Perfusion Imaging of the Human Cervical Spinal Cord

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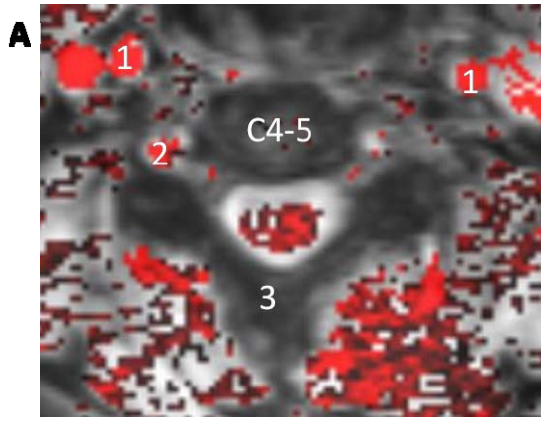
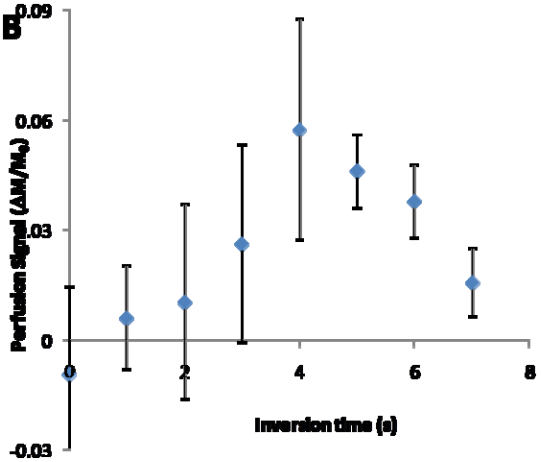
Introduction: Noninvasive quantification of blood flow in the spinal cord may not only help in the diagnosis and evaluation of cord pathologies like tumors, ischemia and neurodegeneration, but also may enable the functional imaging of the lower motor neurons. However, perfusion imaging of the cervical cord is challenging due to the small size of the structures and physiological artifacts associated with this region, as well as due to the different routes of perfusion of the cord. The region of cervical enlargement is nourished by the anterior and posterior spinal arteries running down from the medulla in the brain and reinforced by segmental medullary arteries running along spinal nerve roots[1]. This can essentially give rise to watershed regions of perfusion, with flow in both superior and inferior directions into the imaging slab. In this work, perfusion imaging of the cervical cord was performed using thin imaging slabs and a high resolution presat-FAIR sequence.





Method: C4-C6 segment of the spinal cord were scanned in five healthy subjects (Age of 27 ± 9 years, 1 female) using a presat-FAIR[2,3] sequence with parameters: saturation time=5 s, TE=17 ms, GRAPPA=4, acquisition matrix=128x128, in-plane resolution=1 mm^2, slice thickness=5 mm and 20% gap, 5 slices for a total imaging volume of 30 mm, and 20 or 40 repetitions. TR was minimized to reduce inter-slice time interval. Control and tagged images were acquired using alternating 40 mm and 500 mm slice-selective hyperbolic secant inversion pulse and the inversion time (TI) was varied between 35 ms and 7 s in 8 steps to determine the wash-in and wash-out profiles of the labeled spins. $\Delta M/M_0$ was calculated at each TI from ROIs drawn on the cord and perfusion quantified using modified double subtraction strategy [5,2,3].

Results and Discussion: Representative perfusion weighted image obtained at TI of 4s (in red) at the level of C4-5 disc and overlaid on the anatomical image is shown in Fig. A. Strong perfusion signal is seen from the cervical cord and prominent vessels such as carotid (1) and vertebral (2) arteries and other soft tissues. Medullary and spinal vessels were not visible. A plot of perfusion signal ($\Delta M/M_0$) at various inversion times show clear wash-in and wash-out patterns from the cervical cord (Fig. B). The average transit delay in the cervical cord (~2s) was longer than those of the brain, probably due to the smaller caliber and slower flow in the feeding arteries. Peak perfusion signal was obtained between TI of 4s and 5s for all subjects. The average quantitative perfusion from the ROI was determined to be 26 ± 11 ml/100mg/min.

Conclusion and Future Direction: Perfusion signal could be obtained from the cervical cord with sufficient SNR using the presat-FAIR sequence. The sequence is being modified with a pair of diffusion gradients to avoid contamination from large vessels and CSF. We propose to modify the QUIPSS II sequence[4] with a train of thin presaturation pulses on either side of the imaging slab to deliver a plug flow of labeled spins to the cervical thickening, and facilitate easier quantification. Perfusion differences between grey and white matter may be better delineated with higher resolution and better SNR sequence, which could be achieved with outer volume suppression and more signal averaging.

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References: [1]Gray's Anatomy. 38th British ed. New York, NY: Churchill Livingstone Inc; 1995; [2]Magn Reson Med 41:829–840 (1999); [3]Magn Reson Med 62:430–439 (2009); [4]Magn Reson Med 39:702-708 (1998); [5]Magn Reson Med 1998;40:383–396