Automatic segmentation for the evaluation of cardiac substructure dose in support of epidemiological research on cardiovascular morbidity after breast radiotherapy

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Introduction: Patients who have received breast radiotherapy are at increased risk for developing cardiovascular disease. However, the structures most responsible for cardiac complications are currently unknown. Unfortunately, due to the tedious nature of the task, it is typical only for the whole heart, not heart substructures, to be contoured during treatment planning. As a result, most research on cardiac risk to date has used mean dose to the whole heart as a radiation exposure indicator. Studies considering heart substructures tend to have a small number of patients and are not sufficiently powered. We demonstrate an automatic algorithm to segment heart substructures which can be applied to large patient datasets. Results along this line of research are expected to improve prescriptive criteria for minimizing subsequent cardiac events, thereby improving long-term quality of life for breast cancer survivors.

Methods: We collected DICOM-RT data for 100 breast cancer patients enrolled in the Radiotherapy Comparative Effectiveness clinical trial who were treated using photons. For each CT, a cardiology team provided a manual segmentation of the whole heart (WH), left/right atria, left/right ventricles and left anterior descending artery (LAD). A cardiac atlas library was developed for the automatic segmentation using 30 patients and the remaining 70 patients (40 left-side, 30 right-side) were used for performance testing. The input to the algorithm was the manual contouring of the WH which is drawn at time of treatment planning. The automatic segmentation consists of a selection of a most similar heart from the atlas library followed by a structure-guided B-spline transformation. The automatically contoured results were then compared with manual delineations to evaluate geometric and dose similarity.

Results: The median dice similarity coefficient (DSC) for the four chambers ranged from 66% to 84% and the average surface distance (ASD) was ~4 mm. Performance for the LAD was worse with a mean DSC of 6% and median ASD of ~6 mm which can be explained by the difficulty segmenting such a small structure. The dose calculated using the manual and automatic delineations showed excellent correlation within expected variability of manual segmentation. For left-sided (right-sided) treatments, the mean dose difference for the chambers and LAD was <0.7 Gy (<0.4 Gy) and 1.8 Gy (0.4 Gy), respectively.

Conclusion: Cardiac structure dose based on our automatic segmentation agree with that of manual segmentation. When applied to large patient datasets our automatic segmentation method should facilitate the development of better prescriptive criteria for mitigating cardiovascular morbidity following breast radiotherapy.

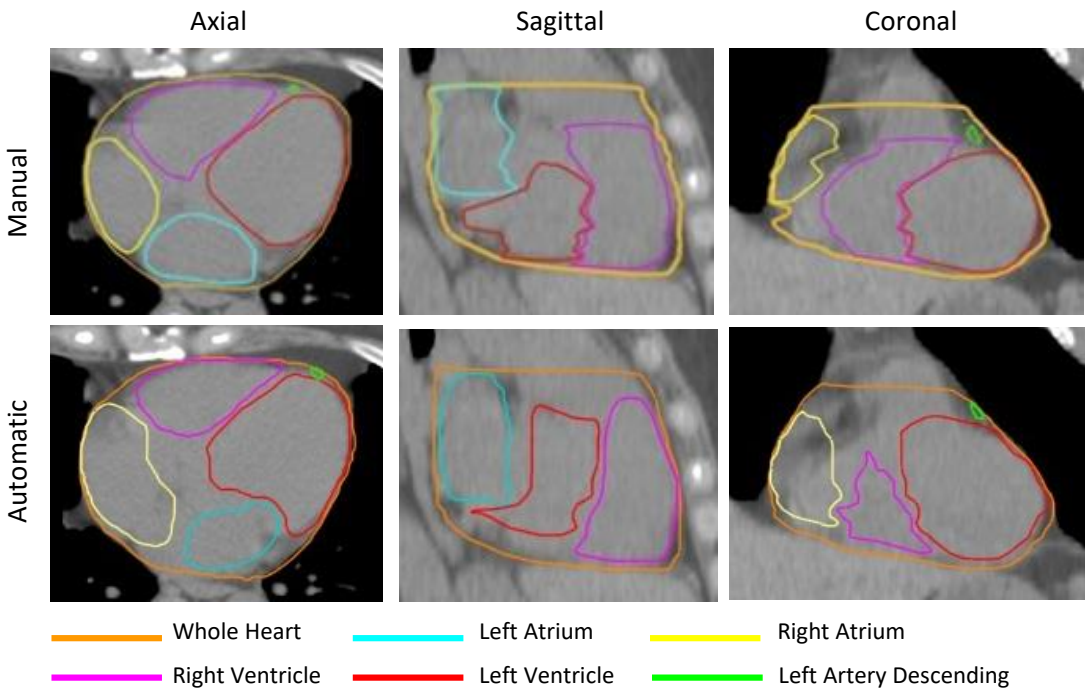

Figure 1. Example comparison of automatic and manual heart substructure segmentations

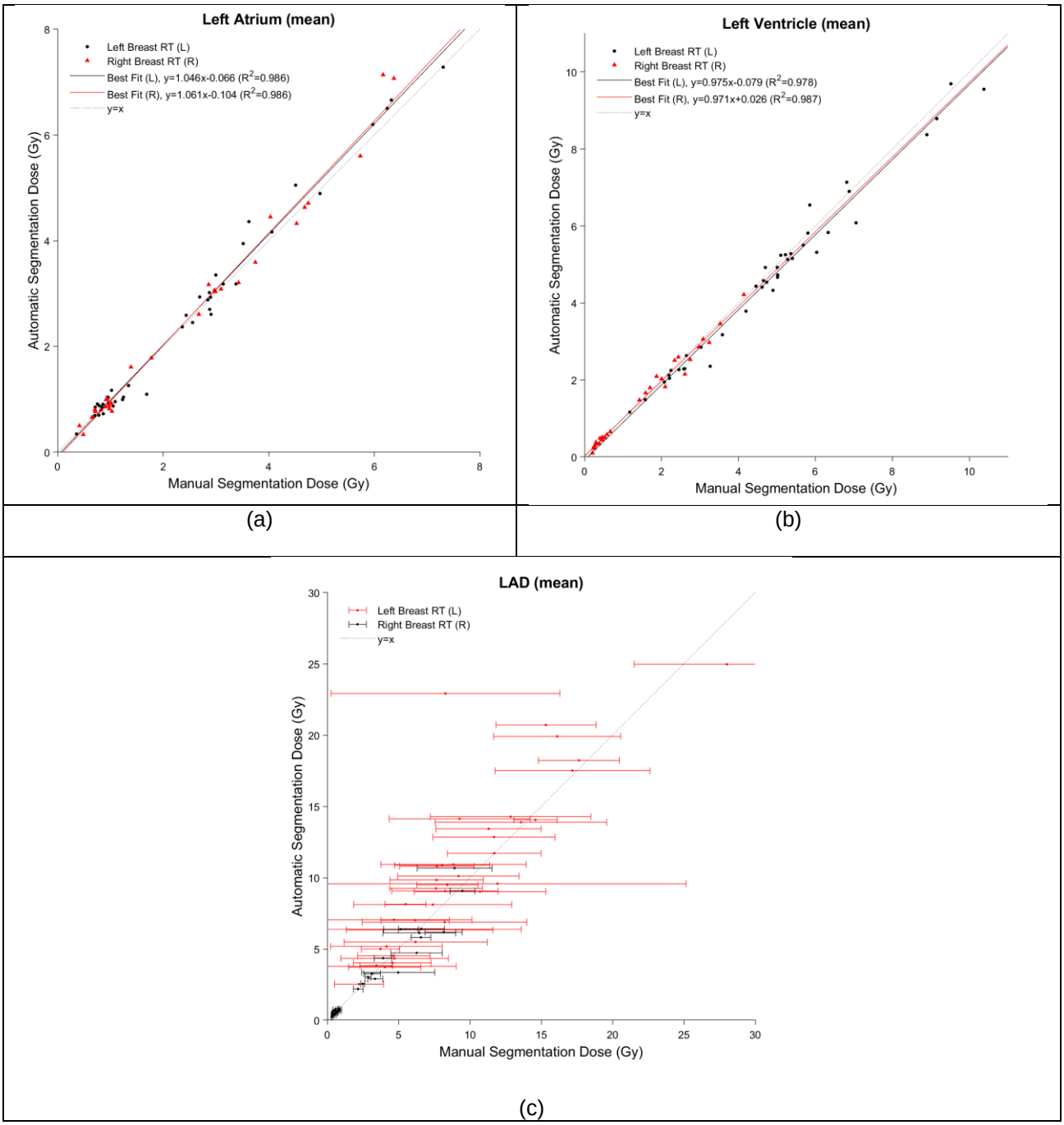

Figure 2. Correlation plots comparing manual and automatic segmentation dose for the left atrium (a), left ventricle (b), and left anterior descending artery (c).