Radiothérapie du sein en décubitus ventral : performances de la segmentation automatique de la cible du traitement et des organes à risque

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Abstract

La technique en procubitus a été préconisée pour améliorer l’épargne des organes dans le cadre d’une radiothérapie sur le sein, sans pour autant diminuer la dose prescrite et l’homogénéité de la dose délivrée sur la cible. La prérogative de la position en procubitus par rapport au décubitus n’est pas facile à prévoir en raison des différents facteurs inhérents à chaque patiente. Ce travail a évalué les différences dans la distribution de dose après planification du traitement en procubitus versus décubitus, en tenant compte des organes à risque (OaR) et des volumes cibles, les seins malades. La segmentation étude s’est penchée sur les éventuels avantages de la segmentation automatique chez les patientes irradiées sur le sein en décubitus ventral avant la planification de la radiothérapie visant ainsi épargner le plus possible les OaR (i.e., le cœur et les vaisseaux coronaires) […]

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Breast cancer radiotherapy

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.

Keywords:
Prone breast radiotherapy
Target volume delineation
Auto-segmentation
Dosimetry

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
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, Hagendorf, Switzerland) version 5.4.0, were compared to the reference (Vref) drawn by the Sr. Parameters such as Dice (defined as Dice = 2 Vref ∩ Vref + Vref ∩ Vref) where Vref is the ith group of structure investigated) [9], sensitivity (Se) and inclusiveness (incl) indexes (defined as Se = Vref ∩ Vref + incl = Vref + Vref), 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 <95% of the prescription dose). The volume of normal tissue being overdosed, thus receiving a dose ≥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, –2 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 Dice significantly correlated with ASR (pAS = 0.03 and pAS+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 cm³ (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) < 20 cm³, 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 cm³, were identified.

Discussion

Here we have reported for the first time, the results of auto-segmentation 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] 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 Krendli 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.
comparison between centers, but also to reduce inter-observer variability, as shown in a supine breast contouring RTOG study [1].

Regarding the dosimetric results, we would like to point out that they are dependent on the treatment technique employed (tangential fields). Tangential fields are less influenced by small in-field left–right border contour differences, while cranial-caudal differences may be more important as these limits are used to define jaw apertures.

Furthermore, it is difficult to evaluate the influence of the AS performance on the structures that were subsequently edited, because intra-observer variability is introduced in this process. Nevertheless, even if the automatic segmentation performance wasn’t as good as manual contouring by an expert observer, it did not degrade the final edited contours, which were similar to expert manually delineated ones. In this study we aimed to investigate which Dice values could be considered clinically acceptable from a plan quality (dosimetry) point of view, and to establish how intra-observer variability would be the smallest. Our reasoning being that, if it is important to correlate Dice values to dose/volume effects, it is even more important to find a parameter predicting the Dice value before planning [12]. The ASR parameter could help in selecting patients for whom extra care is required when reviewing structures. If Dice values higher than 0.965 (high pendulousness, associated with good dose target coverage and less than 15 cm² of normal tissue outside the target volume receiving the prescribed dose) can be achieved by automatic segmentation in the future, then we could argue that not editing the structures would not worsen the plan quality results for some patients, for this treatment technique. Hurkmans et al. [13] have shown that intra-observer contouring variability is smaller than inter-observer variability for supine breast treatment, and this is also likely to be true for prone breast treatment. It is a clinical objective to reduce contouring variability.

To summarize, auto-segmentation tools look promising for prone breast contouring and could help to reduce inter and intra-observer contouring variability with a gain in contouring time. Nevertheless multicenter studies with several experienced radiation oncologists following a prone consensus contouring guideline and using an independent expert-contoured atlas database are needed. Such studies could further assess if contouring reproducibility of CTVs in prone position can be predicted by ASR, which could be a surrogate of Dice in predicting dose/volume effects when planning.

Conflicts of interest statement

The Radiation Oncology Department of the HUG has a research agreement with Varian Medical Systems.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.radonc.2016.04.041.

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