Quantitative DWI for differentiation of benign and malignant breast lesions: the influence of the choice of b-values

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Introduction
Dynamic contrast enhanced (DCE) MRI of the breast has obtained a prominent role in clinical practice because of its high sensitivity for detecting invasive breast tumors. The specificity of DCE MRI of the breast is lower. A promising adjunct MRI technique is Diffusion Weighted Imaging (DWI), which indirectly assesses the cellularity of a lesion. The rationale is that in malignant lesions, the cells are more densely packed in a certain volume than in benign lesions and normal tissue, leading to less intra- and extracellular space for Brownian motion of the water molecules. This results in a lower Apparent Diffusion Coefficient (ADC) (mm²/s) in malignant lesions. However, perfusion effects can also contribute to the ADC value. Perfusion effects cause a substantial signal attenuation already at low b-values, which explains the contribution of mainly perfusion effects to the ADC when only low b-values are used. Since in well-perfused tumor tissue, perfusion effects are expected to be larger than diffusion effects, the ADC found using only low b-values is higher than the ADC obtained with higher b-values. At higher b-values, the signal loss due to perfusion effects is already complete, so only diffusion effects remain, leading to a relatively low ADC which is mainly attributed to diffusion. It was shown by Le Bihan et al. and Thoeny et al. that omitting low b-value scans from the fit procedure used to calculate the ADC considerably decreases the contribution of perfusion effects to the diffusion measurement. Since both perfusion and diffusion are thought to be different in benign and malignant lesions, it is unclear which combination of b-values allows optimal differentiation between benign and malignant breast lesions. In this study, we evaluated which combination of b-values is optimal for the differentiation of benign and malignant breast lesions.

Materials & Methods
Seventy-one patients with 88 nonpalpable suspicious breast lesions detected on x-ray mammography were included in this study. All patients underwent biopsy after MRI to confirm the diagnosis histologically. Written informed consent was obtained from all patients and the study was approved by the ethics board of our institution. Images were acquired on a 3-T whole body system (Intera Achieva, Philips, Best, The Netherlands). Patients were placed in prone position. Signals were acquired using a 4-channel bilateral open breast coil (MRI devices, Würzburg, Germany). From our MR breast tumor scan protocol, the 3D post-contrast fat-suppressed T1-weighted gradient-echo sequence totally covering both breasts was used to depict the lesions. The DWI series was a fat-suppressed single-shot EPI sequence with four b-values: 0, 150, 499 and 1500 s/mm². An ROI was placed inside the lesion on the b=0 s/mm² diffusion weighted images which were shown adjacent to the T1-weighted images at the same anatomic location. The signal intensity was averaged over the ROI for each case that lies 1.5–3 times the interquartile range (IQR) from the median

Results
Eighty-eight lesions in 71 patients were analyzed. Size of the lesions ranged from 4 mm to 40 mm (median 11 mm). Histology of the lesions included 14 non-invasive carcinomas and 38 invasive carcinomas. However, perfusion effects can also contribute to the ADC when only low b-values are used. Since in well-perfused tumor tissue, perfusion effects are expected to be larger than diffusion effects, the ADC found using only low b-values is higher than the ADC obtained with higher b-values. At higher b-values, the signal loss due to perfusion effects is already complete, so only diffusion effects remain, leading to a relatively low ADC which is mainly attributed to diffusion. It was shown by Le Bihan et al. and Thoeny et al. that omitting low b-value scans from the fit procedure used to calculate the ADC considerably decreases the contribution of perfusion effects to the diffusion measurement. Since both perfusion and diffusion are thought to be different in benign and malignant lesions, it is unclear which combination of b-values allows optimal differentiation between benign and malignant breast lesions. In this study, we evaluated which combination of b-values is optimal for the differentiation of benign and malignant breast lesions.

Conclusions
The ADC varies with the choice of different b-values. The diagnostic performance is not affected by the choice of the b-values. The results imply that to differentiate benign from malignant breast lesions, the choice of b-values is not relevant. However, when the ADC value is compared to reported ADC threshold values in literature, the b-values used to calculate the ADC should be taken into account.

References

Figure 1. DWI (b=0, 150, 499 and 1500 s/mm2), post-contrast T1 weighted image and ADC map of a patient with an invasive carcinomas (arrow)

Figure 2. Distribution of ADC values of benign (left box), non-invasive carcinomas (middle box) and invasive carcinomas (right box) for all five methods to calculate the ADC (color coding for the 5 methods is explained in the table). * = outlier: cases lie 1.5–3 times the interquartile range (IQR) from the box; ** = extreme value: cases lie >3 times the IQR from the box.

Figure 3. ROC curve and AUCs of ADC values of benign and invasive carcinomas for all five methods to calculate the ADC (the non-invasive carcinomas (n=14) were excluded from the ROC analysis)