Optimization of acquisition and post processing strategies for deconvolution-based perfusion quantification of breast tumors using T1-weighted DCE MRI

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Introduction MR derived Tumor Blood Flow (TBF) has the potential to become a noninvasive angiogenic marker that could also be explored in the context of anti-angiogenic therapies for which *in vivo* biomarkers are currently lacking [1]. Thus, an accurate assessment of TBF can become crucial in deciding the best management for breast cancer patients. We have recently shown the feasibility of quantifying perfusion parameters in human breast tumors using a deconvolution analysis of second bolus Dynamic Contrast Enhanced MR (DCE MR) data [2,3]. In these studies, after locating the lesion on low temporal resolution first bolus post contrast subtracted images, a second bolus injection of the same dose was administered during a single slice high temporal resolution dynamic inversion-prepared turbo field echo sequence. However, the mean TBF values reported in these studies were higher than the results from PET studies [4]. We believe that the methodology described in these reports establishes only a baseline for further improvements in either acquisition or post processing schemes. Factors presumed to affect the TBF estimation are given in Figure 1. In this work, we explore three different key aspects of acquisition/ post processing strategies to improve the accuracy of TBF assessment namely contrast bolus dose, Flip Angle (FA) and tracer concentration C(t) estimation.

Materials & Methods: The slice where the tumor enhanced maximally was identified on the subtracted low temporal resolution whole breast first bolus dynamic data on a 1.5 T scanner (Philips Intera). High temporal resolution (360 ms) DCE MR data were acquired during the passage of a second bolus at that slice position using an inversion-prepared turbo field echo sequence (TR/TE/TI 4.9ms/2.4ms/196ms 128x67 matrix reconstructed at 256x204, FOV 230x183 mm^2, slice thickness 6 mm, 600 images). The three key aspects in the acquisition/ post processing strategies that were evaluated were (1) Effect of contrast dose reduction on signal saturation and Signal to Noise Ratio (SNR) [5]. (2) Effect of varying FAs in the context of inflow effects and signal saturation [6]. (3) R1 calibration either with a two point method (two FA, 5° & 50°; local calibration) or with a phantom of known concentration (global calibration). Image post-processing was performed on a personal computer using software written in-house in IDL [7].

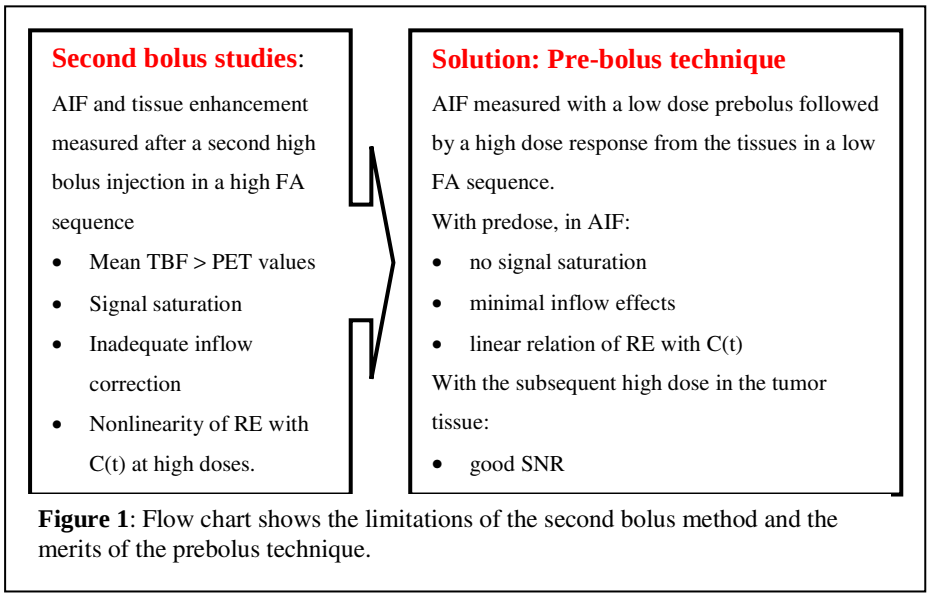

Figure 1: Flow chart shows the limitations of the second bolus method and the merits of the prebolus technique.

Results: The main results of the optimization studies are: (1) At low FA (12°) there is virtually no first-pass peak in the AIF at higher doses, but, as the dose is reduced, a clear peak appears with signs of saturation even at the lowest second bolus dose (5ml). However inflow fluctuations are minimal. At high FA (50°) on the other hand, in spite of the presence of a first pass peak in the AIF at all concentrations, severe inflow fluctuations obscure the intensity curve.(2) Reduction of the contrast dose from the 20 ml standard injection greatly impairs the SNR in the tumor tissue using both FAs. (3) The two point calibration method yields inaccurate R1 estimation due to adding up of errors in multiple steps of R1 quantification. Global calibration in combination with using the body coil reduces the already compromised SNR and also suffers from B_1 inhomogeneity due to the simultaneous presence of the breast coil. Relative enhancement (RE) can be accepted as an alternative if local concentrations stay low.

Conclusion: In breast tumors, with the existing second bolus method, simultaneous accomplishment of an unsaturated AIF curve and a tissue curve with adequate SNR are diverging demands. To achieve an accurate TBF quantification within these constraints, use can be made of a prebolus technique [8] in a low FA sequence with RE as the tracer concentration estimate (Figure 1). In the prebolus technique, a low dose prebolus provides data that permit reconstruction of an accurate AIF, while a subsequent high dose bolus allows acceptable tumor SNR (Figure 2). Our preliminary results in a small cohort of breast tumors suggest that TBF values comparable to PET based literature values can be obtained by this approach (data not shown).

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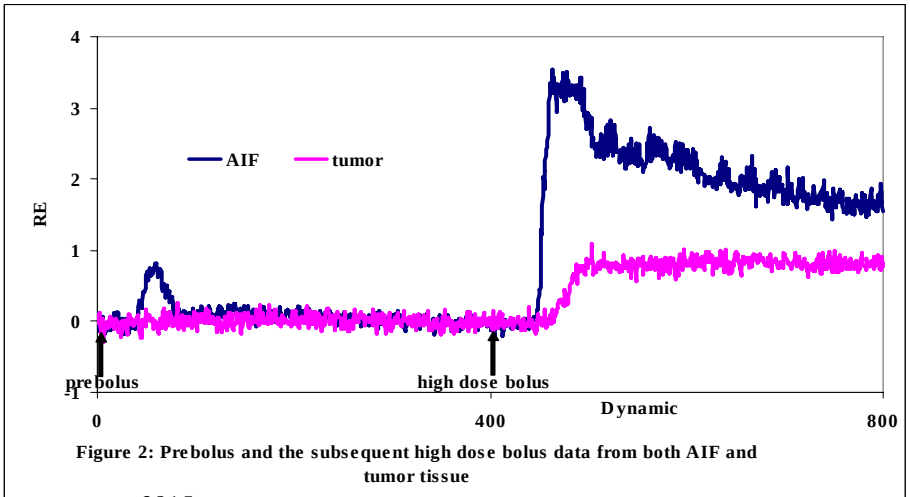

Figure 2: Prebolus and the subsequent high dose bolus data from both AIF and tumor tissue