Interactive intensity thresholding based breast density assessment in sequential MR examinations

S. N. Reed[1], G. Ertas[1], and M. O. Leach[1]
[1]Cancer Research UK and EPSRC Cancer Imaging Centre, Institute of Cancer Research, Sutton, Surrey, United Kingdom

Introduction

The proportion of radiodense fibroglandular tissue in the breast, termed breast density, has been shown to be a strong risk factor for breast cancer [1]. When compared to x-ray mammography, MR imaging allows direct volume estimates of the proportion of fibroglandular breast tissues and therefore may provide more accurate breast density assessments [2-5]. In this study, we investigate the value of interactive intensity thresholding in the assessment of breast density from sequential MR examinations.

Materials and Methods

The left and the right breasts are first segmented from other regions of the body, such as the chest muscles, lungs, heart and ribs on three-dimensional T1-weighted images using our own robust and fast semi-automated algorithm that detects midsternum location automatically and then identifies left and right breast volumes separately [6]. The segmented breast volume is inspected visually and some manual corrections are performed to completely cover the breast volume anterior to a coronal plane lying immediately posterior to the pectoral muscle. The fibroglandular tissues inside the segmented volume of each breast are discriminated from fat using an interactive intensity thresholding algorithm embedded in the MRIBView software developed at our institute [3, 7]. This method uses pre-contrast T_1 weighted images corrected for intensity uniformity using an averaging window moved across the proton density image in the coronal plane. To make a correction in the axial plane, a user controlled uniformity factor variable is utilized. The expert navigates between the slices presented in axial, sagittal and coronal planes and interactively sets the axial uniformity factor and the intensity threshold applied to the T1- weighted image until the best tissue classification is achieved. The breast density is calculated as the ratio of the number of detected voxels of fibroglandular tissue to the total number of voxels inside a segmented breast volume. This method identifies a significantly higher fraction of breast tissue (52% for Fig 1) than previous techniques based on coronal slices, for which segmentation stops at the chest wall. Systematic differences between the left and the right breast density estimates are tested using the independent samples t-test with either a pooled or a separate variance as determined by the Levene's test for equality of variances. To determine the correlation between the densities estimated for the left and the right breast, the Pearson correlation coefficient r is calculated and a linear regression curve is fitted. The density estimation consistency is evaluated using Bland-Altman and Box plots and quantified by the mean absolute difference in estimated densities. All statistical analyses are performed using SPSS 15 (SPSS Inc., USA)

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Results

Proton density weighted and T_1 weighted magnetic resonance images from 17 high-risk healthy women (age: 35-47 years, mean age: 40.8 years) who were monitored annually during the UK multi-centre study of MRI screening for breast cancer (MARIBS) were analyzed [8]. These images were acquired using dedicated breast coils and a pre-determined 3D spoiled gradient echo pulse sequence (flip angles of 6° and 35°, $1.33\times1.33\times2.5$ mm^3 spatial resolution). A total of sixty-three MR scans were performed sequentially for minimum period of three years per each patient.

To illustrate MR based breast density estimation, a representative image slice from a 35-year-old woman with a dense breast is considered. T1-weighted images acquired during follow-up are presented in Fig.1a-c. The fibroglandular breast tissues classified inside the segmented breast volume are seen in Fig, 1d-f. Calculated mean densities over the left and right breast volumes for the 1st, 2nd and 3rd year are 24.2%, 24.5% and 24.4%.

The results of statistical analyses of the estimated breast densities in sequential MR examinations from all patients are shown in Table 1. There is high correlation (r=0.958) and no systematic difference (P<0.05) between the calculated left and right breast densities. Moreover, as shown in Fig.2b and 2c, there is good consistency in density estimations, which is further quantified by the low mean absolute difference (2.8%).

Discussion and Conclusion

The results of the density measurements confirm a good consistency between the left and right breasts for each patient. This is highlighted by a low mean absolute difference of 2.8%. The sequential data shows a high level of reproducibility (variance of less than 5%) between patient visits for 13 out of 17 patients. For the remaining 4 patients, an increased variance may be caused by a genuine change in breast composition. The ability to highlight variations from normal breast development in sequential images could give valuable information in assessment of breast cancer risk.

References

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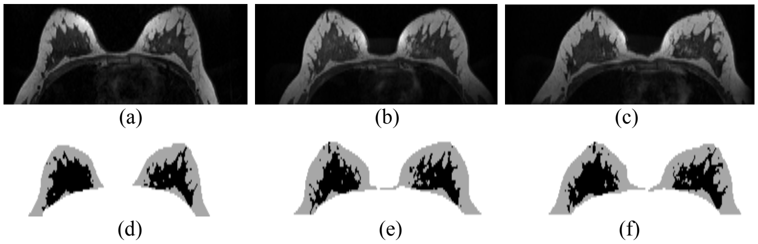
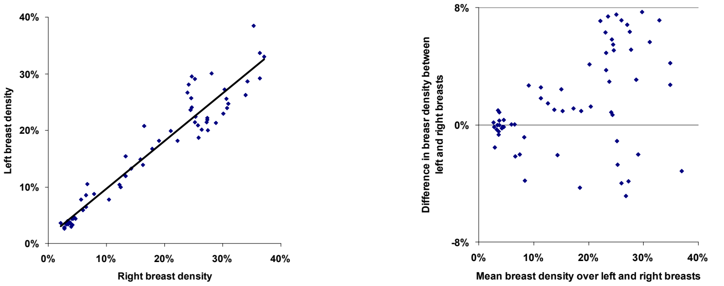

(a) (b) (c)
(d) (e) (f)

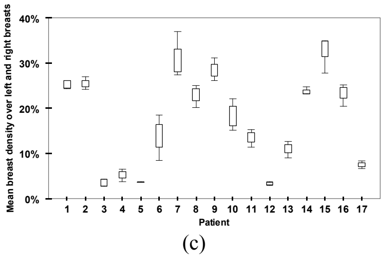
Fig. 1. (a-c) T1-weighted axial images acquired and (d-f) fibroglandular tissue (black coloured area) classified inside the segmented volume (gray coloured area)

Table 1. Left and right breast densities and correlation

Breast Density (mean±SD) in %			Mean Absolute
Left Breast	Right Breast	r value	Difference in %
16 ± 10	18 ± 11	0.958	2.8



(a) (b)



(c)

Fig. 2. The results of statistical analyses of the estimated breast densities in longitudinal follow-up MR examinations (a) Linear regression curve fitted, (b) Bland-Altman plot and (c) Box-plot for the consistency for the left and the right breast densities estimated