Computer-aided Delineation of Targets for Stereotactic Body Radiotherapy Using Dynamic Contrast Enhanced MRI in Patients with Early Stage Breast Cancer: a Feasibility Study

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Target audience clinicians, physicists and other clinical professionals

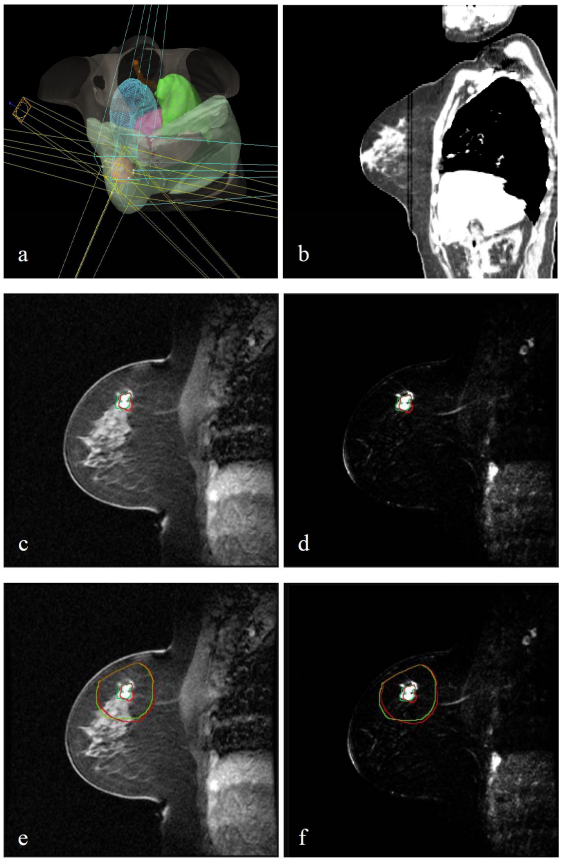
Introduction

Partial breast radiation therapy (RT) has been demonstrated in early studies to be an effective treatment for patients with breast cancer, and has been widely adopted as a convenient alternative to six weeks of conventionally fractionated whole breast radiotherapy. In this work, single-fraction pre-operative stereotactic body radiotherapy (SBRT) was used to treat patients with early stage breast cancer, which demands accurate tumor and target delineations. Dynamic contrast-enhanced (DCE) MRI uses fast imaging and a contrast agent to assess changes in the microvascular environment and has been demonstrated to be useful in detection, diagnosis, and staging of breast cancer [1-3]. Breast DCE-MRI provides valuable information on contrast enhancement kinetics and morphological features of breast tumors which might be valuable in the segmentation of breast tumor and target volumes for SBRT. In this work, the feasibility of computer-aided segmentation of breast target volumes using DCE-MRI was investigated.

Methods

Patients

In this this study, five patients with early stage breast cancer were evaluated. The study was approved by the institutional review board. Each patient was required to have a complete history and physical, and biopsy demonstrating invasive/infiltrating breast carcinoma. A prescription dose of 15Gy was delivered in a single fraction using intensity-modulated radiotherapy. Patients were scanned with MRI about 1-week before and 1-week after SBRT. All the patients underwent surgical tumor resection within 10 days of SBRT using standard surgical procedure.



MRI studies

All MRI scans were acquired with the patients in a prone position on a 1.5T clinical scanner (GE Healthcare, Milwaukee, WI) using a standard 4-channel breast coil. The imaging protocol included T1- and T2-weighted imaging, and DCE-MRI. The contrast agent gadopentetate dimeglumine (Magnevist; Schering, Berlin, Germany) was intravenously administered by power injection with a dose of 0.1 mmol/kg bodyweight at a flow rate of 2 ml/s. DCE-MRI scans were acquired in the sagittal plane with one pre-enhanced and five post-enhanced series using a T1-weighted three-dimensional SPGR dynamic sequence (TR = 6 ms, TE = 2.9 ms, field of view = 24x24 cm^2, matrix size = 256x256, slice thickness = 3.4 mm, no averages). The acquisition time of each volume sequence was about 1 min. The acquired DCE-MRI data were then processed as follows.

DCE-MRI Image registration and processing

All the DCE-MRI data were registered with a set of high-resolution T1-weighted images and then processed to derive the scalar signal denoted as variance of enhancement slope (VES), which can be obtained with Eq. (1) [4-5].

$$\mathrm{VES} = \mathrm{Var}[(I_t - I_0)/t] \qquad (1)$$

where t denotes the time elapsed from contrast injection, and I_0 and I_t indicate the precontrast and postcontrast signal intensity at time t, respectively. VES can be used to represent the pharmacokinetic activity at each pixel. Based on VES mapping, auto-thresholding with a value of 10 times of average intensity of entire volume is used to differentiate breast tumor as gross tumor target (GTV) from background normal soft tissue. After that, GTV is expanded by 15mm, but 5mm away from skin as clinical target volume (CTV). Finally, CTV is expanded by 3mm, but 5mm away from skin to generate planning target volume (PTV) that is used for SBRT planning. The computer-aided segmentation of target volumes using DCE-MRI was compared against manual physician delineation, which is considered as reference.

Results

The left figures show the representative images of one patient: (a) 3D view of the SBRT plan with multiple radiation fields from various angular directions; (b) one sagittal plane of CT; (c-d) sagittal view of computer-aided segmented GTV in green and physician delineated GTV in red in the post-contrast MRI and VES map; (e-f) sagittal view of computer-aided segmented PTV in green and physician delineated PTV in red in the post-contrast MRI and VES map. (c-f) indicated good agreement between computer-aided segmentation and physician delineation. We performed quantitative comparison between computer-aided segmentation and reference. The mean deviations from reference are 12.3±12.4% for GTV, 4.5±4.4% for CTV and 5.3±4.9% for PTV for five selected patients with early stage breast cancer.

Discussion and Conclusion

In this study, an efficient computer-aided segmentation method using DCE-MRI was proposed to delineate breast target volumes for SBRT. These preliminary results indicate good agreement between computer-aided segmentation and physician delineation, and suggest the proposed method can be potentially useful in breast SBRT. Further work is required to determine and improve robustness of the proposed computer-aided segmentation.

References

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