User-Independent Perfusion Post-Processing Using Gradient Echo and Spin Echo EPI at 1.5 T and 3.0 T

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Introduction:

Cerebral perfusion is a fundamental physiologic parameter that reflects the severity and progression of disease in a number of pathologies, including: cancer, stroke, AVMs, and cerebrovascular occlusive disease. Any method of quantifying perfusion should be: (1) accurate, (2) fully automatic, (3) applicable to both Spin Echo (SE) and Gradient Echo (GRE) EPI acquisitions, and (4) independent of field strength. The accuracy of the Bookend technique to quantify cerebral perfusion has been reported [1,2], but initial implementations required lengthy post-processing. Automatic image processing would allow for not only a broader dissemination of this technology, but also use in emergent cases such as acute stroke. We report on a user-independent post-processing algorithm, based on adaptive thresholding [3] using GRE and SE acquisitions at two field strengths (1.5 T and 3.0 T) in volunteers and patients.

Materials and Methods:

Volunteers and patients were scanned at both 1.5T and 3.0T using SE and GRE pulse sequences. Manual and automated post-processing was performed on these image sets. A series of metrics reflecting the accuracy of the measurements were compared.

Imaging Protocol: 9 volunteers were recruited and scanned using a 3.0 T MRI scanner (Trio, Siemens) and 5 acute stroke patients scanned on a clinical 1.5 T scanner (Avanto, Siemens) in this ongoing study. Gradient echo (TR/TE = 1500 ms/46 ms @ 1.5T, 1500 ms/45 ms @ 3.0T) and spin echo (TR/TE = 1500 ms/72 ms @ 1.5T, 1500 ms/61 ms @ 3.0T) were acquired with single contrast injections (0.1 mmol/kg b.w.).

Automatic Processing Algorithm: Image post-processing was fully automated in MATLAB (V6.5, Mathworks). The following steps, which previously required an operator input, have been automated: A) Sagittal sinus (SS) voxels were selected based on T_1 changes and noise thresholding, and B) Deep White Matter (WM) was segmented based on the mean and FWHM of the white matter T_1-distribution [1,2]. C) AIF voxels were selected based on: (1) an adaptive threshold defining the bolus arrival time, and (2) The Integral to Arrival Ratio (IAR), defined as the ratio of the normalized integral of the time signal over the first 4 time points after bolus arrival. The resulting AIF signal is the average of the signals from the voxels that have IAR greater than the mean of IAR distribution by 6 standard deviations. Voxels where signal saturation, or "clipping" of the AIF, is observed are removed from consideration.

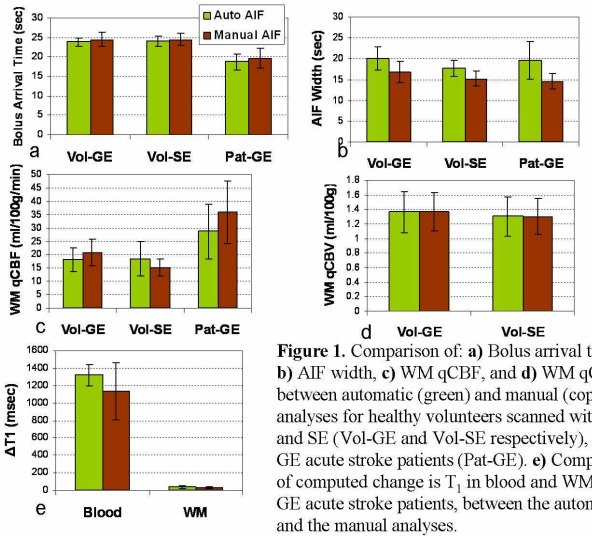

Figure 1. Comparison of: **a)** Bolus arrival time, **b)** AIF width, **c)** WM qCBF, and **d)** WM qCBV between automatic (green) and manual (copper) analyses for healthy volunteers scanned with GE and SE (Vol-GE and Vol-SE respectively), and GE acute stroke patients (Pat-GE). **e)** Comparison of computed change is T_1 in blood and WM for the GE acute stroke patients, between the automatic and the manual analyses.

Data Analysis: We compared the change in blood T_1 values in the SS to determine the difference between the manual and automatic SS detection. The change in WM T_1 values was compared to determine the difference between the manual and automatic WM segmentation. Bolus arrival time and AIF width were compared as these are metrics normally evaluated visually by users when manually choosing AIFs. The automatic quantification of physiologic perfusion was compared to the manual one based on WM qCBV and qCBF. The statistical significance was determined with a paired t-test (α=0.05).

Results/Conclusions:

There is no significant difference in the bolus arrival time (Figure 1a) between the manual and automatic AIF for the healthy volunteers (GE and SE at 3.0 T) as well as the acute stroke patients (GE at 1.5 T) ($p>0.05$). However, the bolus width is systematically broader in the automatic AIF (Figure 1b) with $p<0.05$, due to the inclusion of more voxels in the automatic AIF as compared to the manually selected one, which reduces the effect of transient noise fluctuations in the automatic AIF. There is no significant difference between the automatic and manual analyses of WM qCBF and WM qCBV for the healthy volunteers (Figure 1c,d) using GE and SE at 3.0 T ($p>0.05$), and of the WM qCBF for the acute stroke patients (Figure 1c) using GE at 1.5 T ($p>0.05$). However, the increase in width of the automatic AIF explains the systematic decrease in the automatic WM qCBF values as compared to the manual analysis. Figure 1e shows that changes in blood and WM T_1 values were not significantly different between the automatic and manual analyses of GE acute stroke patients at 1.5 T ($p>0.05$), which proves the accuracy of our automatic SS detection and WM segmentation. In conclusion, we have validated the accuracy of our new automatic perfusion quantification which is shown to give accurate quantitative results using GE and SE at 1.5 and 3.0 T in this initial sample of healthy subjects as well as acute stroke patients.

References: [1] Sakaie et al. JMRI (2005), [2] Shin et al. MRM (2006), [3] Carroll et al. Radiology (2003).