Appropriate methodology for automated scaling of DSC-CBF images for stroke evaluation

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Introduction: DSC perfusion studies are routinely performed for the assessment of stroke and brain tumor patients and are being used with increasing frequency in large scale clinical trials. A persistent DSC problem in routine imaging and clinical trials is that DSC CBF images are difficult to scale with accuracy. Although CBF images derived from DSC are (in principle) quantitative, the absolute CBF values derived from patient studies often show wild global variation and some form of image calibration is needed to reliably interpret measured CBF values. Furthermore it is highly desirable to use a CBF rescaling method that uses a minimum of intelligent user input and which could be automated for the processing of large scale studies. The inability to produce reliable accurate quantitative CBF images across subjects is a major limiting factor that has prevented the use of CBF imaging in favor of less sophisticated Tmax, MTT or TTP assessment in stroke. This study tested alternative fully automated approaches to DSC-CBF image scaling. Two automated approaches to arterial input function (AIF) selection were evaluated and the value of automated venous outflow measurement followed by AIF correction was assessed.

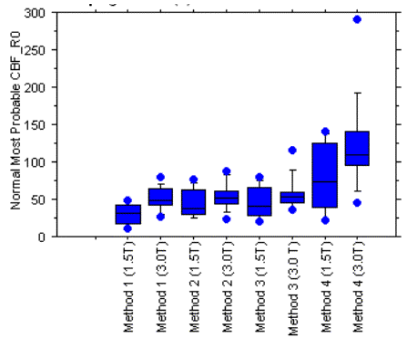

Figure 1: Box plot of most probable CBF measured in normal (Tmax = 0) brain areas using the methods described in the texts. Image calculation was fully automated. Minimal standard deviation was used

Methods: Anonymized DSC data were chosen from recent clinically-indicated DSC studies performed at our institution for assessment of acute evolving stroke. Requirements for inclusion included the availability of a time-of-flight intracranial MRA study that was performed during the same imaging session, no head repositioning between the MRA and DSC studies, and high quality DSC raw data. 3 T and 1.5 T studies were included to evaluate possible field strength related issues. For this preliminary evaluation, 8 studies performed at 1.5 T and 12 studies performed at 3 T were used. For each study, the 3D MRA raw images were aligned and resampled to match the DSC image space using a geometry matching algorithm. The aligned MRA intensity was used to generate a 3D artery mask in the DSC space and this mask was used to automatically sample the dynamic DSC signal data to produce an AIF estimate. AIFs were also automatically measured using dynamic criteria. VOFs were automatically measured in a similar fashion using different criteria. The across subject variance in the peak of the CBF histogram of the normal (Tmax = 0) tissues (equivalent to the most probable normal CBF) was used to assess each method's performance. Otherwise CBF image calculation was performed using standard automated SVD methodogy. Four different methods were tested: 1) MRA-based AIF selection with VOF correction, 2) Dynamic criteria AIF selection with VOF correction, 3) MRA-based AIF selection without VOF correction, 4) Dynamic criteria AIF selection without VOF correction.

	Mean	Std. Dev.	Count	Minimum	Maximum
Normal Most Probable CBF_R0, Total	62.750	41.847	80	11.000	290.000
Normal Most Probable CBF_R0, Method 1 (1.5T)	29.875	14.446	8	11.000	48.000
Normal Most Probable CBF_R0, Method 1 (3.0T)	50.667	15.352	12	26.000	80.000
Normal Most Probable CBF_R0, Method 2 (1.5T)	44.875	19.475	8	25.000	76.000
Normal Most Probable CBF_R0, Method 2 (3.0T)	53.167	17.806	12	24.000	87.000
Normal Most Probable CBF_R0, Method 3 (1.5T)	45.750	21.901	8	20.000	79.000
Normal Most Probable CBF_R0, Method 3 (3.0 T)	57.333	21.517	12	36.000	116.000
Normal Most Probable CBF_R0, Method 4 (1.5T)	79.500	46.485	8	22.000	141.000
Normal Most Probable CBF_R0, Method 4 (3.0T)	123.833	60.927	12	45.000	290.000

Table 1

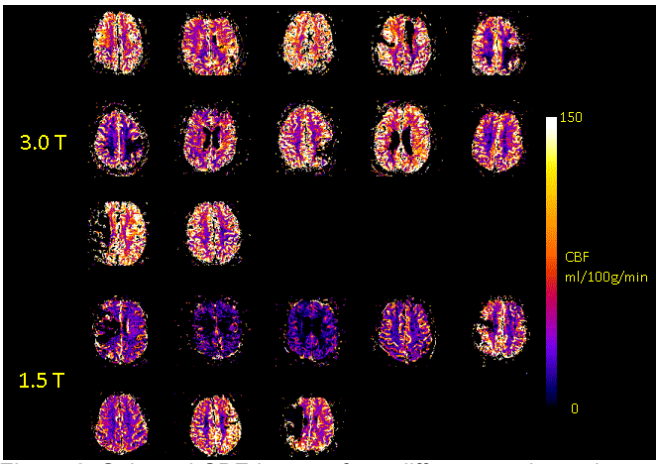

Figure 2: Selected CBF-images from different stroke patients calculated automatically using Method 1.

Results: The best performing method was method 1, although performance of method 2 was similar (Figure 1 and table 1). Figure 2 provides examples of the images produced by fully automated processing using the optimal method. The data indicate that even with optimal processing, a between patient variance of about 40% in the value of the normal CBF can be expected (Table 1). This variance may be due to biological factors or to technical factors that introduce subject- or protocol-related bias. For instance one possibility is that the accuracy of CBF calculation depends on the characteristics of the global arterial input, which varies between individuals. Furthermore there appear to be a subtle B0-related bias. Between subject CBF variance appears to be somewhat better at 3.0 T.

Conclusion: Measurement of VOF and correction of AIF partial volume effect are important factors for achieving consistent automatic between-subject scaling of DSC-CBF images. AIF selection using angiographic criteria performed modestly better than AIF selection based on arbitrary dynamic signal criteria. Even with these features included in the CBF processing, an irritatingly large variance in the normal CBF measured over groups of patients remains.