Selection of Diagnostic Features to Differentiate between Malignant and Benign Lesions that Presented as Mass Lesions and Non-Mass Type Enhancement on Breast MRI

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Introduction:

Diagnosis of breast MR lesions as malignant or benign is based on morphological appearances as well as contrast enhancement kinetic patterns of the lesion. For lesions that present as the mass type (that is, with well-defined boundary), there are several features that can be used for making the differential diagnosis. For example, spiculation (morphology), rim enhancement (texture), and the wash-out kinetic pattern are the typical malignant features; whereas smooth margin (morphology), low and homogeneous enhancement (texture) and persistent kinetic pattern are the typical benign features. Therefore, it is relatively easy to find diagnostic features to differentiate between mass type benign and malignant lesions. Yet malignant lesions such as ductal carcinoma in-situ (DCIS) and invasive lobular cancer (ILC) are very likely to present as non-mass-like enhancements. The benign fibrocystic changes are one of the most commonly diagnosed benign diseases on MRI, which often shows non-mass type enhancements. Since the boundary of the non-mass lesion is not well-defined, it is difficult to analyze the morphology; also these lesions often did not show the wash-out pattern in the enhancement kinetics. Therefore, diagnosis of non-mass lesions is much more difficult compared to the mass lesions. In a previous work we have developed a quantitative morphology and texture analysis method to select features for diagnosis of mass lesions [1]. In this study, we applied this method to differentiate between 4 groups of lesions: mass malignant, non-mass malignant, mass benign, and non-mass benign lesions. The morphology (only for mass), texture, and the enhancement kinetic parameters were measured, then a artificial neural network was applied to find features that can best differentiate between them.

Methods:

A total of 116 histological-proven lesions, 88 malignant (43 mass, 45 non-mass) and 28 benign (19 mass, 9 non-mass), were analyzed. The region of interest (ROI) for each lesion was manually outlined by a well-trained operator and further confirmed by an experienced radiologist. For each mass lesion 8 shape/margin parameters and 10 GLCM enhancement texture features were obtained for characterization. For the non-mass lesions, only the texture parameters were obtained, because the shape/margin information could not be reliably analyzed due to lack of clearly-defined boundaries. For every case, the enhancement kinetics was measured, and analyzed quantitatively using the Tofts model to obtain K^{trans} and k_{ep}. The artificial neural network (ANN) was used to select features and the leave-one-out cross-validation was used to evaluate the generated classifier. The areas under the ROC curve (AUC) in the selected classifier to differentiate between: (i) benign vs. malignant mass lesions, and (ii) benign vs. malignant non-mass lesions, finally (iii) all benign vs. malignant lesions, were compared to understand how well they could be differentiated.

Results:

Fig. 1 shows examples of the four types of breast lesions. I: A mass type benign lesion (adenosis), which showed persistent kinetic curve. II: A mass type malignant lesion (invasive ductal cancer, IDC), which showed rim enhancement and rapid wash-in followed by wash-out in the kinetics. III: A non-mass type benign lesion (fibrocystic changes). IV: A non-mass type malignant lesion (DCIS). These two non-mass lesions showed plateau type enhancement kinetics, which would be considered as suspicious, not able to suggest benign or malignant. An artificial neural network (ANN) was performed to select an optimal feature set for diagnosis, and results are listed in Table 1. The selected classifier to differentiate between mass type malignant and benign lesions include 2 shape features (Compactness, NRL Entropy) and 2 texture features (Homogeneity, Gray Level Sum Average), which could reach AUC of 0.87. The kinetic parameter (K^{trans}) could reach AUC of 0.75 by itself. When these 5 features were combined, the diagnostic performance could improve to 0.90. For non-mass lesions, 4 texture features were selected by ANN (Gray Level Sum Average, Gray Level Max Probability, Gray Level Correlation, Gray Level Energy), and the AUC was 0.76. The kinetic parameters could not differentiate between the non-mass type benign vs. malignant lesions, with AUC of 0.55, which is only slightly better than the random guess probability (0.5). When combining the mass and non-mass lesions together for differentiating between all malignant and benign lesions, the selected texture features were (Homogeneity, Gray Level Max Probability, Gray Level Sum Average), which reached AUC of 0.81. When adding kinetic information (K^{trans}), the overall diagnostic performance improved slightly to reach AUC of 0.83.

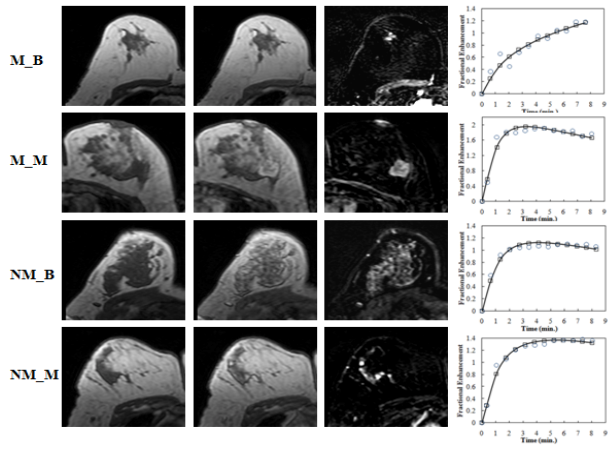

Figure 1. Examples of 4 lesions with kinetic curves: I: mass benign (adenosis), II: mass malignant (IDC), III: non-mass benign (fibrocystic changes), IV: non-mass malignant (DCIS).

Table 1. Discrimination of benign from malignant lesions.

AUC	Morphology	Kinetics	Morphology+Kinetics
Mass B vs. M	0.87	0.75	0.90
Non mass B vs. M	0.76	0.55	0.76
All lesions B vs. M	0.81	0.61	0.83

Discussion:

In this study we characterized the shape/margin and the enhancement texture of lesions, and selected the best diagnostic features to differentiate between mass and non-mass type malignant and benign lesions. For mass lesions, the morphology could yield a high diagnostic accuracy (AUC=0.87), while the enhancement kinetic parameters could further improve the accuracy to (AUC=0.90). For the non-mass lesions, the enhancement texture analyzed from the outlined lesion ROI could only fairly differentiate between benign and malignant lesions (AUC=0.76), and adding enhancement kinetic parameters did not improve the accuracy. The results suggest that when diagnostic features will be used for developing automated breast CAD (Computer-Aided-Diagnosis), different algorithms will be needed for mass and non-mass lesions. For mass lesions, the characteristics (morphology, enhancement texture and kinetics) can be analyzed from the enhanced lesion ROI to reach a high diagnostic accuracy. But for diagnosis of non-mass lesions, this approach based on lesion ROI may not work well. Characterization of the pattern of the enhanced lesion with respect to the pattern of normal parenchymal enhancement around the lesion in the ipisilateral breast, as well as comparison to the contralateral breast by examining whether they were symmetric, was the strategy used by radiologists (according to patterns defined in BI-RADS breast MRI lexicon). Similar quantitative analysis strategy using computer algorithms should be investigated.

Reference: [1] Nie. et al. 2008 ISMRM proceedings, program # 3752, or Acad. Radiol. 2008 (in press).

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