The effect of flow dispersion in arterial spin labeling perfusion

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Introduction

To date, most methods set forth for the analysis of ASL data have assumed that tagged blood is delivered from the tagging region to the imaging region via simple plug flow, i.e. a single transit delay (T_V). In reality, however, flow in the carotid arteries and into the brain is complicated, and has characteristics of plug, laminar, and turbulent flow. Another issue that has not yet been carefully investigated is the dependence of the ASL signal on cardiac pulsations. Since the blood in carotid arteries exhibits time-varying flow velocity as a function of cardiac phases (1), un-gated ASL measures the mean perfusion over a cardiac cycle, assuming that the repetition time is asynchronous with R-R interval. This study attempts to elucidate the effect of different flow velocity upon ASL measurement.

Material and Method

Based on the kinetic model for quantitative ASL proposed by Buxton et al (2), T_V here was modeled as Gaussian distribution, $T_V(t)$. QUIPPS II (3) was used to control the arterial bolus width (T_A) and the delivery function $c(t)$ in the model became $c(t) = \exp(-t/T_{1A})[w(t) \otimes T_V(t)]$, where $w(t) = 1$ as $0 \le t \le T_A$ and 0 otherwise. A template of ASL signal time curves was then generated using the $T_V(t)$ with mean (X_{TV}) = {10, 300, 500, 700, 900, 1100, 1300} ms and standard deviation (σ_{TV}) = {1, 200, 500} ms. While X_{TV} = 10 was used to account for large vessels through the imaging plane, three σ_{TV} values described plug flow (σ_{TV} = 1) and two different degrees of bolus smoothing. ASL images were acquired using PICORE QUIPPS II (3,4) with TI = {300,500,700, 900,1100,1300,1500} ms and TI_1 = 700 ms. For studies with TI shorter than TI_1, QUIPPS II was switched off. Other relevant imaging parameters included: TR/TE = 2400/3.2 ms, 64 x 64 resolution, FOV = 24cm x 24cm x 5mm, 4 axial slices with 1mm gap. A pulse oximeter was used to prospectively trigger the sequence. For each subject, data sets were acquired at two different cardiac phases with trigger delay 300 ms and 660 ms, which corresponds to diastole and systole, i.e. slow and fast flow phases. All the imaging was performed on a 3T GE system on healthy volunteers.

The ASL data with a series of TIs were correlated to each signal-time curve in the template on a pixel-by-pixel basis. The threshold of correlation coefficient was 0.7. The highest correlated signal-time curve along with its X_{TV} and σ_{TV} were assigned to the corresponding pixel. The histograms of X_{TV} and σ_{TV} were then plotted for gray matter.

Results and Discussions

Fig 1 showed X_{TV} and σ_{TV} histograms obtained at different flow phases. While X_{TV} histogram shifted to the right at the phase of slow velocity, no obvious trend was found in σ_{TV} histogram at different flow phases. The mean X_{TV} in Fig 1 was 481 ms and 578 ms at fast and slow flow phase, respectively. σ_{TV} histogram shifted to the left at the distal slice (not shown here), which suggested that the flow pattern became more plug-like after a longer transit rout. While the percentage of plug flow (σ_{TV} =1) was always above 50% regardless of slices and flow phases, X_{TV} varied quite a bit. Fig 2 showed the ASL signal-time curves obtained at different flow phases. Since the slope of the rising band was proportional to blood flow, the flow variation was about ±10% referring to the overall value. In conclusion, the flow phase of feeding arteries causes variation in perfusion measurement even after a substantial damping from carotids to arterioles/capillaries. Without sacrificing generality, a Gaussian distribution-based model of ASL signal-time curves provides a more realistic model to describe tag delivery in terms of both flow dispersion and mean transit delay.

References

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3. Wong EC et al. Magn Reson Med 1998;39:702-708. 4. Wong EC et al. NMR Biomed 1997;10:237-249.

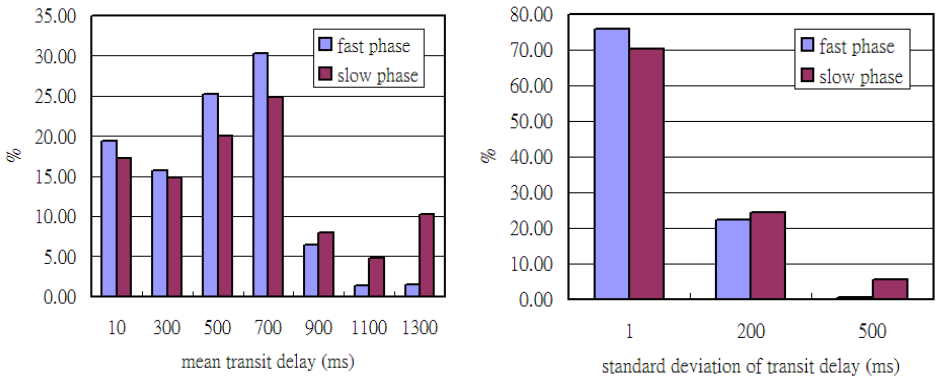

Fig 1. The histograms of mean transit delay (X_{TV}) and flow dispersion (σ_{TV})

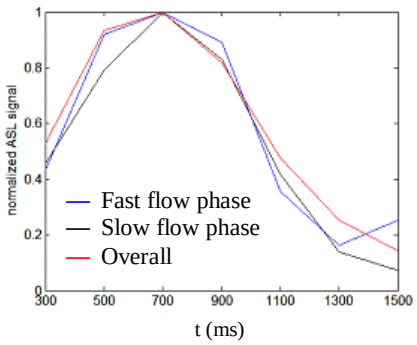

Fig 2. The ASL signals obtained at different flow phases