OC-0164

Integrate range shifting in immobilisation for proton therapy: 3D printed materials characterisation

S. Michiels1, N. Lammens1, A. D’Hollander2, K. Poels3, W. Crijns4, G. Defraene1, S. Nuys1, K. Haustermans1, T. Depuydt1

1KU Leuven, University of Leuven, Department of Oncology, Leuven, Belgium
2Ghent University, Department of Materials Science and Engineering, Ghent, Belgium
3Materialise NV, Department of BioMedical Engineering, Leuven, Belgium
4University Hospitals Leuven, Department of Radiation Oncology, Leuven, Belgium

Purpose or Objective: 3D printing technology is investigated for the purpose of patient immobilization during proton therapy. It potentially enables a merge of patient immobilization, bolus range shifting/compensator and other functions into one single patient-specific structure. Beside minimizing the lateral spread of the proton beam due to the removal of the air gap it also ensures the correct range shifting is present for each beam portal. Compared to a movable nozzle snout this reduces the risk of collision and shifting is present for each beam portal. Compared to a movable nozzle snout this reduces the risk of collision and treatment time, hence can increase cost-effectiveness of treatment. It potentially enables a merge of patient immobilization and structural changes induced by radiation damage. These data will serve as input for the design of 3D printed immobilization structure prototypes.

Material and Methods: In total 9 materials used in 4 different 3D printing production techniques were subjected to testing. Samples with a nominal dimension of 20x20x80mm were 3D printed. The actual dimensions of each printed test object were measured with a calliper. The samples were compression tested according to a standardized method (ASTM D695). The composition in terms of effective atomic number (Z_eff) and relative electron density (RED) to water was derived from dual-energy CT (DE-CT) data. The composition in terms of effective atomic number (Z_eff) and relative electron density (RED) to water was derived from dual-energy CT (DE-CT) data. The composition in terms of effective atomic number (Z_eff) and relative electron density (RED) to water was derived from dual-energy CT (DE-CT) data.

Results: The data of the different experiments are compiled in Table 1. Young’s moduli as low as 1 MPa and as high as 2582 MPa were seen. These experiments will be repeated after extensive radiation exposure to verify radiation hardness of the structural properties. The DE-CT decomposition yielded relative electron densities ranging from 0.62 to 1.20, and Z_eff from 6.06 up to 9.35. The calculated SPR ranged from 0.69 up to 1.21. The differences in range shifts of the obtained Bragg peaks were results of differences in SPR, and of deviations from the nominal 20 mm thickness due to printing technique geometrical tolerances. For 4 out of the 9 materials, a different orientation of the sample with respect to the beam incidence resulted in more than 5% difference in the obtained range shift. Measurements using a Bragg-peak ionization chamber will be included allowing a water equivalent thickness measurement validation of the material decomposition method with DE-CT.

Conclusion: 3D printed materials exhibit a wide variation in structural and radiological properties. The quantification of these characteristics can be used for optimal material selection for the design of a 3D printed immobilization structure for proton therapy with integrated range shifting.

Proffered Papers: RTT 2: Improving quality for breast cancer treatments

OC-0165

Deep inspiration breath hold - can it be detrimental to the heart?

B. Done1, A. Michalski1, A. Windsor1,2

1Central Coast Cancer Centre, Radiation Oncology, Gosford, Australia
2University of New South Wales, Faculty of Medicine, Randwick, Australia

Purpose or Objective: Deep inspiration breath hold (DIBH) is widely used internationally as a standard treatment for left-sided breast cancer patients. Preliminary results from our institution suggest that there is a cohort of patients who have an increase in cardiac dose with DIBH compared to free breathing (FB). To our knowledge, there are no published studies assessing if DIBH can be a detriment in selected patients. Our primary objective was to identify patient cohorts based on the potential detriment to heart dose constraints. The secondary objective was to evaluate predictive criteria which would define the degree of benefit of DIBH.

Material and Methods: All patients who had left breast or chest wall radiotherapy and had both a FB and DIBH CT simulation scans at a single institution were selected for this study. Planning target volumes (PTV), lung, heart and left anterior descending (LAD) artery were contoured on both FB and DIBH CT data sets. Both data sets were planned using parallel opposed tangents and dynamic wedges. Plans were prescribed either 50Gy in 25 fractions or 42.4Gy in 16 fractions. DIBH plans were considered acceptable for treatment delivery where the heart dose constraints were reduced, without exceeding lung dose tolerances. Given the lack of guidelines on LAD contouring and acceptable dose constraints, LAD was contoured and doses recorded for
research purposes, but not used for clinical decision making. Doses to the PTV, lung, heart and LAD were recorded. Four patient groups were identified for comparison: those who had at least one heart parameter worse with DIBH, minimal benefit arbitrarily defined as less than 20%, moderate benefit defined as between 20%-70% and a major benefit defined as greater than 70%.

Results: Data was collected for a total of 70 patients. Overall, using DIBH, lung volume increased on average by 68% (range: 18.5% - 124.3%) while the heart volume in the treatment field was reduced by an average 69.5%. The LAD volume within the treatment field was reduced by 53%. The degree of benefit for heart and LAD doses is outlined in table 1. 10% had at least one heart parameter worse with DIBH. Where the mean heart dose was higher all other heart constraints were worse. Five patients had an increase in the heart volume and maximum heart distance in the treatment field.

Table 1: Number of patients (n) and the detriment or degree of benefit to the heart and LAD doses compared to the range of lung volume increase (%). using DIBH versus free breathing

<table>
<thead>
<tr>
<th>% of lung volume increase</th>
<th>Dose Increase</th>
<th>Minimal Dose Reduction (&lt;20%)</th>
<th>Moderate Dose Reduction (20-70%)</th>
<th>Maximum Dose Reduction (&gt;70%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart mean</td>
<td>4.9 (5.09±0.1)</td>
<td>11.4 (27.9±0.8)</td>
<td>48.4 (24.5-124.3)</td>
<td>70.4 (6.10-100.4)</td>
</tr>
<tr>
<td>Heart max (62%)</td>
<td>7.0 (5.99±0.9)</td>
<td>8.3 (33.2-24.4)</td>
<td>24.3 (24.5-101.3)</td>
<td>61.7 (9.12-24.9)</td>
</tr>
<tr>
<td>Heart 125 Gy</td>
<td>4.2 (3.73-0.1)</td>
<td>7.0 (23.6-0.9)</td>
<td>51.8 (21.5-70)</td>
<td>78.4 (6.19-124.6)</td>
</tr>
<tr>
<td>LAD at 23 (62%)</td>
<td>3.0 (20.8-0.9)</td>
<td>10.3 (23.7-123.6)</td>
<td>25.8 (23.2-310.3)</td>
<td>19.2 (4.9-124.3)</td>
</tr>
<tr>
<td>LAD max (62%)</td>
<td>3.0 (20.8-0.9)</td>
<td>10.3 (23.7-123.6)</td>
<td>25.8 (23.2-310.3)</td>
<td>19.2 (4.9-124.3)</td>
</tr>
<tr>
<td>LAD 125 Gy</td>
<td>6.0 (5.99±0.9)</td>
<td>10.3 (23.7-123.6)</td>
<td>17.2 (21.3-93.9)</td>
<td>30.4 (3.0-124.3)</td>
</tr>
</tbody>
</table>

Conclusion: Patients where DIBH was detrimental to heart dose constraints, no clear correlation could be drawn to identify this cohort of patients. Lung volume or percentage increase did not necessarily lead to more favourable outcomes, thus could not be used as a criteria for patient selection for DIBH. We aim to establish further predictive criteria in the second phase of this study. Until such time dual planning remains essential to identify patients who should not be offered DIBH.

OC-0166
The influence of tumour location in the breast on boost modality selection.
E. Reilly1, C. Baker2, M. Flynn3, H.M.O. Mayles2, A.J. Reilly4
1Altnagelvin Area Hospital, Radiotherapy, Londonderry, United Kingdom
2Clatterbridge Cancer Centre, Radiotherapy Physics Department, Wirral, United Kingdom
3University of Liverpool, School of Health Sciences, Liverpool, United Kingdom
4Altnagelvin Area Hospital, Radiotherapy Physics Department, Londonderry, United Kingdom

Purpose or Objective: To establish whether photon or electron beams provide better dose coverage to tumour bed sites in different regions of the breast.

Material and Methods: 10 patient data sets were selected from a trial cohort, 2 patients each with tumour beds in one of 5 regions within the breast. - Superior Lateral Quadrant (SLQ), Superior Medial Quadrant (SMQ), Inferior Lateral Quadrant (ILQ), Inferior Medial Quadrant (IMQ) and the Central Quadrant. The dose to the whole breast treatment of 50Gy in 25 fractions was combined with a boost plan to the tumour bed of either photons or electrons with a dose of 16Gy in 8 fractions. Dose to the PTV, lung, heart and breast tissues outside the tumour bed were assessed by using DVHs.

Results: Tumours in the SLQ received better dose coverage by the photon boost plans. In all other areas of the breast the tumour bed coverage objectives were met with either photons or electrons. The target coverage in the combined plans was at least the same as or better than electrons with photon beams in all cases (Figure1). Electron beam coverage is dependent on surface contour regularity and tumour geometric shape, particularly if the PTV is not perpendicular to the skin surface and so requiring higher electron energies for PTV coverage at the deep margin. Lung had consistently lower doses with photon boost plans as the higher electron energies selected for target coverage in some plans increased lung dose (Figure2). The breast outside the tumour bed received lower doses with photon boosts. The heart doses were not consistently lower with either modality.

Conclusion: Electrons were a less favourable modality for SLQ tumours, but either photons or electrons could be suitable for treating tumours in other regions of the breast in terms of target coverage and organ sparing. As photon boosts provided the same as or better coverage than electrons in combined plans, it would be feasible to use photons for all boosts. However, individualised planning is necessary to account for tumour position in relation to normal anatomy, surface contour and geometrical shaping of the tumour bed to optimise PTV coverage and organ sparing. If using electrons particular attention must be paid to the use of bolus for beams planned on irregular surface contours.

OC-0167
Advanced left-side breast cancer: does VMAT allow doses of organs at risk to be reduced?
P. C. Yu1, H.H. Nien2, C.J. Wu1, Y.L. Tsai1
1Cathay General Hospital, Radiation Oncology, Taipei, Taiwan
2University of Liverpool, School of Health Sciences, Liverpool, United Kingdom

Purpose or Objective: This study was to quantify the reduced dose of right lung and right breast tissue by modified volumetric modulated arc therapy (MVMAT) for advanced left-side breast cancer including lymph node irradiation.

Material and Methods: For all cases, the clinical target volume (CTV) consisted of the left breast, axillary lymph nodes, internal mammary chain lymph nodes, infracavicular lymph nodes, and supracavicular lymph nodes. 7 patients of MVMAT and 5 patients of volumetric modulated arc therapy (VMAT) were generated with the Eclipse Version11 treatment planning system. VMAT plans were generated using a five full rotation without avoidance sector. MVMAT plans were generated using a five partial rotation with avoidance sector. Two half arcs were for supracavicular lymph nodes. Gantry angle started at 179 degree, stopped at 335 degree, and the 60-120 degree was set to be avoidance sector.