Automatic AIF Estimation in Multi-echo DSC-MRI of Pediatric Patients - Avoiding The Noise Floor

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Target Audience: Investigators and clinicians interested in robust perfusion imaging techniques.

Purpose: It has been suggested that multi-echo DSC-MRI perfusion studies are preferable to single-echo alternatives due to their ability to correct for dynamic changes in T_1 relaxation times across the brain [ref 1]. However, multi-echo DSC-MRI perfusion studies are limited by signals that decay at later echo times to the point that they are indistinguishable from underlying noise. These 'saturated' signals lead to erroneous estimates of T_2^*, which can bias estimates of the arterial input function (AIF) leading to inaccurate estimates of perfusion characteristics [ref 2]. This drawback of multi-echo perfusion studies can be avoided if voxels that saturate into the underlying noise can be identified and removed from consideration when calculating the AIF. Here we propose two new signal guidelines that can be used to reduce the number of voxels suffering from signal saturation from being included in estimates of the arterial input function in multi-echo acquisitions. Furthermore, we evaluate these methods in a population of pediatric patients assessing the performance of these AIF selection rules in a clinical context.

Methods: [*Subjects*] Perfusion data from forty-five pediatric patients receiving multi-echo DSC-MRI perfusion studies were gathered and anonymized in accordance with local Internal Review Board policies. [*Imaging*] All patients were imaged axially axially at 3T using a body transmit and eight channel head only receive coil. Images were acquired using a dual echo, single-shot, gradient echo, echo planar imaging pulse sequence ($TR/TE_1/TE_2$=1.5s/15.19ms/45.4ms, θ=90□, FOV = 224x224mm, 21 slices, vox.dims.= 3x3x4.5mm, SENSE factor = 1.8, SPIR fat saturation). A series of 205 dynamic images were gathered, discarding the first five images to allow magnetization to reach temporal steady state. Patients were injected with a standard clinical contrast agent dose (Magnivist, 0.2ml/kg) after 40 dynamic scans. [*ΔR_2^* mapping*] Maps of T_2^* were estimated for each image using a log-linear fitting method. Time courses from these maps were used to calculate ΔR_2^* for use in all further analyses, thus correcting for dynamic changes in T_1 relaxation times. [*AIF selection*] Five criteria were used for identifying voxels for use in measuring the AIF: (1) top 5% of voxels across the brain in terms of steepness of the rise in ΔR_2^*, (2) top 5% of voxels across the brain in terms of narrowness of the ΔR_2^* peak, (3) top 5% of voxels across the brain in terms of ΔR_2^* peak height, (4) top 95% of within brain voxels in terms of Pearson's correlation coefficient between the ΔR_2^* time course measured from the first and the second echo independently, and (5) top 95% of within brain voxels in terms of the difference in ΔR_2^* peak height measured from TE_1 and TE_2 independently. Of these, criteria 1-3 represent common AIF selection guidelines, whereas criteria 4-5 represent new guidelines for avoiding voxels that saturate into the noise floor. [*Analysis*] For each patient, the AIF was calculated as the mean time course of ΔR_2^* (measured from quantitative T_2^* maps). Separate AIFs were calculated using just criteria 1-3 as well as using criteria 1-5 for selecting the appropriate voxels.

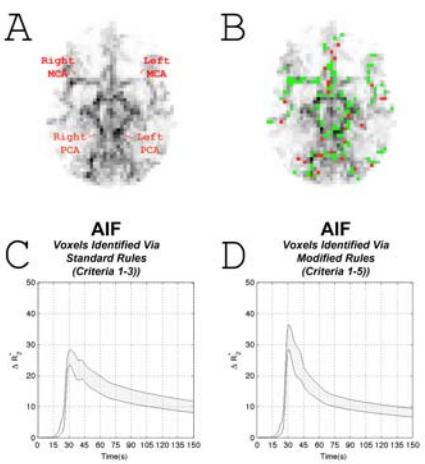

Figure 1: (A) An axial minimum intensity projection of ΔR_2^* rise times visualizing the general location of major cerebral arteries. (B) Voxels identified as for measurement of the AIF. *Green:* Satisfy criteria 1-3 and violate criterion 4 and/or 5; *Red:* Satisfy all criteria 1-5. (C &D) The mean+std AIF across patients using criteria 1-3 (c) and using criteria 1-5, i.e. excluding voxels that saturate to the noise floor at later echo times (d).

Results: In all patients, a significant number of voxels satisfying selection criteria 1-3 were found to saturate into the noise floor at the later echo time. Across patients, 39 +/- 9% of the voxels satisfying criteria 1-3 also passed criteria 4-5. The majority of voxels surviving all five conditions were located either on peripheral arteries, or were peripheral relative to major arteries. (e.g. Fig. 1B) This may be due to the lower baseline signal in major arteries in combination with the larger concentration of contrast agent and supports previously proposed guidelines of refraining from choosing voxels centrally located within major arteries for measurement of the AIF. When comparing the average time course from all voxels satisfying criteria 1-3 verses those satisfying criteria 1-5, we observed an 20 +/- 13% increase ΔR_2^* peak height and a decrease in peak width when including criteria to remove saturated voxels from AIF calculation (Figure 1C&D).

Conclusion: We have shown that multi-echo perfusion studies provide a new and important source of information for identifying voxels that saturate into the noise floor. These voxels can be excluded from use in AIF estimation, leading to an increase in the AIF ΔR_2^* peak height, and decrease in AIF ΔR_2^* peak width. Additionally, we have shown the practicality of these measurements across a pediatric clinical population.

References: [1] Vonken, Evert-jan Ph A., et al. *JMRI* 10.2 (1999): 109-117. [2] Willats, Lisa, and Fernando Calamante. *NMR in Biomedicine* (2012).