Removal of CSF Contamination in VSASL and QUIXOTIC using a long TE CSF Scan

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Introduction: In Velocity Selective ASL (VSASL) (1) and the QUIXOTIC method for the estimation of oxygen extraction fraction (OEF) (2), flow/diffusion weighting gradients are used to selectively attenuate the signal of flowing spins within certain velocity ranges. In these methods, the flow weighting is strong enough that diffusion related attenuation in CSF, which has high diffusivity, can become significant, and the CSF signal can contaminate the desired vascular signal. In VSASL this results in overestimation of CBF, and in QUIXOTIC it biases the venous T2 toward high values because of the long T2 of CSF. We introduce here a method to remove the CSF contribution to the VSASL and QUIXOTIC signals using direct detection of CSF.

Methods: The strategy used here is to acquire a second echo with very long TE (~500ms) such that only CSF signal is present, and use this CSF signal to estimate and remove the CSF contribution from the first echo. If the scan contains voxels with only CSF, then the T2 of CSF can be estimated using the first two echoes, otherwise, T2 can be estimated using 2nd and 3rd echoes, or using a separate scan through the ventricles, or assumed from literature values. Scanning was performed on a GE 3T MR750 scanner with a commercial 8 channel head coil. VSASL and QUIXOTIC were both implemented using BIR-4 based velocity selective saturation (VSS) pulses, and cutoff velocities of 2cm/s. For VSASL either one or two VSS modules (3) were used. QUIXOTIC was implemented using BIR-4 based T2-preparation. Flow compensation was used on all axes between the first and second echoes to minimize flow related artifacts in the CSF image. Across the normal subjects tested for this project, the measured T2 of CSF was consistently near 1300ms, and this value was used for all corrections. The second echo was scaled by $e^{-(TE_2-TE_1)/T_2}$ and subtracted from the first echo, giving a nominally CSF free first echo.

Results: Calculated CBF maps are shown in **Figure 1** for one and two VSS module VSASL, with and without BGS, and before and after CSF correction. A CBF map collected using PICORE/QUIPSS II tagging, which should not have CSF contamination is shown for comparison. Note that there is periventricular gray matter, as seen in the PICORE scan, which is obscured in the VSASL scans prior to CSF correction, but correctly represented after CSF correction. Also in the Figure are QUIXOTIC images before and after CSF correction, and average CBF and T2 numbers in the table at the bottom.

Discussion: CSF can generate significant systematic errors in both CBF measured using VSASL and QUIXOTIC measurements of venous T2. The method described here for correction of these effects is shown to bring these CBF and T2 measures closer to the expected ranges. For VSASL with one VSS module, the CSF estimate was much cleaner when BGS was used (see second row of **Figure**). This may due to significantly reduced fluctuation of the CSF signal with BGS. However, in our VSASL experiments with two VS modules, CSF correction was effective even without BGS. We hypothesize that with one VS module, which produces $M_Z \propto \cos(v)$, motion sensitivity is enhanced because Mz is both positive and negative across velocities, leading to cancellation that is dependent upon the local distribution of CSF velocities. Dual VSS VSASL results in $M_Z \propto \cos^2(v)$, which is strictly non-negative, and may lead to the more uniform CSF signals we have seen. An alternative strategy to the one employed here is to use a separate long TE scan for CSF detection, rather than a second echo in the scan of interest. The advantage of this alternative approach is that the estimation of the true CSF content may be more accurate, because of the lack of the preparation pulses present in VSASL and QUIXOTIC, but the disadvantage is that it requires correction for not only TE, but also T1 and possibly diffusion related modulations.

References

1. Wong et al, MRM 55:1334, 2006
2. Bolar et al, ISMRM p. 628, 2009.
3. Guo et al, "Increased tagging efficiency in Velocity Selective ASL using Multiple Velocity Selective Saturation Modules", ISMRM 2011, submitted.