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Quantification of Dispersion Effects in Arterial Spin Labelling Perfusion MRI

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Abstract : Introduction: Arterial spin labelling (ASL) is an increasingly popular perfusion MRI technique, in which arterial blood water is magnetically labelled in the neck before flowing into the brain, providing a non-invasive measure of cerebral blood flow (CBF). The accuracy of ASL CBF measurements, however, is hampered by dispersion effects; the distortion of the ASL labelled bolus during its transit through the vasculature. In spite of this, the current recommended implementation of ASL – the white paper (Alsop et al., MRM, 73.1 (2015): 102-116) – does not account for dispersion, which leads to the introduction of errors in CBF. Given that the transport time from the labelling region to the tissue – the arterial transit time (ATT) – depends on the region of the brain and the condition of the patient, it is likely that these errors will also vary with the ATT. In this study, various dispersion models are assessed in comparison with the white paper (WP) formula for CBF quantification, enabling the errors introduced by the WP to be quantified. Additionally, this study examines the relationship between the errors associated with the WP and the ATT – and how this is influenced by dispersion. Methods: Data were simulated using the standard model for pseudo-continuous ASL, along with various dispersion models, and then quantified using the formula in the WP. The ATT was varied from 0.5s-1.3s, and the errors associated with noise artefacts were computed in order to define the concept of significant error. The instantaneous slope of the error was also computed as an indicator of the sensitivity of the error with fluctuations in ATT. Finally, a regression analysis was performed to obtain the mean error against ATT. Results: An error of 20.9% was found to be comparable to that introduced by typical measurement noise. The WP formula was shown to introduce errors exceeding 20.9% for ATTs beyond 1.25s even when dispersion effects were ignored. Using a Gaussian dispersion model, a mean error of 16% was introduced by using the WP, and a dispersion threshold of $\sigma=0.6$ was determined, beyond which the error was found to increase considerably with ATT. The mean error ranged from 44.5% to 73.5% when other physiologically plausible dispersion models were implemented, and the instantaneous slope varied from 35 to 75 as dispersion levels were varied. Conclusion: It has been shown that the WP quantification formula holds only within an ATT window of 0.5 to 1.25s, and that this window gets narrower as dispersion occurs. Provided that the dispersion levels fall below the threshold evaluated in this study, however, the WP can measure CBF with reasonable accuracy if dispersion is correctly modelled by the Gaussian model. However, substantial errors were observed with other common models for dispersion with dispersion levels similar to those that have been observed in literature.

Keywords : arterial spin labelling, dispersion, MRI, perfusion
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