Simultaneous Mapping of Cerebral Blood Flow and Venous T2*

K. St. Lawrence[1], J. Wang[2]
[1]Lawson Health Research Institute, London, Ontario, Canada, [2]Department of Radiology, University of Pennsylvania, Philadelphia, Pennsylvania, United States

Introduction: Cerebral blood oxygen saturation provides important information regarding brain function under normal and pathological conditions (1). Existing MRI methods for measuring oxygen saturation are based on susceptibility effects, which can be difficult to quantify due to macroscopic field variations (2,3). In an earlier study, we demonstrated that venous T_2* affects the capillary contribution to the arterial spin labelling (ASL) signal (4,5). This effect resulted in a decrease in the cerebral blood flow (CBF) measurements acquired with increasing echo time at a high field strength (4 T). In this study, we investigated if the echo-time dependence of the ASL signal can be used to determine venous T_2*. Considering the dependence of blood T_2* on oxygenation levels (6-8), this approach could be used to measure cerebral blood flow and cerebral blood oxygen saturation simultaneously.

Methods: Data were collected at 4 T (GE Medical Systems) using a FAIR sequence with an inversion time of 1600 ms and a saturation pulse applied proximal to the imaging slices at 800 ms after the labelling pulse. The acquisition delay following the saturation pulse allowed sufficient time for all of the labelled water to flow into brain tissue. Images were acquired using an EPI sequence with 8 slices (8 mm each & 2 mm gap), a FOV = 240 x 160 mm^2, and a matrix = 64 x 40. Basal CBF was measured in four healthy volunteers at four echo times (19, 32, 45, 58 ms). The CBF images were transformed to Talairach coordinates using SPM software and the group CBF maps reduced to an in-plane resolution of 16 x 16 before data analysis.

Estimates of venous T_2^* were obtained by fitting the echo-dependent CBF images with a tracer kinetic model that included the capillary contribution to the ASL signal (5). The transverse relaxation rate (i.e., $1/T_2$*) in the capillary compartment was assumed to be a linearly combination of arterial and venous blood. For the non-linear least-squares fitting, all other model parameters besides venous T_2^* were kept constant, namely: T_1 and T_2* values for tissue and arterial blood, the permeability-surface area product and the capillary blood volume.

Results: Group CBF and venous T_2* images are shown in Fig. 1. The CBF images are presented at the same spatial resolution as the T_2* images. For grey and white matter respectively, CBF = 70.2 ± 9.3 and 41.1 ± 7.6 ml $100g^{-1}$ min^{-1}, and venous T_2* = 10.8 ± 4.2 and 9.3 ± 4.7 ms. Unlike the CBF images, no differences between grey and white matter were evident in the T_2* images. Since venous T_2* is related to oxygen saturation, this is expected as cerebral oxygen extraction is known to be uniform across the healthy brain (1,2).

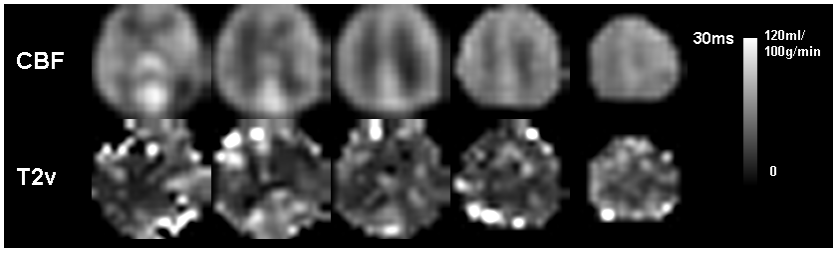

Fig. 1 CBF and venous T_2* images averaged over four subjects. The CBF images were generated from the ASL acquired at TE = 19 ms. The venous T2* images represent the best fit to the multi-echo ASL data.

Conclusion: Assuming a quadratic dependence on field strength (6), our average estimate of venous T_2* is in good agreement with previous results measured at 1.5 T. This implies that venous T_2* data could be converted to images of cerebral blood oxygen saturation. The advantages of our approach are the venous T_2* values are localized to the capillary bed, due to the ASL weighting, and the T_2* estimates may be less sensitive to background field variations than other approaches since the ASL signals are normalized. However, to become a feasible method for imaging blood oxygen saturation, the signal-to-noise ratio of the ASL should be improved and the sensitive of the T_2* estimates to the other model parameters determined. The sensitivity of the technique could also be improved by collecting the data at higher fields to enhance the effect of blood T_2* on multi-echo ASL data.

References:

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