Results: The average breathing amplitude in our patient population was 8.70 ± 3.0 mm. The average period was 3.99 ± 1.0 seconds per breath. Both compared well with literature values.

Based on repeat CT data, DC was = 0.90 for group 1 (j) and (4). However, DC for group 2 (irregular periodicity), was only 0.83, which is significantly lower (p < 0.002). Computed volumes were nearer to expected volumes using AVE CT, but using AVE CT always leads to underestimation. Volumes computed in MIP CT reconstructions cover the expected volumes better, but there is a chance of overestimation of up to 20% in volume.

Conclusion: Even though 4D CT scanning has been around quite some time, this is one of the first studies to address the effects of clinically found breathing irregularities. The selected test data seem to be adequate for lung ca. patients, and selected types of irregularities are commonly seen by therapists operating CT scanner and linac.

The study indicates that irregular respiratory patterns introduce the element of “chance” in the position and size of delineated tumour volumes, depending on amount and type of irregularity. Therefore, it is recommended to always take into account effect of breathing pattern irregularity in scanning and treatment planning for lung tumours.

Since 4D imaging typically consists of scanning while tracking a marker position, the recommendation probably holds for every CT scanner used in radiotherapy, and possibly also for PET and MRI scanners.

PO-0918
Validation of freeware-based mid-ventilation CT calculation for upper abdominal cancer patients
S. Vieira1, J. Stroom1, K. Anderle2, B. Salas1, N. Pimentel1, C. Greco1, Fundação Champalimaud, Radiotherapy, Lisboa, Portugal 1GS Helmholtz, Center for Heavy Ion Research, Darmstadt, Germany

Purpose or Objective: Most institutes use the ITV approach to account for breathing motion into treatment planning, generally yielding too large treatment volumes. Recent publications showed that use of a mid-ventilation CT (midV-CT) could significantly reduce organ motion and therefore treatment volumes. However, the midV-CT is not available commercially yet. In this work we perform a marker-based validation of our open-source software to generate a midV-CT for upper abdomen cancer patients.

Material and Methods: Planning data from 12 upper abdominal cancer patients (8 liver- and 4 pancreatic patients) were used for this study. These patients were treated with the ITV approach using hypo-fractionated schemes (ranging from 5x7.5 Gy to 1x24 Gy). Each patient had a gold marker implanted close to the CTV center of mass (COM). 4DCT data consisted of 10 amplitude-based breathing phases (CT BrillianceTM, Philips). In our planning system (EclipseTM, Varian), the position of the marker was measured by hand for each breathing phase and patient. In the open-source medical imaging 3D-Slicer, B-spline deformable registration was used to register the plan CT and the different phases of the 4DCT. The resulting transformation matrices were then used by our 3D-Slicer modules to automatically generate the midV-CT and the COM motions of any planning volume or marker. Subsequently, the marker position in the midV-CT was compared to the average marker position in Eclipse. Furthermore, the Eclipse marker motion curves and amplitudes were compared with the marker and CTV motions from 3D-Slicer. Additionally, treatments plans were generated for one patient using the midV-CT and compared with our ITV-based clinical plan.

Results: The mean CTV volume was 24.7 ± 22.0 cc (1SD) and the mean marker to CTV COM distance was 12.7 ± 6.2 mm (1SD). The midV-CTs are generated by 3D-Slicer within 30 minutes using a PC. Motion validation results are shown in Table 1. Differences in the mean COM of the marker in Eclipse and in midV-CT are within 1 mm, indicating an accurate midV-CT generation by our software. Average amplitude differences are within 1 mm but Eclipse motions tend to be slightly larger, possibly due to the uncertainty of manually finding the marker in the 4D phases. Correspondingly, RMS differences between motion curves of Eclipse and 3D-Slicer were therefore 0.2-0.6 mm, whereas the RMS differences between marker and CTV motion in 3D-Slicer only 0.1-0.2 mm (Fig 1a).

The latter suggests that well-placed markers can estimate CTV motions. Fig 1b shows differences in dose volume histograms between the ITV and the midV-CT approach.

Table 1. Differences in the mean COM of the marker in Eclipse and 3D-Slicer

<table>
<thead>
<tr>
<th></th>
<th>Average COM (mm)</th>
<th>RMS (mm)</th>
</tr>
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<tbody>
<tr>
<td>Marker in Eclipse</td>
<td>0.1 ± 0.4</td>
<td>0.1 ± 0.4</td>
</tr>
<tr>
<td>Marker in 3D-Slicer</td>
<td>0.2 ± 0.6</td>
<td>0.2 ± 0.6</td>
</tr>
<tr>
<td>CTV in Eclipse</td>
<td>0.1 ± 0.3</td>
<td>0.1 ± 0.3</td>
</tr>
<tr>
<td>CTV in 3D-Slicer</td>
<td>0.2 ± 0.7</td>
<td>0.2 ± 0.7</td>
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</table>

Figure 1: (a) Breathing motion curves of marker and CTV for Eclipse (E) and 3D-Slicer (S) for patient 1. (b) Dose volume histograms using midV-CT and the ITV-based (based on the calculated midV-CT using clinical contours; the dotted line refers to the calculated midV-CT using clinical contours; the dotted line refers to the calculated midV-CT using clinical contours; and the dotted line refers to the calculated midV-CT using clinical contours).
Conclusion: Accurate midV-CT can be generated using freeware. This opens the prospect for its use in our clinical practice, allowing treatments in the upper abdomen with more adequate GTV-to-PTV margins. For lung cancer patients the approach should work even better due to the higher contrast images.

Poster: Physics track: (Quantitative) functional and biological imaging

PO-0919
Optimal respiratory gated FDG-PET for characterizing intra-tumour heterogeneity in lung cancer

J. Bussink1, W. Grootjans2, F. Titier3, C. Van der Vos4, D. Vriens5, C. Cheze Le Rest5, W. Oyen6, L.F. De Geus-Oei7, D. Visvikis8, E. Visser9

1Radboud University Medical Center, Radiation Oncology, Nijmegen, The Netherlands
2Radboud University Medical Center, Department of Radiology and Nuclear Medicine, Nijmegen, The Netherlands
3University Hospital Poitiers, Department of Nuclear Medicine-, Poitiers, France
4Leiden University Medical Center, Department of Radiation and Nuclear Medicine, Leiden, The Netherlands
5University Hospital Poitiers-, Department of Nuclear Medicine, Poitiers, France
6University of Brest, INSERM- UMR1101- LAtIM, Brest, France

Purpose or Objective: Radiotracer uptake patterns in FDG-PET through computation of textural features can be used to improve characterization of lung cancer lesions for disease prognostication and response monitoring and tumour delineation purposes. Respiratory motion artefacts cause lesion blurring resulting in loss of intra-tumour heterogeneity. We have investigated the effect of respiratory gating on the recovery of intra-tumour heterogeneity.

Material and Methods: FDG-PET/CT imaging was performed in 70 lung cancer patients. Amplitude-based optimal respiratory gating (ORG) was performed on bed positions covering the thorax. The duty cycle (percentage of the total PET data) used for image reconstruction of ORG images was 35%. Non-gated images were reconstructed using 126 seconds of PET data, yielding similar noise characteristics as ORG.

Results: Respiratory gating did not result in statistically significant differences in the heterogeneity parameters. Subgroup analysis revealed a significant effect of ORG on the heterogeneity parameters of lesions in the lower lobes. The mean increase for entropy, dissimilarity, ZP and HIE, considering lesions in the lower lobes was 1.3±1.5% (p=0.02), 11.6±11.8% (p=0.006) 2.3±2.2% (p=0.002), and 16.8±17.2% (p=0.006) respectively. For the centrally located lesions, the mean increase for entropy, dissimilarity, ZP and HIE was 0.58±1.7% (p=0.6), 5.0±19.0% (p=0.4) 0.59±4.0% (p=0.9), and 4.4±27.8% (p=0.4), respectively. Lesions in the upper lobes showed a mean increase of -0.35±1.8% (p=0.3), -1.0±7.7% (p=0.3), -0.4±2.7% (p=0.5), -1.7±13.2% (p=0.4), for entropy dissimilarity, ZP and HIE, respectively. There was no significant correlation between lesion volume and the change in parameters between non-gated and ORG images.

Conclusion: Results from this study indicate that ORG significantly impacts characterisation of intra-tumour heterogeneity, particularly for lesions in the lower lung lobes. This suggests that adequate management of respiratory motion artefacts is important for improving characterisation of intra-tumour heterogeneity in PET.

PO-0920
Early prediction of individual response in neo-adjuvant adaptive Radiochemotherapy for rectal cancer

R. Raso1, P. Passoni2, A. Palmisano3, C. Fiorino2, G.M. Cattaneo1, F. De Cobelli1, A. Esposito1, P. Mangi1, N. Slim1, N.G. Di Muzio2, R. Calandrino1

1San Raffaele Scientific Institute, Medical Physics, Milano, Italy
2San Raffaele Scientific Institute, Radiotherapy, Milano, Italy
3San Raffaele Scientific Institute, Radiology, Milano, Italy

Purpose or Objective: Developing a radiobiologically consistent model predicting individual outcome for rectal cancer patients (RCPs) treated with an adaptive boost approach during neo-adjuvant radiochemotherapy (RCH).

Material and Methods: Forty-two RCPs were treated within a prospective observational study. CH consisted of oxaliplatin (on days: -14, 0, 14) and 5-fluorouracil (from day -14 to end) being day 0 the start of RT. All patients were treated with Helical Tomotherapy (18x2.3Gy) with an adaptive concomitant boost technique delivering 3Gy/fr on the residual gross tumor volume (GTV) in the last 6 fractions (fr), based on MRI imaging taken at fr 9. GTVs were contoured by a single radiologist on axial T2 MRI images acquired for initial planning (V_PRE), at fr 9 for the adaptive planning (V_MID) and before surgery, after a median time of 8.9 weeks after the end of RCH (V_POST). Based on a Poisson-like tumor regression model and neglecting repopulation and inter-patient variability of the removal kinetics of killed cells, the parameter (1-ΔV(D))/V_PRE was taken as a surrogate of tumor control probability (TCP), where ΔV(D)=V_MID/V_PRE or V_POST/V_PRE, considering D at fr 9 (TCP_MID) or at the end of RCH (TCP_POST). The discriminative power of TCP_MID/TCP_POST in predicting the pathological complete remission (pCR, n=14) was assessed by the AUC of the corresponding ROC curves. Then, two-variables logistic (LOG) models including V_PRE and ΔV(D) as covariates were also considered and the ROC curves of the four models (TCP_MID/TCP_POST,LOG_MID, LOG_POST) were compared. In addition, an estimate of the residual cells at surgery (V_S) was robustly taken as the product of the pathologically assessed fraction of viable cells and V_POST. Spearman correlation rank test was used to evaluate the correlation between the models and V_S.

Results: All models showed a high discriminative power in predicting pCR (p-value=0.0001). AUCs for TCP_MID was 0.87 (specificity: 71.4%, sensitivity: 96.4%, best cut-off: 5.85), higher than TCP_POST (0.82), although the difference did not reach significance (p=0.18). TCP_MID/TCP_POST were also highly correlated with V_S (R=0.77 and 0.74,p<0.0001). Similar performances were found for LOG_MID/LOG_POST with AUC=0.90/0.87 and R=0.79/0.77. No significant differences were found when comparing TCP models against the corresponding LOG models.

Conclusion: A radiobiologically consistent model including early regression (TCP_MID) measured on T2-MRI images well predicts pCR and is strongly correlated with the estimated residual cells number after adaptive RCH; similar performances were obtained with a logistic model including V_PRE and V_MID/V_PRE. The corresponding models using V_POST showed a slightly, statistically not significant, worse