Comparison of arterial transit delays and bolus widths in children and adults as measured with arterial spin labeling

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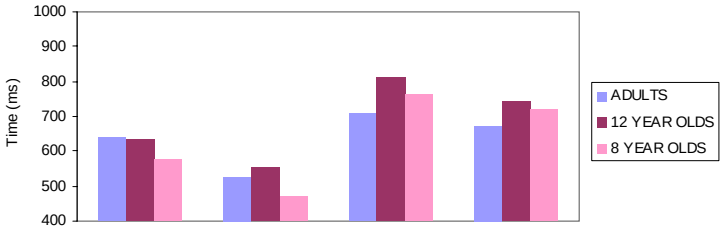
INTRODUCTION: Arterial spin labeling (ASL) perfusion imaging techniques measure cerebral blood flow (CBF) in a noninvasive manner that is advantageous for safely studying developmental changes in CBF in healthy children. To date, developmental studies of CBF have been primarily limited to patients [1] and the use of exogenous tracing techniques [2-4]. With ASL the quantification of CBF depends on the identification of appropriate values of physiological parameters that may change with age, namely the transit times of the spin labeled blood to the region of interest and the bolus width of the arterial tag. In this study, we used ASL to measure the transit times and bolus width in two groups of healthy children (ages 8 and 12) and a group of healthy adults (ages 20-30) during rest and visual stimulation. ASL data were acquired at different post-labeling delay times and fitted to a theoretical model [5] to measure and compare the physiological parameters of children and adults.

METHODS: Five 8-year-old children (2 female), four 12-year-old children (2 female), and 5 adults (ages 20-30, 3 female) participated in the study. All imaging was performed on a 3T Varian System (Palo Alto, CA), equipped with a volume head transmit coil and a single channel surface receive coil (Nova Medical, Wakefield, MA). Perfusion images were obtained with the PICORE [6] sequence with a single-shot gradient-echo EPI readout. The imaging parameters were: $\theta = 90°$, FOV = 24.0×24.0 cm^2, TR/TE = 2000/27.3 ms, 3 slices, slice thickness = 8.0 mm. Axial slices were acquired at an oblique angle, in plane with the calcarine sulcus. The inversion slab was 100 mm thick, and the distance from the edge of the inversion slab to the proximal edge of the first slice was 10.0 mm. 160 time frames were acquired during the functional paradigm. In six separate runs, inversion delay times, TI, were set to 300, 600, 900, 1200, 1400, and 1600 ms, respectively. The task consisted of a block design visual paradigm consisting of 4 cycles of a 40 second on/off colored radial checkerboard flashing at 8 Hz. Reconstructed data were motion corrected using the image registration program in AFNI [7]. Perfusion time-series were calculated for all TI values and functional maps were generated from the averaged time-series of TI = 1400 ms and 1600 ms. Voxels were assumed to be activated if the correlation coefficient with a boxcar waveform after detrending was above 0.4. The first 4 points of each epoch were ignored in the transit curve analysis due to signal fluctuations. Selected data were fitted to a theoretical ASL kinetic model proposed by Buxton [5] assuming a plug flow profile. Only voxels that exceeded correlation coefficients of 0.7 for the goodness-of-fit criteria of the fitted curves were included in the mean analysis. Average estimates of arterial bolus width T_A, and local arterial transit delays Δt, were obtained for each subject.

RESULTS AND DISCUSSION: Figure 1 is a summary of the mean and standard error of arterial transit delays and arterial bolus widths during rest and activation for child groups, ages 8 and 12, and adult group ages 20-30. Group comparisons suggest a possible trend of shorter trans it times in 8-year-old children during both rest and activation compared to adults (*t* test, p = .08 for both rest and activation). Transit times in 12-year-old children did not differ significantly from adults', nor did the bolus widths for either group. The indication of faster arterial transit in 8-year-olds concurs with previous studies using exogenous tracing techniques that report increased cerebral blood flow in children to approximately 10 years of age followed by a decline toward adult levels in adolescence [2-4]. The measured transit times and bolus widths also provide insight into the selection of parameters for quantitative ASL. For example, in pulsed ASL using the QUIPSS II sequence [8], quantification is achieved by the addition of saturation pulses to spoil magnetization that remains in the tagging region at a delay of TI_1 after the inversion pulse. One requirement of this sequence is for TI_1 to be less than the arterial bolus time T_A, the clearance time for the blood to leave the tagging region. An additional requirement is that the image should be acquired after a delay $TI_2 > TI_1 + \Delta t$ after the inversion pulse. Based on our 8-year-old child group, appropriate values for TI_1 and TI_2 for this age are approximately 600 ms and 1300 ms, respectively. For comparison, typical values for the adult age group are TI_1=700 ms and TI_2=1400 ms [8].



Age	t (ms)				T_A (ms)			
	Rest		Activation		Rest		Activation	
20-30	640.9	8.1	526.0	9.3	706.6	9.4	671.5	10.1
12	634.0	10.9	553.3	11.2	811.3	14.8	742.8	23.3
8	578.8	13.3	472.1	9.0	763.6	18.1	720.3	12.0

Figure 1: Summary of mean and standard error of arterial transit delay t, and bolus width T_A measurements.

CONCLUSIONS: We have compared estimates of arterial transit time and bolus widths obtained from fitting ASL data to a theoretical model for children and adults. Our preliminary results, currently based on a limited sample size, indicate possible differences in arterial transit delays between 8-year-old children and adults. By 12 years of age, transit times are not significantly different from adult parameters. Bolus widths are comparable between children and adults.

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