An improved arterial model for QUASAR ASL that permits estimation of arterial flow speed

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TARGET AUDIENCE – Scientist and clinicians with interest in perfusion MRI

PURPOSE – QUASAR is an established sequence for the study of perfusion without any injection of contrast agent that uses arterial spin labelling principles. It exploits the use of a vascular crushing gradient to extract signals from blood both in arteries and in tissue. Model-free and model-based approaches have been proposed[1,2] to estimate perfusion and other parameters of interest such as arterial blood volume. In particular a full model has been introduced to take into account the different direction of vascular gradients employed during the different phases of acquisition. The original version of this model used a simple relation to describe the alignment of blood velocity vector with gradients[2]. In this work a more realistic relationship between the crushing gradients and the blood flow is introduced based on the principles of perfusion tensor imaging[3].

METHODS – The original two component model for QUASAR data in[2] assumed that the effect of the bipolar crushing gradients could be described as a linear effect: removing the component parallel to the crusher direction and ignoring the flow speed. The new model describes the crushing effect using the projection of the average velocity vector along the vascular crushing gradient direction and integrating over the range of velocities in the artery, thus following the work of Frank et al.[3]: Sinc($2\pi v \max(\boldsymbol{a}\cdot\boldsymbol{g},0)$), where $\boldsymbol{a}$ is the direction of arterial flow, $\boldsymbol{g}$ is the vector of the crushing gradient, v is the mean flow velocity and is a further parameter that must be estimated in the model. We will refer the new model as *Sinc* and the original simpler model as *Original*. The estimation of both the *Sinc* and *Original* models was performed in the same Bayesian framework as Chappell et al.[2] (the tool QUASIL in FSL), including M0 calibration and actual flip angle determination from the low flip angle acquisition. Both models were compared for estimation of perfusion, bolus arrival time (BAT) and arterial blood volume (aBV). Additionally the Free Energy parameter from the algorithm was used as index of goodness-of-fit and model parsimony. All the results were transformed into a standard space using the reference 3D T1 MPRAGE to perform group comparisons. Data were analysed from 7 subjects each having been scanned 4 times over two sessions (as part of the QUASAR reproducibility study[4]). Scan parameters: TR/TE/ΔTI/TI1=4000/23/300/40 ms, 13 TIs (40-3640 ms), 64x64 matrix, 7 slices, slice thickness 6 mm with 2 mm gap, FOV 240x240 mm, flip-angle=35/11.7o, SENSE=2.5. 6 repetitions containing 3 non flow suppressed pairs (1 with low flip angle) and 4 pairs with flow suppression (Venc 4 cm/s), a total of 84 measurements with duration 5 mins 52 s.

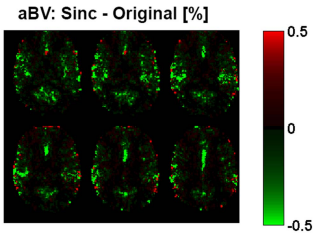

Fig. 1 Arterial Blood Volume absolute differences between the two models estimates

RESULTS – Fig. 1 reports the differences in aBV obtained with both models. aBV estimates obtained with *Sinc* were lower than those of *Original* model (aBV_{Sinc}=1.82±1.62% (mean±SD) $aBV_{Original}$=2.21±1.70%, Wilcoxon rank-sum test p<0.001). Fig. 2 shows perfusion estimates obtained with both models with percentage differences between them. Perfusion estimates with the *Sinc* model were 56.72±12.23 for GM and 26.04±12.63 for WM, while with *Original* model were 55.63±12.63 and 25.94±11.09 (mean±SD [ml/100g/min]), respectively. Perfusion estimates were not significantly different between the two models (Wilcoxon rank-sum test: p_{GM}=0.64,p_{WM}=0.82). In Fig.1 (4th subplot) the difference of *log(-FE)* between the two models is shown: negative differences (green values) indicate a better performance of the *Sinc* model which was the case primarily in regions of high aBV where arteries would be expected in the brain. Estimates of mean arterial blood speed in the principal arterial vessels are shown in Fig. 3 as a mean across the group: values of mean flow speed in the range 3-5 cm/s were found in areas where middle cerebral artery braches would be expected.

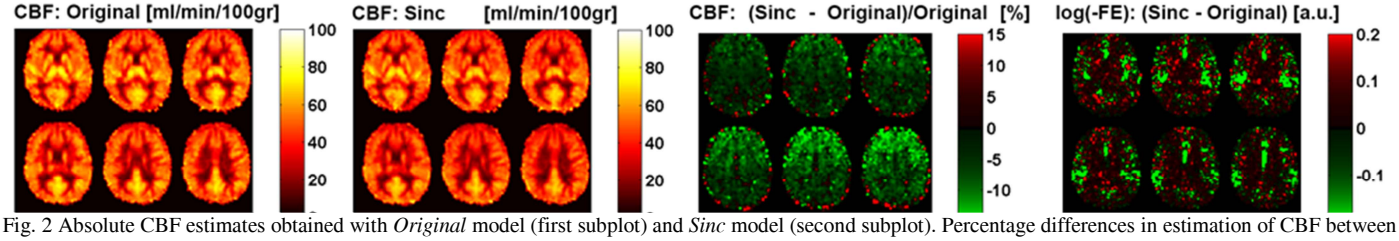

Fig. 2 Absolute CBF estimates obtained with *Original* model (first subplot) and *Sinc* model (second subplot). Percentage differences in estimation of CBF between the two models (third subplot). Differences in Free Energy estimates give a measurement of model performance (green value indicates better performance for the *Sinc* model) (fourth boxplot). All the figures show a mean value obtained after registration on MNI space.

DISCUSSION – Perfusion estimates were comparable in both GM and WM; however, the *Sinc* model gave narrower CBF confidential intervals in both tissue types. The Free Energy comparison indicated that the *Sinc* model could better describe the signal in voxels where the arterial component is predominant, consistent with the improvement in the arterial model and resulting in significant lower estimates of aBV (p<0.01). It was also found that the *Sinc* model could provide plausible estimates of mean blood speed in the arterial vessels from QUASAR ASL. The mean blood speed estimated might be affected by partial volume effects due to the low resolution of the data and further validation is required to understand the robustness of this measurement.

CONCLUSION – An improved model for QUASAR ASL has been developed. It gives comparable estimates in perfusion, and BAT (data not shown) to the existing model, but is a better representation of the data in regions of high aBV. It is able to provide some quantification of flow speed in arteries exploiting information already present in the data, which might be valuable in pathologies such as stenosis.

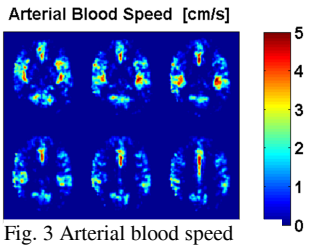

Fig. 3 Arterial blood speed estimated with the *Sinc* model proposed.

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