Accuracy of quantitative 3D DCE-MRI using Variable Flip Angle T1 mapping, B1 Correction, and the Bookend Method

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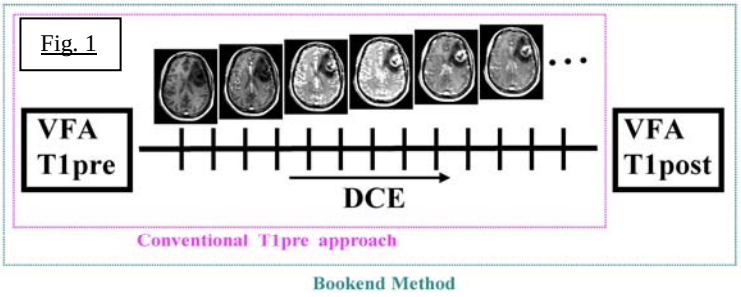
Introduction: Quantitative dynamic contrast-enhanced (DCE) MRI can help characterize brain tumors, therefore guiding treatment (1,2). An important component of quantitative DCE-MRI is estimation of Gd-based contrast agent concentration ([Gd]) as a function of time in tissue. This is conventionally accomplished by acquiring a pre-DCE T_1 map via the variable flip angle (VFA) method (Fig 1, Conventional T_{1pre} approach), which allows conversion of DCE signal to [Gd] (3). This approach, however, is sensitive to variations in the rf transmit field (B_1), which can introduce errors in [Gd] estimation (3). Two previously published techniques may potentially reduce these errors: 1. B_1 mapping (4) and 2. the "Bookend Method" (3), the latter involving an additional post-DCE T_1 map (Fig 1). We investigated the accuracy of [Gd] values achievable with four different combinations of these techniques.

Methods: A 4-liter aqueous phantom was imaged with a Siemens 3T Trio and 32-ch. head coil. Gadovist (Bayer) was used to achieve 10 different ascending [Gd] (T_{1pre}=1140 ms). Each [Gd] was verified using Inversion Recovery (IR), considered a "Gold Standard" (assumed T_1 relaxivity = 3.9 $mM^{-1}s^{-1}$). The imaging protocol used was similar to (1). B_1 maps were acquired with a stimulated echo technique (5). [Gd] was estimated using either the conventional T_{1pre} or the Bookend (BE) Method, each with and without B_1 correction of VFA and DCE. [Gd] was also computed with T_{1pre} or BE, using IR instead of VFA (with B_1 correction of DCE), to aim for the highest achievable accuracy. Overall accuracy was assessed by linear regression of estimated versus actual [Gd] (ideal slope= 1.0).



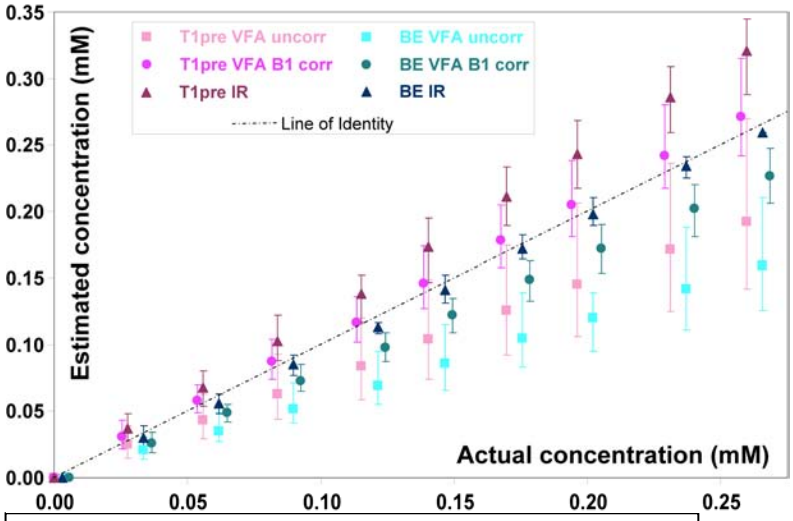
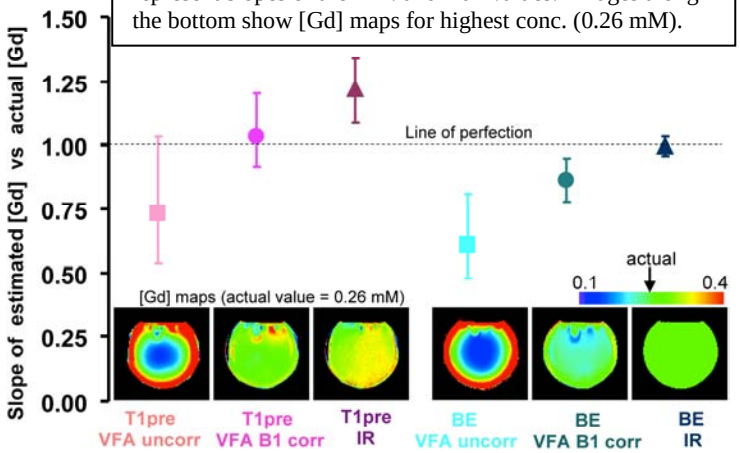


Fig.2 (above) Estimated vs actual [Gd]. Points = mean values of 60 cm^2 ROI. central slice. Error bars= min. & max. values in ROI.

Results: The most accurate technique was BE IR (slope min=0.96, mean=0.99, max=1.03), followed by T_{1pre} VFA corrected (0.91, 1.03, 1.20). In terms of intra-slice variation, however, BE VFA corrected (0.78, 0.86, 0.95) was superior to T_{1pre} VFA corrected.

Discussion: The most accurate [Gd] values are obtained with the BE method and accurate T_1 values (i.e. BE IR). T_{1pre} VFA B_1 corr results were also good; however, when the most accurate T_1 maps (IR) were used, [Gd] was overestimated. This shows that the T_{1pre} method may be unreliable even with B_1 correction. Conversely, BE results consistently improve with increasing T_1 map accuracy.

Fig. 3 (below) Slopes of mean values in Fig 2. Error bars represent slopes of the min. and max values. Images along the bottom show [Gd] maps for highest conc. (0.26 mM).



Conclusion: When estimating [Gd] in tissue for quantitative DCE-MRI, the best results will be achieved using the Bookend Method and accurate T_1 maps. B_1-corrected VFA does not consistently deliver enough T_1 accuracy, indicating that further improvements in T_1 mapping techniques are required.

References: 1. Nguyen et al, AJNR2012;33:1539. 2. Lacerda and Law, Neuroimaging Clin N Am. 2009;19:527. 3 Cron et al, MRM 1999; 42: 746. 4. Manuel et al, MRM 2011;65:1377. 5.. Akoka et al, MRM 1993; 11: 437.