QUANTITATIVE BACKGROUND PARENCHYMAL ENHANCEMENT ESTIMATION ON BREAST DCE-MRI BY MEASURING RELATIVE VOXEL-WISE ENHANCEMENT

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TARGET AUDIENCE: Radiologists, oncologists, and quantitative scientists for breast cancer risk assessment in high-risk women.

PURPOSE: Studies suggest that background parenchymal enhancement (BPE) in breast DCE-MRI is associated with an increased breast cancer risk for high-risk populations.[1] Most previous work on BPE estimation is however, based on readers' qualitative assessment, using for example 4-category criteria based on the Breast Imaging-Reporting and Data System (BIRADS).[1] Although useful, this kind of assessment is coarse and subjective, which makes it difficult to standardize. The purpose of our study is to develop a fully automated computational method for quantitative BPE estimation and optimize the related parameters to identify the BPE.

METHODS: We estimate BPE through identifying the enhancing voxels in the DCE-MRI images by measuring the relative voxel-wise enhancement, and specifically by examining how much a voxel's intensity (*Is*) in the subtraction (SUB) image (SUB=post-contrast – pre-contrast image) has changed due to the contrast agent injection, relative to the intensity (*Ip*) of the corresponding voxel in the pre-contrast image. We define a voxel-wise BPE enhancement ratio as $R = Is / Ip \times 100$. Based on this definition, the voxels that have an equal or greater value than a predefined enhancement ratio threshold *R* are then identified as the enhancing voxels. Different parameterization of R will lead to varying amount of BPE estimation; yet no consensus value for selecting the ratio R is currently established for BPE estimation. We investigate a range of *R* from 0% to 100% and compare the estimated BPE with manual BPE segmentation from an experienced radiologist, which we consider as our gold standard for the purpose of validation. The best value or range of the ratio *R* is determined based on the correlation with the corresponding manual segmentation. In principal only the voxels belonging to the fibroglandular tissue (FGT) of the breast enhance as they uptake the contrast agent. Hence, we estimate the BPE specifically on the region of FGT. To do that, we apply previously-validated fully automated methods to segment the FGT region. The breast is segmented in T1-weighted non-fat-suppressed images using a chest wall line extraction algorithm.[2] Then within the segmented breast, we use an atlas-based segmentation algorithm [3] to delineate the FGT. The obtained segmentation masks are translated to the corresponding pre-contrast and third time-point subtraction (SUB 3) series after an alignment by rigid registration (considering that the enhancement is estimated for background parenchymal rather than lesions, SUB 3 is used as advised by radiologists). This enables us to identify the enhancing voxels from only the FGT region in the SUB images. Based on the whole-breast segmentation, the FGT segmentation and the voxel-wise BPE estimation, we compute three BPE-related measures: (1) Absolute total volume of BPE identified over the FGT region (|BPE-f|), (2) Percentage of |BPE-f| relative to the absolute volume of the FGT (%BPE-f/f), (3) Percentage of |BPE-f| relative to the absolute volume of the whole-breast (%BPE-f/b). The whole-breast, FGT, and BPE are also manually segmented by a 15-year experienced breast imaging radiologist by using custom developed interactive software (MRwizard v-1.0). The three measures computed from the automated estimation are compared to the same measures derived from the manual segmentation using the Pearson correlation coefficient.

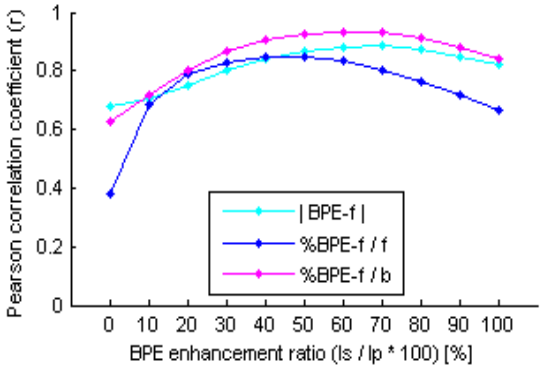

Fig. 1: Correlations for varying BPE enhancement ratios.

RESULTS: We processed 58 3D bilateral breast MRI scans (56 slices per scan) randomly selected from a high-risk screening population [4] with cancer-unaffected, T1-weighted, non-fat-suppressed sagittal view imaging. The 58 cases span the full BI-RADS density ranges (17, 13, 14, and 14 cases for BI-RADS categories I, II, III, and IV, respectively). Results of the correlations for the three BPE-related measures are shown in Fig. 1. The mean (±SD) correlations between the automated and manual estimates are 0.81±0.07 for |BPE-f|, 0.74±0.13 for %BPE-f/f, 0.85±0.10 for %BPE-f/b, respectively across the range of *R* = 0%-100%. When the ratio values are set up as 70%, 50%, and 60%, the highest correlations are achieved for |BPE-f| (r=0.88), %BPE-f/f (r=0.84), and %BPE-f/b (r=0.93), respectively. Fig. 2 shows a BPE estimation example.

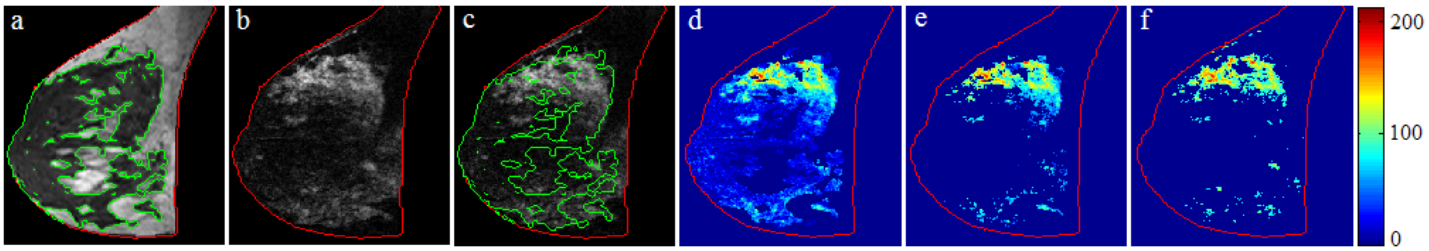

Fig. 2: Quantitative BPE estimation. a. Whole-breast (red) and FGT segmentation (green). b. SUB 3 image. c. Translated FGT segmentation contours on SUB 3. d. Color-coded FGT on SUB 3. e. Color-coded BPE estimation on FGT (BPE-f) with *R*=70%. f. Color-coded manual BPE segmentation.

DISCUSSION: Our results suggest that there is a range rather than a single value of the enhancement ratio threshold *R* that high correlations are achieved between automated and manual segmentation. This range should be optimized within the context of specific clinical applications.

CONCLUSION: We have developed a fully-automated algorithm for BPE estimation in breast DCE-MRI. Our algorithm achieves high agreement with manual segmentation and could be used to standardize measures of BPE in clinical applications. Further work is underway to determine the value of such automated BPE measures as imaging biomarkers in breast cancer risk assessment.

REFERENCES:

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