SCT) image set are also normally reconstructed.

Traditionally lung SBRT treatment plans were performed based on tissue homogeneity assumption, the selection of CT image sets for treatment planning is not critical for dose calculation. More recently, new RTOG protocols on lung SBRT recommend the use of heterogeneity correction in radiation dose calculation. However, there is no specification in the selection of CT date set for treatment planning. Dependent on each institution's treatment protocols, treatment plans may be performed on the FB CT, AIP CT, or even on the SCT. The difference in Hounsfield unit (HU) among those CT image sets may lead to variation in tumor dose coverage. However, the investigation of dose variation for plans based on different CT image sets is rare. In this study, we respectively investigated the impact on dose coverage of treatments plans performed on FB CT, AIP CT, and SCT for lung SBRT. For each plan, 4D dose was calculated and compared with the dose coverage from other plans.

Methods and Materials

Five patients who had previously undergone SBRT for lung cancer were retrospectively investigated. For each patient, a FB CT and a 4DCT were acquired using a Brilliance 16-slice scanner (Philips Medical Systems, Cleveland, OH). Based on the 4DCT scans, two post-processing CT images were reconstructed: AIP CT and SCT. GTVs were delineated on these 4D CT images using the Eclipse treatment planning system (Varian Medical Systems, Inc. Palo Alto, CA) and combined to create the the internal target volume (ITV). The planning target volume (PTV) was created by adding a uniform 5 mm margin to the ITV.

Methods and Materials

Three treatment plans were created with tissue heterogeneity on FB CT, AIP CT and SCT respectively. The prescribed dose is 20 Gy per fraction for a total 3 fractions. For each plan, the corresponding 4D dose was calculated through three steps. First, the plan parameters were copied to individual 3DCT images of the 4DCT image sets, and dose was recalculated with the beam monitor unit (MU) identical to that used in the original plan. At the same time, a B-spline based deformable image registration was performed, which registered the 3DCT images from all other phases to the reference phase at end-exhale. The last step in 4D dose calculation was to map the recalculated doses on each individual 3DCT images to the reference CT image using the transformation metrics obtained from image registration. The mapped doses were added together to form the 4D dose where each mapped dose was weighted by a probability of observing the tumor inside its corresponding phase bin. 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 tumor properties for the 5 cases used in this study, which include the tumor volume location, and 3D motion amplitude. Figure 1 shows the tumor D100 of the three plans performed on AIP CT, FB CT and SCT for the five patients. Figure 2 shows the corresponding mean lung dose (MLD) of the total lung. The total lung V20 is demonstrated in Figure 3. The difference in tumor D100 is observable, but the differences in MLD and V20 are minimal.

Table II lists the average difference in terms of tumor D100, MLD and V20 of the total lung and ipsi-lateral lung among those three plans. Treatment plans based on AIP CT are likely to deliver highest tumor dose, while the treatment plans based on SCT deliver the lowest tumor dose. The difference in mean tumor D100 between the plans based on AIP CT and those on SCT is about 0.6 Gy. However the differences in tumor D100 among those three plans are statistically insignificant.

Results

At the same time, treatment plans based on SCT tend to deliver the minimal lung dose in terms of MLD and V20. While the treatment plans based on FB CT deliver the highest lung dose. The mean differences in terms of MLD and V20 of the total lung for treatment plans based on FB CT and those on SCT are 0.31 Gy and 0.14% respectively, though the difference is insignificant.

Table I Tumor properties of the five patients used in this study. RLL = right low lobe, RML = right middle lobe, LLL = left low lobe

Patient number	1	2	3	4	5
$GTV_{50\%}$ (cm^3)	126.7	1.9	3.85	10.1	41.3
Location	RLL	RML	RML	RLL	LLL
3D Motion (cm)	1.0	0.7	1.0	1.7	1.1

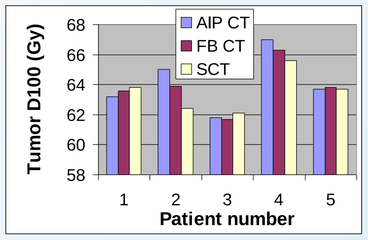

Fig. 1 Tumor D100 of the three plans performed on AIP CT, FB CT and SCT for the 5 patients

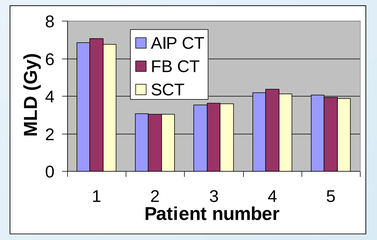

Fig. 2 Mean lung dose of the three plans for the 5 patients

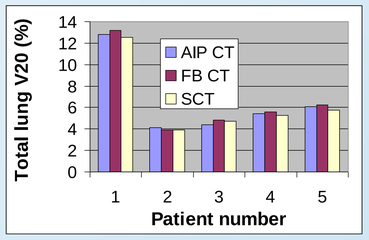

Fig. 3 Total lung V20 of the three plans for the 5 patients

Table II Mean differences in dose coverage among those three plans

	AIP CT – FB CT	AIP CT – SCT	FB CT – SCT
Tumor D100 (Gy)	0.28±0.61(p=0.363)	0.62±1.35 (p=0.361)	0.34±0.77 (p=0.379)
MLD (Gy)	-0.07±0.15 (p=0.390)	0.07±0.11 (p=0.221)	0.14±0.15 (p=0.107)
Lung V20 (%)	-0.19±0.26 (p=0.186)	0.13±0.25 (p=0.321)	0.31±0.27 (p=0.058)
MLD of ipsilateral lung (Gy)	-0.15±0.19 (p=0.141)	0.11±0.19 (p=0.265)	0.26±0.23 (p=0.059)
V20 of ipsilateral lung (%)	-0.35±0.53 (p=0.217)	0.29±0.51 (p=0.270)	0.64±0.7 (p=0.067)

Discussions

Treatment plans were created using heterogeneity correction on three different CT image sets: AIP CT, FB CT and SCT. Difference in CT HU among those CT image sets leads to variation in tumor and lung dose coverage. Treatment plans performed on AIP CT tend to deliver the highest tumor dose, while treatment plans performed on SCT are most favorable in sparing the lung. However the impact on tumor and lung dose coverage is statistically insignificant.

Traditionally treatment plans are performed on FB CT. In some institutions, both free-breathing CT scan and 4D CT scan may be acquired for patients treated with lung SBRT. While the 4D CT scan is used for target definition, FB CT image is used to perform treatment planning. This study shows that the difference in terms of tumor and lung dose coverage for treatment plans performed on either FB CT, AIP CT or SCT is indistinguishable, which indicates that the additional FB CT scan is unnecessary if it is only used for the purpose of treatment planning. In other words, the selection of CT image sets for treatment planning is not critical in lung SBRT.

Conclusions

Treatment plans performed on AIP CT, FB CT and SCT are statistically indistinguishable. The selection of the CT image sets used for treatment planning for lung SBRT is not critical.

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* Email: jianzhou.wu@Swedish.org

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