A novel method for automatic extraction of apparent diffusion coefficients in breast MRI

A Novel Method for Automatic Extraction of Apparent Diffusion Coefficients in Breast MRI

D. McClymont[1], A. Mehnert[1], A. Trakic[1], D. Kennedy[2], and S. Crozier[1]
[1]University of Queensland, Brisbane, QLD, Australia, [2]Queensland X-Ray, Brisbane, QLD, Australia

Introduction

Diffusion weighted (DW) MRI—and in particular the apparent diffusion coefficient (ADC)—shows potential for improving the characterization and classification of enhancing breast lesions identified using dynamic contrast-enhanced (DCE) MRI. Nevertheless, to date there does not exist a well defined and objective method for computing a representative ADC value for such lesions. Typically an average ADC is computed for a manually selected region of interest (ROI) [1]. This is problematic for two reasons. Firstly the choice of ROI is subjective. Differences in ROI selection between individuals, as well as the reproducibility of selection for a given individual, can lead to variation in the mean ADC. In addition ROIs are often defined to be circular or elliptical which imposes an arbitrary geometry on the ROI [2]. Secondly, given the heterogeneity in breast lesions, an ensemble average of ADC may not provide a truly representative value. It is assumed that a representative ADC will be present in the area of neovascularisation, as indicated by rapid contrast enhancement. In order to improve the objectivity, reproducibility and efficiency of representative ADC computation, we propose an automated method based on the selection of hypo-intense areas on the ADC map corresponding to regions of greatest initial contrast enhancement identified in the DCE-MRI data. We also present an evaluation of the method using routine clinical data.

Materials and methods

Breast MRI data used in this study originate from clinical breast MRI examinations of 17 women performed on a 1.5T Signa Echospeed MR Scanner from GE Medical Systems. The DCE-MRI data were acquired using a 3D FSPGR pulse sequence with TE = 3.4ms, TR = 6.7ms, acquisition matrix of 256×256, in plane resolution of 0.61mm and a slice thickness of 1.4mm. The DW-MRI data were acquired with a b-value of 500, TE = 67.7ms, TR = 3950ms, matrix size of 128×156, in plane resolution of 1.25mm and a slice thickness of 7mm. The OsiriX (http://homepage.mac.com/rosserantoine/osirix) region growing tool was used to manually segment lesions, in 3D, in each DCE-MRI dataset. In particular the tool was applied to the volume obtained by subtracting the precontrast volume from the first postcontrast volume. A total of 26 lesions, of which 18 were malignant and 8 were benign, were segmented. In most of the breast exams, the diffusion sequence preceded the dynamic series. However, in three exams corresponding to six lesions, the diffusion sequence followed the dynamic series. It has previously been shown that the presence of contrast agent can reduce the ADC of breast tissue [2].

The proposed method for computing the representative ADC of a lesion comprises the following steps. Firstly, the degree of initial contrast enhancement is calculated for each voxel as the difference between the first postcontrast value minus the precontrast value divided by the precontrast. This enhancement volume is then filtered slice-wise by a 3×3 mean filter in order to reduce noise and motion artifacts. The maximum initial enhancement in the segmented lesion (i.e. the lesion mask) is selected to be a representative feature of the entire lesion, and the position of this voxel is spatially co-located to the nearest voxel in the diffusion weighted images. Apparent diffusion coefficients are computed for each voxel [3] and filtered slice-wise using a Gaussian kernel with a standard deviation equal to the pixel spacing of the dynamic series. The ADC value at the location corresponding to the greatest initial enhancement is selected as the representative ADC value. The method was applied to all 26 lesions.

Results and discussion

Figure 1 shows one slice of an enhancement volume showing the segmentation mask for a malignant lesion. Figure 2 displays the same mask resampled onto the ADC volume. It is clear that in this case, a circular ROI and ensemble average of ADC values would not be appropriate for determining a representative ADC. Figure 3 shows a scatter plot of maximum enhancement against ADC for all 26 lesions. Figure 4 shows the receiver-operator characteristic (ROC) curves for both ADC and enhancement. The areas under each curve are 0.80 and 0.64 for the enhancement and ADC respectively. While the classification performance of ADC is not as good as that of enhancement, the result confirms the value of using the ADC for discriminating benign and malignant lesions reported in the literature [1]. What is significant here is that the manner of computation of the representative ADC is objective and automatic.

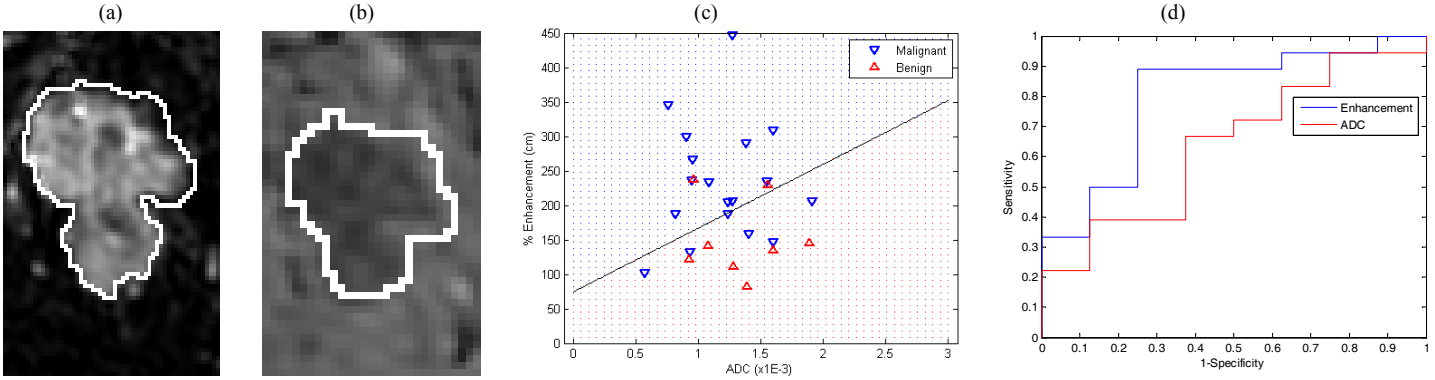

Figure 1: (a) Zoomed in DCE image of a breast lesion; (b) Corresponding ADC image of the same lesion in (a); (c) Scatter plot of ADC and DCE features; and (d) ROC curves for the two features - areas under the curve: DCE(0.799 ± 0.088), ADC(0.639 ± 0.115)).

Conclusions

The results demonstrate that it is possible to improve the objectivity, reproducibility and efficiency of representative ADC computation using the proposed method. This method utilizes dynamic contrast enhanced MRI to locate an appropriate region from which to extract the ADC without the need for manual segmentation.

Acknowledgements

This work was supported under the Australian Research Council's Discovery Projects funding scheme (project number DP0879250).

References

[1] S.C. Partridge *et al, J. Magn. Reson. Imag.*, vol. 31, Mar. 2010, pp. 562-70.
[2] S. Yuen *et al., J. Magn. Reson. Imag.*, vol. 29, May. 2009, pp. 1080-4.
[3] E. Stejskal *et al, Journal of Chemical Physics*, vol. 42, 1965, pp. 288 - 292.