

Analysis of breast dynamic contrast enhanced MRI using Principal Component Analysis Combined with a Model-Based Method

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A wide range of breast dynamic contrast-enhanced (DCE) sequences and protocols, image processing methods, and interpretation criteria were developed and evaluated in the last twenty years. Special attempts were made to better understand the origin of the contrast observed in breast lesions using physiological models that take into account the vascular and tissue-specific features that influence tracer perfusion. In addition, model-free algorithms to decompose enhancement patterns in order to segment and classify different breast tissue types have been developed. The purpose of our work was to evaluate a new method that integrates PCA with a model based analysis and test its diagnostic ability to differentiate between different breast lesions. Data were obtained from patients that underwent clinical DCE-MRI examination and their diagnosis was biopsy proven. Analyzed lesions included 15 benign and 68 malignant tumors, predominantly, invasive ductal carcinoma (IDC) and invasive lobular carcinoma (ILC). Two sequence protocols were used, both according to the three time point (3TP) method, with time resolution of 80 or 120 seconds.

Principle component analysis (PCA) was performed on intensity scaled or enhancement scaled datasets of a central slice of a lesion. Projection of the temporal pattern in each voxel onto the eigenvectors produced new scalar values termed projection coefficients. Calculation of these values per voxel, for each eigenvector, yielded projection coefficient maps presenting the spatial distribution of these coefficients.

The similarity in each eigenvector among all malignant cases led us to calculate a representative median eigenvector base. In addition, we calculated at voxel resolution, on the same central slice, the 3TP parameters and the physiological parameters: influx and efflux transcapillary transfer constants (k^{trans} , k_{ep} respectively) with the latter constant influenced by the extracellular volume fraction (v_e ; $k_{\text{ep}} = k^{\text{trans}} / v_e$). The PCA derived projection coefficients were correlated with both the 3TP and the physiological parameters, leading to an adjustment of the eigenvector base by rotation to reflect physiological behavior. Projection coefficients of the rotated eigenvector base served to distinguish between different pathologies. ROC curves were applied for the assessment of the diagnostic relevance of the various steps.

We found that PCA, in addition to its high ability to differentiate between benign and malignant lesions, enabled us to distinguish between IDC and ILC, provided we used the higher temporal resolution of 80 seconds. Thus, increasing the temporal resolution improves the differentiation between different pathologies. Overall, the reproducibility of the eigenvectors, eigenvalues and rotation angle, as well as the fast image analysis makes this approach suitable for developing computer aided diagnosis.