Correlations Between Increased ASL Perfusion and Decreased ADC in Newborns with Hypoxic Ischemia

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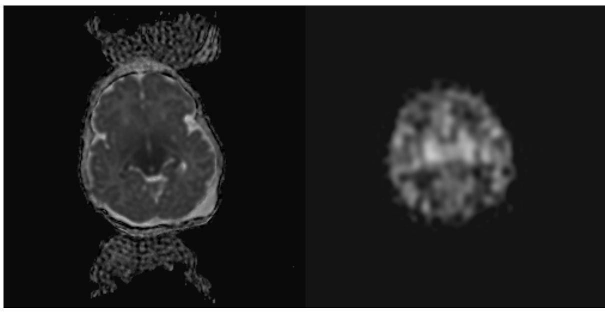
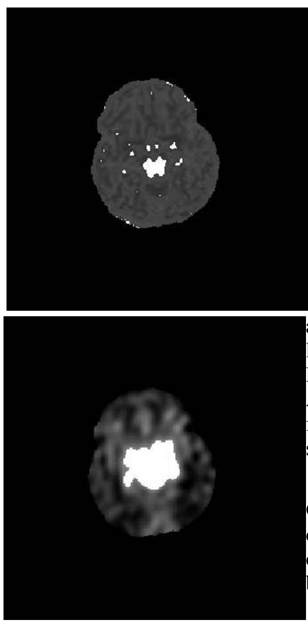
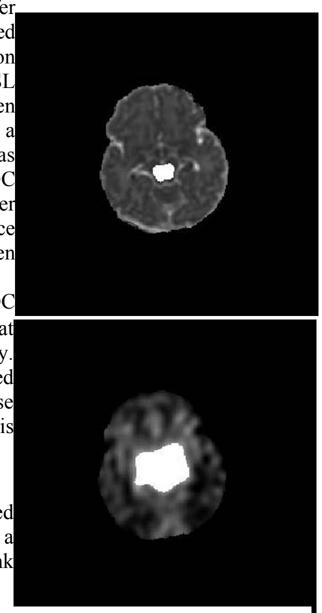
INTRODUCTION: Diffusion Weighted Imaging (DWI) MRI offers a means to study the actual fiber structure of brain organization. The DWI data can be processed to determine the Apparent Diffusion Coefficient (ADC), which measures the magnitude of water diffusion through cerebral tissue. Increasingly, the ADC is also used as a means to detect ischemic brain lesions, tagging areas of structural degeneration in the brain. Another functional marker of brain activity is arterial spin labeled cerebral blood flow (ASL-CBF), which tags the perfusive behavior of blood activity in the brain. In clinical practice, we have noticed a qualitative relationship in newborns between decreased ADC values and elevated ASL perfusion in regions of ischemic insult. This study presents a method to determine if any such correlation might. Measuring such a correlation between low ADC values and high ASL perfusion would indicate that post-trauma ischemic regions in fact have hyperfusion of blood flow in the damaged area, a finding that runs contrary to typical ischemic observations in adult subjects.



METHODS: A cohort of ten pediatric subjects ranging in age from birth to four days old, and presenting with hypoxic ischemia were scanned on a with a clinical GE 1.5T SIGNA EXCITE scanner, acquiring both diffusion weighted imaging (DWI) data and arterial spin labeled (ASL-CBF) volumes in a single session. For normative comparisons, DWI and ASL-CBF data was also collected on a group of nine neurologically normal children ranging in age from 2 days post-natal to approximately 3 months old. An automated software pipeline was developed to analyze these volumes for correlations between areas of possibly low ADC signal and corresponding high ASL perfusion. Typical input ADC and ASL volumes are shown on Left.

Using FSL's 'flirt' and 'bet' tools, the ADC and ASL volumes were first registered to the B0 volume. Subsequently, the brain was extracted from the B0 volume to create a binary brain mask. This mask was applied to the registered ADC and ASL volumes, and the resultant data was intensity normalized to values between 0.0 and 1.0 using FreeSurfer tools. A MatLAB statistical region-of-interest (ROI) detector was developed that tagged regions with abnormal voxel intensities on both volumes (Figure on Left, with ADC on top and ASL on bottom). An adaptive filter (Figure on Right with ADC on top and ASL on bottom) then removed voxels that were falsely tagged (typically regions between gray/white tissues with changing intensities) or noisy. On a slice-by-slice basis, a normalized 2D cross-correlation between the ROI on both the ADC and ASL data was then calculated. Correlation values close to 1.0 indicated high correlation between ADC and ASL on a given slice, close to 0.0 indicated no correlation. This data was further weighted by the number of adjacent slices that showed correlation to remove single-slice false correlations, resulting in a final measurement that demonstrated correlation between the ADC and ASL and extending for at least two adjacent slices.





RESULTS: Using this method, we noted a positive correlation between decreased ADC and increased ASL for regions of ischemic lesions with slice dimensional lengths of at least 4mm. With larger lesion volumes, the correlation confidence increased substantially. For normal subjects, we measured no correlation between decreased ADC and increased ASL. A typical correlation profile is shown in the Figure below, extending in this case from slice 16 through slice 23. Correlation results across the ischemic study group is shown in the Table on Left.

CONCLUSION: Ischemic lesions presented with lower ADC, indicating reduced diffusion. For large lesions -- typically with slice length of > 4mm -- we have observed a corresponding increase in ASL. Future work will seek to explore the physiological link between low ADC and corresponding high ASL measurements.

Age	Correlation Integral	ADC ROI Vol (ml)	ASL ROI Vol (ml)
003D	2.96	20.93	11.816406
003D	2.69	1.09	2.681003
001D	5.30	4.87	6.642388
000D	11.44	8.33	25.437032
004D	4.10	1.32	5.656104
001D	5.07	9.33	4.690943
02D	1.15	0.34	1.074026
002D	1.69	0.69	1.538733
002D	5.60	3.56	24.311011