Significant Differences Found in the Distribution of Pulsatile Flows in the Preterm Infant Brain Compared to the Adult Brain

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Introduction

Flow in the brain is composed of extracellular fluid (ECF) flow, cerebral blood flow (CBF), and cerebrospinal fluid (CSF) flow. In (1) we described a frequency band-specific pulsatile flow imaging (FB-SPFI) approach to analyze pulsatile flow, based on EPI series frequency analysis. FB-SPFI relies on post-processing of image data from a rapidly acquired gradient-recalled EPI times series in a select imaged slice. When applied to the infant brain, each voxel's signal displays characteristic contributions from oscillating (ie pulsatile) ECF, CSF and CBF inflow from out-of-slice fresh spins. This provides key physiological information, since each frequency range relates to some physiological process(es) in the infant's body. We showed that the increased water content of the immature preterm infant brain enhances pulsatile flow whose frequency distribution reveals infant physiology, and can provide detailed microstructural information, as DT-MRI, when flow data is acquired in 3D. CSF flow in the adult brain was later investigated by Strik et al (2) using the same approach, and compared to results from adult brain parenchyma and brain blood vessels. Strik et al (2) described the frequency distribution of pulsatile flows in the adult brain as being dominated by 70-80% of high frequency cardiac and respiratory contributions.

Methods

30 (18 M; 12 F) preterm infants (both neurologically normal infants and infants exhibiting brain pathology) underwent MRI examinations at 28-40 weeks postconceptional age (PCA). Institutional approval for MRI was obtained, and informed consent was obtained from the parents. All infants were fed prior, and asleep during the exam. No sedation was used. There was constant supervision by a physician. ECG and O2SAT monitoring and hearing protection were used, with a vacuum fixation pillow to cradle the head and body. Data were acquired on a 1.5T GE HORIZON LX Echospeed MR Scanner using a commercial head coil. Morphological MRI was initially obtained. Flow imaging raw data were obtained in each case from an axial brain slice superior to the lateral ventricles with Nyquist frequency 6.0Hz using gradient-recalled echo planar imaging with: TE 45ms TR 167ms, FA 45deg, 64x64 matrix, FOV 15cm, 1 NEX, 256 sequential acquisitions, 3.0mm thick, Bw 62.5kHz, ν=A/P, 1/2 phase encoding. The monitored cardiac rate range was recorded by the supervising physician and used to select the cardiac pass-band frequency range. The typical rate of 40-50 breaths/min (0.67-0.83Hz) was used for selection of the respiratory pass-band frequency range. Post-processing was performed using MATLAB software. The multi-image time domain voxel data for each infant's brain slice was transformed via the Fast Fourier Transform (FFT) to Fourier (ie. frequency) domain data, from which signals in specific frequency bands (ie specific finite frequency ranges) are extracted, representing the pulsatile flow in those specific frequency ranges. Band-specific voxel data is combined to produce a greyscale image for each infant-specific frequency range: very low 0.001-0.05Hz, low 0.05-0.15Hz, mid 0.15-0.6Hz, respiratory 0.6-0.9Hz, mid-high 1-2Hz, cardiac approx 2.25-3Hz (nomenclature is an augmented form of that used in describing adult flow studies). A brain mask was created for each subject from steady-state data and eroded four times to eliminate CSF dominated intracranial space. The percent of specific frequency band signal was then computed for all subjects, and SPSS software was used to compute group statistics.

Results

Table I, first row, displays the frequency distribution of FB-SPFI signal results from the whole preterm infant brain. Adult brain results in Table I, for comparison, are from (2). The results in Table I show that, observed from preterm infants, 60% of total observed signal is due to pulsatile flows in the very low (29%) and low frequency (31%) bands, more than 3x that observed (15%) in adult brain parenchyma. Among infants 28-42wks PCA no significant age-dependency in signal in each band was found. The frequency distribution of these results differs *significantly* from the results obtained by Strik et al (2) from adult brain parenchyma which are dominated by high frequency pulsatile flows in the adult respiratory (15%) and cardiac (70%) band signals, respectively.

	Percent of Total Signal in Each Frequency Range			
	Very Low	Low	Respiratory	Cardiac
Preterm infant brain parenchyma	29±3	31±2	24±1	16±2
Adult brainstem parenchyma & pariental lobe	6	9	15	70
Adult CSF	4	4	11	80
Adult Arterial System	4	6	10	80
Adult Venous System	14	16	8	60

Table I. Percent of total signal from spectrum in major frequency ranges.

Conclusion

The frequency distribution of pulsatile flow signal in observed frequency bands from preterm infants was the complete reverse of that seen in the adult brain parenchyma, with more signal observed from the low frequency bands in the infant brain compared with the adult brain where the cardiac band dominates. This prominent low frequency pulsatile flow may result from physiological events (swallowing and sucking, neck movement, esophageal peristalsis, head motion and postural changes, and venous flow and vascular motion) and possibly external sensory stimuli playing a role in pulsatile brain flow in the preterm infant during the period of intense early neurodevelopment, prior to the predominance of respiratory and cardiac influences.

References

(1) GP Zientara, et.al., Abs 9th ISMRM, 2001, 406. (2) Strik C, Klose U, Erb M, Strik H, Grodd W, J Magn Res Img 2002, 15: 251-258.

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