CARDIOVASCULAR DOSIMETRY FOLLOWING RADIOTHERAPY USING HYBRID COMPUTATIONAL PHANTOMS

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CONTEXT AND OBJECTIVE

Many studies have shown an increased risk of cardiovascular diseases following radiotherapy. To date, cardiovascular retrospective dosimetry is based on the use of a “representative” patient’s CT images or simple mathematical phantoms. Here, patient modelling is performed with hybrid computational phantoms in order to achieve personalized and detailed heart dose calculation, particularly for the coronary arteries.

MATERIALS AND METHODS

Overview

Radiotherapy treatment data of patients suffering from a left-side breast cancer were collected in the radiotherapy department of the Pitié-Salpêtrière hospital. First, the modelling process was assessed by modifying it with complete anatomical information (CT images) of 3 patients (“A” patients). Second, models were built from two low-contrast orthogonal digitally reconstructed radiographs (DRRs) of 3 patients’ chest (“B” patients) to assess it in the case of restricted anatomical information as in old radiotherapy charts. The DRRs were performed with a home-made script from the CT images and the first “A” patient’s model used as template, was deformed to best fit the radiographs. In this case, CT images were only used to validate the modelling. Models were inserted in DICOM format into the Treatment Planning System (TPS) by generating pseudo-CT images.

Model creation process from CT images

1. RHINOCEROS 3D (1) – Creation of the hybrid computational phantom
2. BINVOX (4) – Delineation of the organs of interest
3. DCMTK (5) + TPS – Inclusion of a detailed heart model

Model building from two orthogonal radiographs

1. Display of the radiographs
2. Masks covering organs of interest
3. Creation of mask intersections
4. Scaling of template organs
5. Fitting of the heart model between the lungs
6. Resulting model (without bones)

Validation of the models

Morphology

Volume comparison (ΔV) and Dice Index (DI) (6)

Dosimetry

Dose distribution and dose-volume histograms comparisons between the CT and the pseudo-CT

Results

Morphological and dosimetric comparison between CT and pseudo-CT

<table>
<thead>
<tr>
<th>Patient</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔV (%)</td>
<td>D1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External contour</td>
<td>0.5</td>
<td>0.98</td>
<td>5.6</td>
<td>0.97</td>
<td>1.0</td>
<td>0.98</td>
</tr>
<tr>
<td>Breast</td>
<td>1.0</td>
<td>0.96</td>
<td>0.1</td>
<td>0.97</td>
<td>0.4</td>
<td>0.95</td>
</tr>
<tr>
<td>Left lung</td>
<td>0.3</td>
<td>0.96</td>
<td>0.2</td>
<td>0.95</td>
<td>0.3</td>
<td>0.97</td>
</tr>
<tr>
<td>Right lung</td>
<td>0.4</td>
<td>0.96</td>
<td>2.1</td>
<td>0.98</td>
<td>0.8</td>
<td>0.97</td>
</tr>
<tr>
<td>Heart</td>
<td>8.9</td>
<td>0.87</td>
<td>7.3</td>
<td>0.87</td>
<td>1.2</td>
<td>0.87</td>
</tr>
</tbody>
</table>

Dosimetric reconstruction for the B2 patient (LAD = Left Anterior Descending coronary artery)

For the “A” patients, good morphological and dosimetric agreements validated the method. For the B patients, differences between CT and pseudo-CT were more significant. A dosimetric reconstruction with CT images of two kinds of “representative” patients (one in terms of breast and heart volumes - CT_Rep.WH; the other in terms of weight and height - CT_Rep.WH; as in Taylor’s method (7) highlighted that the models were not systematically better than a “representative” patient.

Cardiovascular dosimetry for the A2 patient

In the left-breast radiotherapy context and for the studied cases, the heart was located in a high dose gradient.

Coronary mean doses were at least 5-fold higher than heart mean doses.

The LAD coronary artery, located near from the inter-ventricular groove, had higher mean dose than the right and circumflex ones.

Conclusion

• Created from CT images, hybrid computational phantoms are interesting because of the insertion of a detailed heart model that allows to identify and delineate the heart substructures, particularly the coronary arteries.

• Built from two orthogonal radiographs, these phantoms can be seen as a representative patient with the possibility of morphological deformations depending on the available anatomical data (orthogonal and/or beam field control radiographs, some external contours, etc.). If a library of chest female phantoms is used to reconstruct the doses of a large number of patients, it can be expected that the doses will be more accurate than in current practice.

• The whole heart is not a good surrogate to assess the doses to the coronary artery.

References