Effect of k-Space Weighted Image Contrast with golden-angle view ordering on diagnostic accuracy for lesion discrimination

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TARGET AUDIENCE: Researchers (academic and industry) and clinicians interested in kinetic model analysis of DCE-MRI

PURPOSE: In an effort to balance morphological and kinetic information in DCE-MRI data sets, the clinical community must always tradeoff spatial versus temporal resolution. One approach to balancing these two conflicting system requirements is to take advantage of information redundancy in images to extract higher resolution information from under sampled data[1]. While algorithms that take this approach show great promise, they can affect image quality in complicated, unexpected ways that hinder their acceptance by the clinical community. In this study, we quantitatively evaluate temporal blurring of DCE-MRI data sets generated using a k-space weighted image contrast[2] (KWIC) image reconstruction technique with golden-angle (GA) view ordering[3] (GA-KWIC) by examining the effect on estimated pharmacokinetic model parameters in simulation.
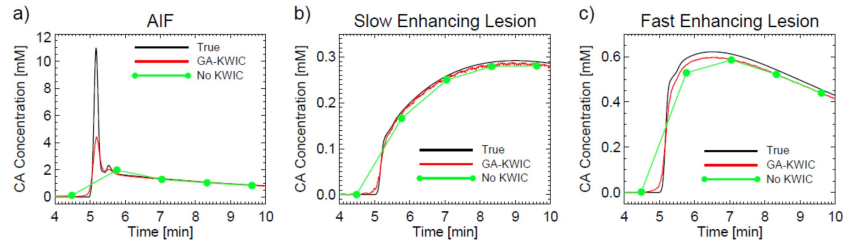

Fig 1. Kinetic curves for the a) AIF and 10 mm b) slow- and c) fast-enhancing lesions from Object A. Data simulated with GA-KWIC matches the true curves better than when no KWIC weighting is used. The matching is better for more slowly-varying curves.
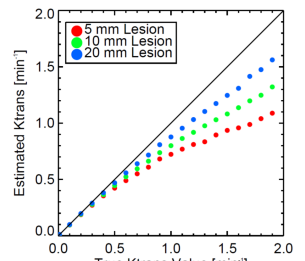
METHODS: *Object Model.* Two different object models (A and B) were simulated. They consist of a two-dimensional (2D) circular component (150 mm dia.) to represent glandular breast tissue in a square flat background representing air. Each object contained a set of circular shapes to represent lesions or arteries. Kinetic curves of the lesions and arteries were described by the generalized kinetic model[4] and a population arterial input function (AIF)[5], respectively. Object A contained a 10 mm artery and two 10 mm lesions, one with a slow-enhancing kinetic curve (K^{trans}=0.08 min^{-1}, v_e=0.30^2) and the other with a fast-enhancing kinetic curve (K^{trans}=0.33 min^{-1}, v_e=0.42). Object B had twenty lesions all with the same diameter (either 5, 10, or 20 mm), and K^{trans} values of 0.01 and 0.1 to 1.9 min^{-1} in increments of 0.1 min^{-1} and v_e=0.35 for all lesions. *System Model.* DCE-MRI data sets were simulated using a spoiled gradient echo imaging sequence (flip angle=12 degrees, repetition time=3.6 ms, echo time=1.47 ms, 1.0x1.0 mm^2 res., 610 views/frame) with GA view ordering and a three-dimensional (3D) stack-of-stars acquisition. Data were generated in 2D, but time between each radial view acquisition was 0.126 sec, as for a 3D sequence with 35 slices. Reconstructed images were generated using a KWIC algorithm similar to that presented in Lin et al.[6], but with a Fibonacci number of views for each annuli. *Simulations.* A qualitative look at the effect of GA-KWIC on the temporal resolution of DCE-MRI data sets was performed by comparing the true kinetic curves with two separate data sets for Object A, one simulated using the GA-KWIC algorithm and the other with GA view ordering, but no KWIC weighting. The effect of temporal blurring on diagnostic accuracy of lesion discrimination was quantitatively evaluated using simulations generated with Object B. Receiver operator characteristic (ROC) curves and area under the ROC curve (AUC) values were generated for the discrimination of benign and malignant lesions for the true and measured K^{trans} distributions. It was assumed that lesion K^{trans} values followed a Gamma distribution (order=2, peak at K^{trans}=0.08 min^{-1} for benign lesions, order=4, peak at K^{trans}=0.33 min^{-1} for malignant lesions).

Fig 1. Estimated versus true K^{trans} values for different lesion diameters. Smaller lesions have a larger K^{trans} estimation bias.

RESULTS: Figure 1 compares true kinetic curves with those generated using the GA-KWIC algorithm and GA view ordering, but no KWIC weighting. For the AIF and slow- and fast-enhancing lesions, the GA-KWIC algorithm better matches the true curve than when KWIC weighting is eliminated. The match is better for more slowly varying kinetic curves. Figure 2 compares true K^{trans} values and those estimated from data simulated with GA-KWIC. The estimation bias increases as K^{trans} increases and as the lesion size decreases. Figure 3 shows true and estimated K^{trans} distributions for benign and malignant
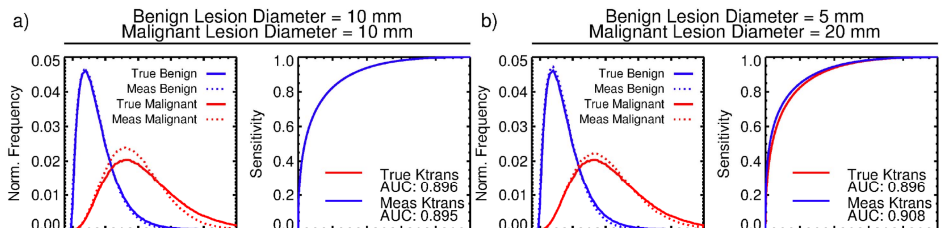

Fig 3. Comparison of true and estimated diagnostic accuracy. Different average K^{trans} values and lesion sizes for benign and malignant lesions result in estimation errors in AUC values, but the errors are small compared with typical sampling errors in clinical studies.

lesions and the corresponding ROC curves. For benign and malignant lesions both with 10mm diameters, the true and measured K^{trans} values are 0.896 and 0.895, respectively. When benign lesions have a 5 mm diameter and malignant lesions a 20 mm diameter, the true and measured K^{trans} values are 0.896 and 0.908, respectively.

DISCUSSION: The temporal information extracted from DCE-MRI data sets is improved when using the GA-KWIC algorithm. This effect is dependent on the true curve type with better matching seen for more slowly-varying kinetic curves. Since malignant lesions have more rapidly-varying curves, on average, than benign lesions, estimated K^{trans} values for malignant lesions have a larger estimation bias than for benign lesions. The influence of this effect on estimated diagnostic accuracy using GA-KWIC data is not significant. Since, for GA-KWIC, views from a larger temporal range contribute to the higher frequency regions of k-space, smaller lesions manifest more temporal blurring than larger lesions. Smaller lesions do have a larger K^{trans} estimation bias than larger lesions; however, the influence of this effect on AUC is minimal even for populations with very different benign and malignant lesion sizes.

CONCLUSION: Implementation of GA-KWIC to improve temporal resolution of DCE-MRI data sets is dependent on lesion size and kinetic curve type. Our simulation data substantiate that the magnitude of these effects should not detrimentally affect clinical studies of diagnostic accuracy.

REFERENCES: 1. Tsao and Kozerke, JMRI 2012;36:543-560 2. Song and Dougherty, MRM 2004;52:815-824 3. Winkelmann et al., IEEE TMI 2007;26:68-76 4. Tofts et al., JMRI 1999;10:223-232 5. Parker et al., MRM 2006;56:993-1000 6. Lin et al., MRM 2008;60:1135-1146.