Multimodality Computer-Aided Breast Cancer Diagnosis with FFDM and DCE-MRI

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Rationale and Objectives: To investigate a multimodality computer-aided diagnosis (CAD) scheme that combines image information from full-field digital mammography (FFDM) and dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) for computerized breast cancer classification.

Materials and Methods: From a retrospective FFDM database with 432 lesions (255 malignant, 177 benign) and a retrospective DCE-MRI database including 476 lesions (347 malignant, 129 benign), we constructed a multimodality dataset of 213 lesions (168 malignant, 45 benign). Each lesion was present on both FFDM and DCE-MRI images and deemed to be a difficult case given the necessity of having both clinical imaging exams. Using a manually indicated lesion location (ie, a seed point on FFDM images or a region of interest on DCE-MRI images, the computer automatically segmented the mass lesions and extracted lesion features). A subset of features was selected using linear stepwise feature selection and merged by a Bayesian artificial neural network to yield an estimate of the probability of malignancy. Receiver operating characteristic (ROC) analysis was used to evaluate the performance of the selected features in distinguishing between malignant and benign lesions.

Results: With leave-one-lesion-out cross-validation on the multimodality dataset, the mammography-only features yielded an area under the ROC curve (AUC) of 0.74 ± 0.04, and the DCE-MRI-only features yielded an AUC of 0.78 ± 0.04. The combination of these two modalities, which included a spiculation feature from mammography and two kinetic features from DCE-MRI, yielded an AUC of 0.87 ± 0.03. The improvement of combining multimodality information was statistically significant as compared to the use of single modality information alone.

Conclusions: A CAD scheme that combines features extracted from FFDM and DCE-MRI images may be advantageous to single-modality CAD in the task of differentiating between malignant and benign lesions.

Key Words: Breast cancer; computer-aided diagnosis; multimodality imaging; full-field digital mammography; dynamic contrast enhanced magnetic resonance imaging.

Breast cancer is a leading cause of mortality in American women, with an estimated 192,370 new cancer cases and 40,170 deaths in the United States in 2009 (1). Although there are limited methods for curing breast cancer, recent statistics show that there has been a steady decrease in the annual death rate from breast cancer among women, from 32.69 in 1991 to 24.00 in 2005 (per 100,000 population). This decrease accounts for nearly 40% of decreases in cancer death rates for women and largely reflects improvements in early detection and treatment (1).

Medical imaging plays a crucial role in reducing breast cancer mortality, with contributions to early detection through screening, diagnosis, image-guided biopsy, treatment planning, and treatment response monitoring (2,3). As the primary imaging modality for early detection and diagnosis of breast cancer, mammography has achieved significant success and has reduced the mortality from breast cancer by 15%–35% (4,5). However, about 15%–20% of cancers are still missed, and 65%–85% of breast biopsies are performed on benign lesions (2,6–8). Consequently, complementary imaging modalities, such as breast dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) and breast sonography (ie, breast ultrasound imaging), are being investigated to improve the accuracy of breast cancer diagnosis.

DCE-MRI is regarded as the most sensitive additional imaging modality for supplementing mammography (2).

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Clinical studies have demonstrated its ability to provide accurate diagnosis, extent of disease and multicentricity, and the ability to detect mammographically occult cancers in the contralateral breast (9,10). Peters et al (11) conducted a meta-analysis to determine the diagnostic performance of DCE-MRI in patients with breast lesions. From 251 studies between January 1985 and March 2005, they analyzed 44 eligible studies and obtained an overall sensitivity of 0.9 and an overall specificity of 0.72. Although the sensitivity of breast MRI is encouraging, its specificity is relatively low and varies widely with both cancer prevalence in the studied population and the interpretative criteria used to differentiate malignant lesions from benign ones.

To aid radiologists in distinguishing between malignant and benign lesions, various investigators are developing computerized image analysis methods for characterization and diagnosis of lesions in breast images (12,13). Computer-aided diagnosis (CAD) was initially introduced for mammography (14–16), and then extended to breast sonography (17–20) and breast MRI (21–23).

Although the results of CAD systems for single imaging modality are encouraging (16,20,24–30), merging information across different modalities is recently attracting more attention. Because different imaging modalities provide complementary information regarding lesions, combining information from two or more modalities may increase diagnostic accuracy. Several investigations have been conducted to combine information from mammography and sonography to improve the diagnostic accuracy of breast cancer. Some studies assessed the performance of the computerized multimodality (mammography and sonography) schemes alone (31,32), whereas other studies evaluated the influence of multimodality CAD systems on radiologists' diagnostic accuracy (33–35). However, to the best of our knowledge, very few studies have investigated combining information from mammography and DCE-MRI in distinguishing between malignant and benign lesions.

This study aims to investigate the potential of computerized methods that use computer-extracted features from both mammograms and DCE-MRI images in the characterization

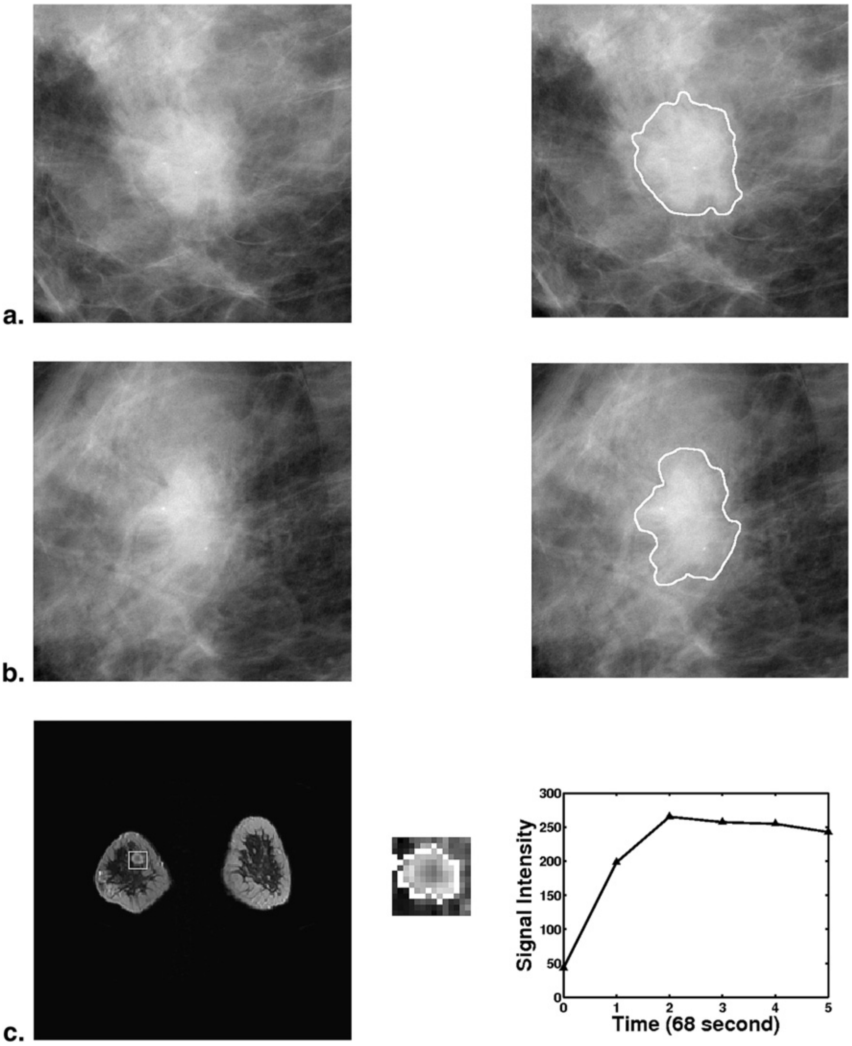

Figure 1. Example of a malignant lesion imaged by both mammography and dynamic contrast-enhance magnetic resonance imaging (DCE-MRI). **(a)** A mammographic region of interest (ROI) in CC view. *Left:* original image; right: image with computer-delineated contour superimposed. **(b)** The corresponding ROI in MLO view. *Left:* original image; *right:* image with computer-delineated contour superimposed. **(c)** The corresponding MRI. *Left:* a MRI slice containing the same mass lesion; *middle:* lesion with computer-delineated contour superimposed; *right:* the computer-identified characteristic kinetic curve of the lesion. MLO, medio-lateral oblique; CC, cranial-caudal.