A Quadrant-Based Quantitative Analysis of Background Parenchymal Enhancement in Breast MRI

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PURPOSE: Background parenchymal enhancement (BPE) is the contrast enhancement of normal fibroglandular breast tissues measured by dynamic contrast-enhanced (DCE) MRI. High level of BPE has been associated with breast cancer risk [1]. Despite the potential importance of BPE, there is little effort to systematically assess BPE quantitatively and compare it to the qualitative Breast Imaging-Reporting and Data System (BI-RADS) classification. Herein, we present a quadrant-based analysis of breast parenchyma, in an attempt to search for regional variations in BPE that may influence corresponding qualitative assessment.

METHODS: With institutional review board approval, a retrospective analysis of breast DCE-MRI was performed on 172 patients with BI-RADS 1 (normal) or 2 (benign) final assessments from 2007 to 2010. Qualitative BPE was classified into categories of minimal (n=58), mild (n=47), moderate (n=40), and marked (n=27) [2,3]. Fibroglandular tissue was segmented from pre-contrast T1-weighted images using a fuzzy C-means clustering method [4]. One pixel erosion at the periphery of each breast tissue mask was applied to compensate for motion artifacts between pre- and post-contrast scans. The quadrant analysis of the left breast was performed using the nipple as an anatomical reference on the sagittal image. Automatic segmentation yielded four approximately equal quadrants: lower inner (LIQ), lower outer (LOQ), upper inner (UIQ) and upper outer (UOQ) which were confirmed on coronal and axial images (Figure 1). A percent enhancement map (percent BPE=100*(S_1-S_0)/S_0 where S_0/S_1=pre/post-contrast signal intensity) was generated. The mean percent BPE value, termed PBPE, was calculated over the breast tissue mask for each quadrant. The Wilcoxon signed-rank test was used to compare the quadrant PBPEs. Linear models were used to determine the effect of age on quadrant PBPE. Spearman's correlation was used to assess the correlation between quantitative PBPE and qualitative BI-RADS classification.

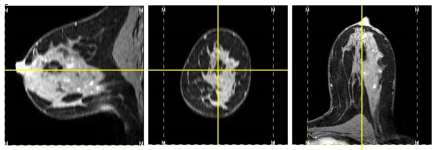

Figure 1. Quadrant analysis of the left breast was performed on the sagittal image (left) using the nipple as an anatomical reference. Subsequent segmentation yielded four quadrants that were confirmed by the corresponding coronal (middle) and axial images (right).

RESULTS: PBPE values within the four separate quadrants exhibited distinct contrast enhancement behaviors. The upper quadrants showed significantly higher PBPE values than the lower quadrants with median PBPE at 16.91% for UIQ and 16.87% for UOQ vs. 14.40% for LIQ and 14.49% for LOQ. Estimated (pseudo-) median difference = 2.02%, 95% CI (1.19, 2.87), $p < 0.0001$ for UIQ vs. LIQ and 2.42%, 95% CI (1.57, 3.26), $p < 0.0001$ for UOQ vs. LOQ. The differences between estimated inner and outer quadrant medians for upper and lower sections were small and did not achieve statistically significance ($p = 0.11$ and 0.53 for UIQ/UOQ and LIQ/LOQ respectively). The effect of age had a statistically significant association with 3 out of 4 quadrant PBPE values. In a single predictor/unadjusted model, LIQ showed an estimated change of -18.4% per 10 years increase in age, 95% CI (-34.5, -2.20), $p = 0.03$. Similar relationship was found in UIQ and UOQ: -17.6% for UIQ (95% CI (-35.3, 0.224), $p = 0.05$) and -23.2% for UOQ (95% CI (-41.3, -5.07), $p = 0.01$) per 10 years. Although LOQ also exhibited a similar trend with estimated change of -12.4% and 95% CI (-27.1, 2.42), it did not achieve statistical significance ($p = 0.10$). Statistically significant but mild Spearman correlations were detected between all quadrant PBPEs and qualitative BI-RADS with UOQ being the highest: estimated correlation $\rho = 0.33$, 95% CI (0.19, 0.46), $p < 0.0001$ and $\rho = 0.29$, 95% CI (0.06, 0.50), $p = 0.017$ in the patient subset of moderate and marked BI-RADS classifications. Figure 2 shows the distribution of quantitative UOQ PBPE values in each qualitatively assessed BI-RADS BPE category. Higher categories of BI-RADS corresponded to an overall increase in PBPE (this association was more pronounced in younger patients: data not shown). It is worth noting that Figure 2 indicates that there was considerable overlap in PBPE values across BI-RADS BPE classifications.

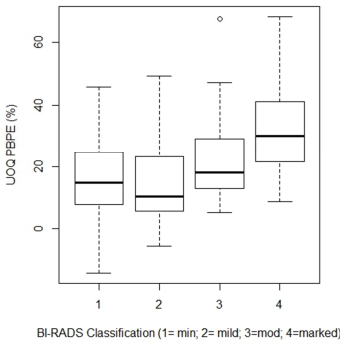

Figure 2. Distribution of the upper outer (UOQ) quadrant PBPE values in each BI-RADS classification: 1= minimum; 2= mild; 3= moderate and 4= marked.

DISCUSSIONS: The quadrant analysis reveals a distinct regional enhancement behavior within the normal breast. Upper quadrants exhibit higher enhancement with the UOQ PBPE values estimated to have the highest (positive) correlation with BI-RADS classification. The covariate effect of age indicates that younger patients having higher regional PBPE may result in higher qualitative interpretations. The high overlap of PBPE values across BI-RADS categories indicates a lack of agreement between quantitative and qualitative assessments. Possible contributing factors include image artifact effects on quantitative PBPE and variability of observer's subjective BI-RADS interpretations. In conclusion, this study provides the first quantitative assessment of BPE by quadrants in a non-cancer population and indicates that regional enhancement in the breast has an influence on the BI-RADS interpretation, particularly in the moderate and marked categories.

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