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Short Communication

Automatic segmentation of breast in prone position: Correlation of similarity indexes and breast pendulousness with dose/volume parameters

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ABSTRACT

This study evaluates edited/reviewed automatically-segmented structures of the breast target in patients planned in prone position and their dose/volume effects. Contouring times were reduced using automatic-segmentation. Similarity-indexes and pendulousness showed that targets with *Dice* values over 0.965 and high pendulousness, presented the best dosimetric results.

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Contouring reproducibility is one of the most sensitive points in radiotherapy (RT) planning [1]. Expert panels were created to provide contouring guidelines in order to optimize reproducibility, reduce inter-observer differences, and improve the quality of the procedure [2,3]. Automatic segmentation (*AS*) tools can help reduce contouring time and standardize target contours [4–6], including breast simulated in supine position [6,7].

In this study, we have investigated the use of a commercial atlas-based *AS* tool, Smart Segmentation® Knowledge Based Contouring (Varian Medical Systems, Palo Alto, California), developed to contour the Clinical Target Volume (CTV) for breast cancer patients lying prone aiming to segment simultaneously the CTV, the heart, the left anterior descending coronary artery, and both lungs. We present the analysis on automatic CTV delineation and compare manual *vs.* automatic contouring methods using similarity indexes. Using edited/reviewed automatically-segmented CTVs for treatment planning, we correlated similarity indexes and patient's breast shapes with reference target dose coverage and normal tissue over-dosage.

Materials and methods

Forty breast cancer patients (17 left and 23 right) were enrolled and divided into 2 groups: (a) 13 atlas-cases sampled by breast size (large >1100 cc, medium 600–1100 cc and small <600 cc) and laterality (left vs. right) to implement the *AS* atlas library; and (b) 27 test cases selected to evaluate the reliability of the *AS* tool. All patients gave written informed consent. Patients' characteristics are presented in Suppl. Table 1.

Computed tomography (CT) images of the thoracic region with 3 mm slices were acquired during free breathing with a slow acquisition mode (pitch 0.813 and rotation time 1.5 s) and without IV contrast. Patients were lying prone on a dedicated breast board, kVue™ Access 360™ Prone Breast support (Qfix, Avondale, Pennsylvania), with both arms raised overhead and no radio-opaque wires placed to mark breast borders.

Prior to the *AS* tool testing, we created an atlas library with cases containing structures contoured by a seven-year experienced Radiation Oncologist (senior, *Sr*). Using this library, we manually selected the atlas case based on breast volume and shape similarity. A Dell Precision T5500 computer was used with 2 Intel processors (Intel (R) Xeon® CPU with a E560@ 2.4 and 3.9 GHz processor).

For each test case, contours were manually drawn by the *Sr* radiation oncologist (reference) and by a one-year experienced resident in training (Junior, *Jr*) (manual test structures), independently. Automatic segmentation was performed next. *Jr* and *AS*'s

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CTV contours were optimally adapted by the *Sr*, generating corrected structures (*Jr + Sr* and *AS + Sr*).

Whole breast contouring followed the consensus guidelines of the Radiation Therapy Oncology Group [3] and the Danish Breast cancer Cooperative group [8] (to define the lateral border limits of the CTV using the vessels). All CTVs, drawn manually or automatically, were expanded out of the body and cropped at the skin, while interpolation was used for manual contouring.

Contours performed, using VODCA (MSS GmbH, Hagendorn, Switzerland) version 5.4.0, were compared to the reference (*Vref*) drawn by the *Sr*. Parameters such as *Dice* (defined as $Dice = 2 \cdot Vref \cap Vi / Vref + Vi$ where *Vi* is the *ith* group of structure investigated) [9], sensibility (*Se*) and inclusiveness (*incI*) indexes (defined as $Se = Vref \cap Vi / Vref$ *and* $IncI = Vref \cap Vi / Vi$, respectively) [10,4], absolute center of mass (*COM*) displacements, and percentage of volume difference were assessed.

To measure pendulousness semi-automatic targets were defined using Eclipse™ version 11 (Varian Medical Systems, Palo Alto, California) by adjusting a Volume of Interest (*VOI*) around the breast, using the breast folds and the chest wall muscles as limits. These structures were used to calculate the ratio of the target surface area in contact with air to the total target surface area (*Air to Surface Ratio, ASR*). Fig. 1, presents an example of *ASR* calculation. Times to edit/review the *Jr* and *AS* structures performed by the *Sr* in addition to the total contouring times for each procedure were recorded and compared. Contouring time needed by the *Sr* was used as reference. Finally, treatment plans were implemented with the (*AS + Sr*) defined CTVs, adding a 5 mm margin expansion from CTV to the Planning Target Volume (PTV) which was cropped 5 mm inside the skin. 3D conformal tangential fields were used. Dose-prescription to the PTV and constraints required 95% of the dose to cover at least 95% of PTV volume and no more than 2% volume exceeding 107% of the prescribed dose.

Calculations were performed using the analytical anisotropic algorithm [11] on Eclipse™. Overlaps between *Sr* PTVs (reference) and (*AS + Sr*) PTVs for each patient, allowed us to analyze the amount of *Sr* PTV volume being underdosed (i.e. receiving $\leqslant$95% of the prescription dose). The volume of normal tissue being overdosed, thus receiving a dose $\geqslant$95%, was calculated as the volume of (*AS + Sr*) PTV not overlapping with *Sr* PTV. Wilcoxon signed rank test was used to validate the comparison between different CTV groups and contouring-editing times. Mann–Whitney test and linear regression were also used for analysis.

Results

Mean *Dice* values were 0.93 and 0.91 for *Jr* and *AS*, respectively. Similarity indexes (*Jr + Sr* and *AS + Sr*) were all >0.95 and presented no statistical difference for all analyzed parameters (Suppl. Table 2). The largest difference for the CTVs *COM* was in the cranio-caudal direction for both *Jr* and *AS* contours, with 75% of the coordinates within 15 mm of the reference *COM*. This was due to *AS* and *Sr* CTVs contours ending cranially or caudally on different CT slices (Suppl. Fig. 1), with a median difference of 2 slices (range, −3 to +10) in the cranial region and 0 slices (range, −10 to +6) in the caudal region. The *Sr* CTV median length was 13.5 cm (range, 9.6–17.5 cm) in the cranio-caudal direction. Center of mass shifts for both manual Jr and AS, were reduced with Sr editing, reaching values close to the pixel size resolution. Automatic segmented and corrected CTVs *Dices* significantly correlated with *ASR* ($p_{(AS)} = 0.03$ and $p_{(AS+Sr)} = 0.01$), increasing with pendulousness, but not with volume or laterality. Semi-automatically generated target volume (for *ASR* calculation) correlated with *Sr* CTV volumes ($p = 0.0001$).

Senior's mean times to correct *Jr* (4.84 ± 0.73 min) and *AS* (5.22 ± 0.86 min) were not significantly different ($p = 0.064$). All CTVs, including atlas case selection, were created within a mean time of 2.08 ± 1.3 min. Manual contouring by the *Sr* required a mean time of 12.4 vs. 7.3 min using the *AS* tool and editing/reviewing the structures.

Treatment planning using (*AS + Sr*) PTVs allowed a mean of 94.4% (SD ± 1%) of the *Sr* PTV volume to be covered by 95% of the prescribed dose. *Dices* above 0.95 were associated with good reference target dose coverage, with dose prescriptions according to rules with less than 1% of volume under-dosed. For *Dices* of at least 0.96, differences were within ± 1% of the volume (Fig. 2). Furthermore, to reduce the outside target irradiation to less than 15 cm^3 (approx. 1% the ref-target volume) *Dice* threshold was 0.965. Using this *Dice* threshold seven patients presented a "sum volume" (*Sr* PTV volume being under-dosed and volumes of normal tissue being overdosed) $\leqslant$20 cm^3, corresponding to differences in percentage CTV *Sr* volume of 1–4% depending on the breast volume size. Using *ASR* threshold of 0.75, 5 patients, presenting good dose target coverage (within 1% of the volume) while non-target irradiation tissue <15 cm^3, were identified.

Discussion

Here we have reported for the first time, the results of autosegmentation of CTVs for patients treated in prone position for breast RT. The time taken to draw the CTV was reduced by 40% when the *Sr* used the *AS* tool with manual editing, compared to manual contouring alone. This is similar to what has been reported in the literature for supine patient position [7]. The mean time for manual CTV contouring by the *Sr* (12.4 min) was comparable to the mean times reported by Reed et al. [7] for supine position (20.7 min, range 8.9–45.2 min), but might suggest that target delineation in the prone position could be easier.

Automatic segmentation required the same editing/correcting time as manual contours and resulted in structures of the same quality as for corrected manual contours (i.e. *Jr + Sr*). The mean *Dice* of 0.91 for *AS* was comparable to data reported in the literature for supine position, [6]. However, these studies suggested an influence of breast size on *AS* contours that was not found in our study.

Explanations for this difference could be; (1) the division of the atlas database into three CTV volume groups, (2) the performance of the algorithms used by the *AS* tool, or (3) the prone position itself. It is of note that *Dice* values in the prone position increased with higher *ASR* values (more pendulous breasts).

Dice values of <0.93 in our study were linked to larger dosimetric differences than *Dice* values of >0.96, suggesting that inter-observer variability is an important factor in clinical practice [12]. The *Sr*-edited structures, from both *Jr* manual and *AS* contours, showed higher mean (±SD) *Dice* values than the *Jr* structures, 0.96 (±0.01) and 0.93 (±0.03) respectively. It could be attributed to inter-observer variability (i.e., *Jr* vs. *Sr*) [7,13] or, since the atlas case contours and the contouring corrections were made by the same observer (*Sr*), it might also be possible that this biased the results of the present study, and represents a possible pitfall. Furthermore, since there are no delineation guidelines/recommendations for prone breast radiotherapy, we extrapolated supine guidelines [3,8] to prone position. This might represent a limitation due to deformations, rotations and translations of the breast due to gravity, and patient positioning on the breast support. Data from the literature suggest that target definition for prone breast radiotherapy is variable. For example Formenti et al. used the anterior extent of the latissimus dorsi muscle to delimit the lateral breast boundary [14] while Bartlett et al. [15] and Krengli et al. [16] used the glandular breast tissue, skin folds, and radio-opaque wires to visually encircle the breast to be treated. It is evident that prone guidelines should be developed, not only to allow for plan

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