Extraction of Lesion Features from Contrast-Enhanced MR Mammograms Using Initial and Post-Initial Enhancements

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Introduction

In contrast-enhanced MR Mammography (CE-MRM), dynamic behaviors of lesions are evaluated from sub-regions defined by experts [1] Enhancement curves calculated for these "most suspicious" regions can be visually analyzed [2], however, the overlap in these curves and dependency on experience lead to the development of quantitative techniques [3]. Here, we introduce such a method; it extracts diagnostic features from initial and post-initial enhancement values of the lesions.

Methods

32 breast lesions were imaged on a 1.5 Tesla Siemens Symphony MR scanner equipped with a dedicated four-element phased-array receiver breast coil using T1-weighted 3D fast low angle shot (Flash) sequence with the following parameters: TR/TE 9.80/4.76 msec, flip angle 25°, slice thickness 2.5 mm with no gap and resolution 0.625mm^2, 1precontrast and 5 postcontrast images per slice. There were 15 benign and 17 malignant lesions having average volumes of 1.80cm^3 and 1.92cm^3, respectively. Acquired dynamic 12-bit grayscale image sets were transferred to a personnel computer in DICOM format for further analysis. An automated method was developed to extract six potentially diagnostic features: The maximum value, the minimum value, the mean value, the standard deviation, the coefficient of variation and the skewness of initial and post-initial enhancement values. The method consists of the following stages: (1) Generation of nMITR projection from dynamic MR data [4] (2) Rough selection of a volume of interest (VOI) covering a suspicious region by an expert (by defining the dimension, starting and ending slice numbers) (3) Thresholding of the VOI with an empirically determined value for each patient (4) Identification of enhancing objects (regions) in 3D by an 18-neighbourhood connectivity search and labeling operation (5) Detection of the lesion (the object that had the biggest volume) (6) Morphological hole filling to include necrotic tissues inside the lesion that had low nMITR. (7) Computation of initial and post-initial enhancement values (with 1% precision) of each tissue inside the segmented lesion [5] (8) Extraction of features. This method was implemented using Matlab 7.0 (The Mathworks, Inc., USA).The significance of each feature in discriminating malignancy were evaluated using SPSS 14 (SPSS Inc., USA).The independent samples t-test with either a pooled or separate variance as determined by the Levene's test for equality of variances was performed. Diagnostic accuracies of the features were calculated from the area under the ROC curve (A_z) [6].

Results

nMITR maps are found to be useful in volumetric segmentation of lesions, especially for breasts having moderately enhancing normal tissues of premenopausal women. For two typical lesions; a benign lesion (fibroadenoma) and a malignant lesion (invasive lobular carcinoma), the histogram of initial and post-initial enhancements are presented in Figures 1a-1b and 1c-1d. The values of the computed features are given in Table 1.

Table 1.Extracted features

Lesion	Initial Enhancement						Post-initial Enhancement					
	Max	Min	Mean	SD	CV	S	Max	Min	Mean	SD	CV	S
Benign	3.46	0.34	1.47	0.74	199.12	0.52	3.01	-0.39	0.57	0.51	111.32	1.52
Malig.	4.32	0.25	1.68	0.81	206.63	0.36	2.37	-0.94	0.05	0.38	10.16	2.65

In discrimination of benign lesions from malignant ones, features of initial enhancements are found to be insignificant except for skewness (0.78 ± 0.46 and 0.42 ± 0.34, P=0.02, A_z= 0.73±0.09) while significant features of post-initial enhancements are the minimum (-0.39 ± 0.39 and -0.67 ± 0.23, P=0.02, A_z=0.73±0.10), the mean (0.47 ± 0.29 and 0.03 ± 0.17, P<0.01, A_z= 0.93±0.05) and the coefficient of variation (136.30 ± 75.86 and 0.16 ± 53.75, P<0.01, A_z= 0.94±0.04).

Conclusion

The described enhancement analysis method overcomes difficulties associated with the "subjective ROI" analysis since it uses samples from every tissue within the lesion and may therefore allow for a better standardization of clinical evaluations. The results demonstrate the usefulness of post-initial enhancement based features; the coefficient of variation shows the best performance for diagnosis.

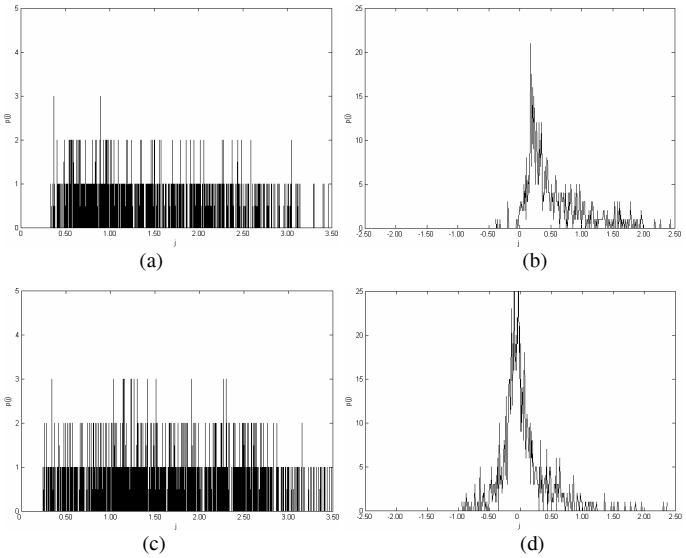

Figure 1. Histogram of initial and post-initial enhancement values (a,b) benign lesion (fibroadenoma) and (c,d) malignant lesion (invasive lobular carcinoma)

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