Dynamic Contrast-enhanced MRI of early stage Breast Cancer: Computation time vs. accuracy in kinetic model analyses

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Introduction

Dynamic contrast enhanced (DCE) MRI is often used for the diagnosis and treatment monitoring of breast cancer. However, patient motion can introduce artificial variation in the signal enhancement curves. Non-rigid image registration can greatly improve signal enhancement curves, but computation time can be long. Reducing the percent of voxels sampled (PS) for estimating the cost function could reduce computation time, but at least theoretically, at the expense of accuracy. This work investigates the influence of PS on kinetic model analysis results and goodness of fit as assessed by the variation of data around the fitted curve.

Materials and Methods

DCE-MRI breast images were acquired on a 3T MRI system (Siemens Biograph mMR) in seven patients with early stage breast cancer. Three-dimensional fat suppressed (quick fat-sat) fast low angle shot (FLASH) images (spatial resolution = 1.0 x 1.1 x 2.0mm, time resolution = 18s) were acquired from patients prior to and at 28 time points following Gadovist (0.1 mmol/kg) injection. Rapid single slice imaging was acquired for 18s post contrast injection before the first DCE image. Deformable image registration of the affected breast was performed with 3DSlicer software. Mattes mutual information was used as a cost metric with an isotropic control point spacing of two cm. Each post contrast image was registered to the pre-contrast image, and this was repeated with PS values of 0.5%, 1%, 5%, 20%, and 100%. Tumours were segmented using Otsu’s method and the Toft’s kinetic model was fit voxel by voxel to the segmented images for a single slice using a population derived AIF (parker et al. Mag. Res. Med. 2006). The rapid slice imaging was used to constrain the lower bound on the contrast bolus arrival time ($t_0$). The best-fit values of the adjustable model parameters ($K_{\text{trans}}, v_e, t_0$), and the coefficient of variation (CV) were extracted from each fit. Registration accuracy was assessed by comparing the median of the CV values from all pixels in each image set vs PS.

Results

Median registration time per image was 6.8, 2.8, 2.1, 1.9, 1.9 (standard deviation of 4.32, 0.81, 0.21, 0.09, and 1.45) minutes for 100%, 20%, 5%, 1%, and 0.5% PS. Visual assessment showed very little movement following registration for all patients. There was a trend towards decreasing CV from unregistered to 5% sampling (an average decrease in the median value of 40%) but no substantial decrease between 5% and 100% sampling. There were large differences in $K_{\text{trans}}$ and $v_e$ between unregistered and registered images, but there were no large differences between 5% to 100% sampling.

Conclusion

Computation time did not change from 0.5% to 5% sampling, although there was a large decrease in the CV. However, the CV from 5% to 100% sampling did not change. Furthermore, output parameters only marginally changed from 5% to 100%. The results suggest that 5% sampling is a sufficient enough sampling to accurately register the images while reducing computation time for the current registration parameters used. Further work will explore registration parameters such as b-spline control point spacing and their impact on accuracy and computation time.