Dynamic contrast-enhanced magnetic resonance imaging of the breast at 3.0 Tesla: Combination of high temporal- and spatial resolution - a new approach

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Introduction:

Dynamic contrast-enhanced magnetic resonance imaging (DCE-MRI) has become the primary tool for detecting and evaluating breast lesions. Advantages, such as the opportunity to determine the actual size and shape of a lesion, the reported excellent sensitivity, and the ability to evaluate the contralateral breast within one procedure are just a few reasons for this development. This work is focused on the bottleneck of DCE-MRI, the trade-off between spatial and temporal resolution. Many studies suggest a higher spatial rather than temporal resolution [1]; others have demonstrated that, for optimal diagnosis of breast lesions, an accurate assessment of both lesion morphology and enhancement kinetics is crucial. Our objective was to develop a DCE-MRI breast imaging protocol at 3.0 Tesla that minimizes this resolution trade-off and to determine how to automatically classify lesions as malignant or benign.

Materials and Methods:

Fifty-one contrast-enhancing breast lesions in 42 patients were analyzed using the newly developed method. The DCE-MRI approach presented here combines high spatial and temporal resolution by splitting the DCE-MRI imaging block into three parts. The first part consists of 17 high temporal resolution measurements (coronal T1-weighted VIBE sequence; fat-suppressed; FOV = 320 x 320 mm; 72 slices, TR/TE 3.61/1.44 ms; 13.2 secs temporal resolution; 1.7 mm isotropic resolution; whole breast coverage; CA injection after 75 seconds), which is followed by a high spatial resolution measurement (T1-weighted Turbo-FLASH; fat-suppressed; FOV = 320x144mm; TR/TE 877/3.8 ms; 96 slices; intended resolution: 1 mm isotropic; 2 min acquisition time; whole breast coverage) at expected contrast maximum. The third part again focuses on high temporal resolution in order to determine the final contrast behaviour (parameters as in part one). The chronological organization of the three-fold DCE-MRI protocol is demonstrated in Fig. 1. Before processing, all DCE-MRI data were motion-corrected. Enhancement curves obtained from 3D data with manually drawn regions of interest (ROIs) were fitted using a modified asymmetric logistic model (Eqn. 1). Model as well as secondary parameters obtained from 51 enhancement curves (27 malignant, 24 benign) were classified using k-means [3].

Eqn.1: $$f_{(t)} = G * \left(1 - \frac{1}{\left(1 + \left(2^{\alpha} - 1\right) * \exp\left(\frac{1}{\tau} * \left(t - t_{1/2} \right) \right) \right)^{1/\alpha}} \right) * \exp(\beta * x)$$

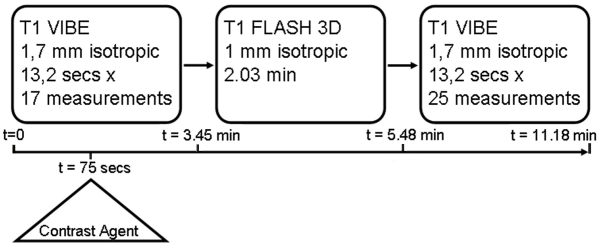

Fig. 1: Chronological order of the three-part DCE-MRI protocol. Part 1 the high temporal resolution part with CA injection after 75 seconds. Part 2 a high spatial resolution measurement (2:03 minutes) which is followed by high temporal resolution measurements.

Results:

The robustness and usability of the applied asymmetric logistic model was demonstrated with an achieved mean R^2 of 0.981 (standard deviation 0.027). Model and secondary parameters were clustered, resulting in a sensitivity of 0.85 and a specificity of 0.75 using kinetic information only, whereas both sensitivity and specificity increased to 1.0 and 0.92, respectively, when using additional morphological information gained from high spatial resolution measurements (obtained by an experienced radiologist / author K. P.).

Conclusions:

This new 3 Tesla breast imaging protocol minimizes the DCE-MRI resolution trade-off by providing a combination of high temporal and spatial resolution. Thus, an accurate assessment of lesion enhancement kinetics and a detailed evaluation of lesion morphology are possible. The modified asymmetric logistic model enables fitting of asymmetric enhancement patterns despite a leakage of data-points in the period of the high spatial resolution measurement. The resulting fitting parameters were successfully used to classify enhancement patterns as malignant or benign lesions using k-means.

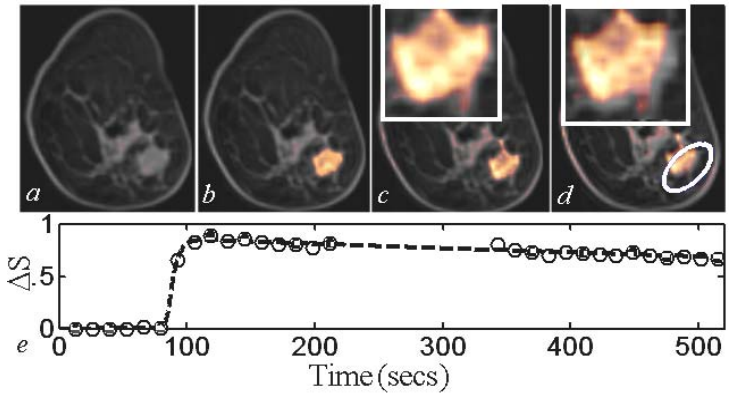

Fig. 2: Contrast enhancement of an IDC NOS G3 at baseline (a), at maximum contrast (b), and at the last acquired time-point (c). The corresponding enhancement curve is shown in (e) and an example of registration performance is given by (c) and (d). Both (c) and (d) represent the last time-point, whereas (c) represents motion-corrected data in contrast to (d); Note the shift of the enhancement in (d) which is overlaid to a baseline-image.

References:

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