Comparison of Pulsed Arterial Spin Labeling (PASL) and Pseudo-Continuous Arterial Spin Labeling (pCASL) Methods for Measuring Brain Perfusion in Newborns

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TARGET AUDIENCE: neuroradiologists and neonatologists/pediatricians taking care of newborns, as well as physicists interested in perfusion-weighted imaging by MRI.

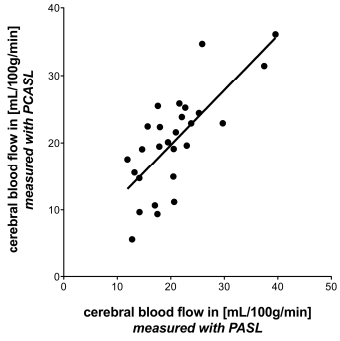
BACKGROUND: Arterial spin labeling (ASL) perfusion-weighted imaging (PWI) by magnetic resonance imaging (MRI) has been shown to be useful for identifying asphyxiated newborns at risk of developing brain injury, whether or not therapeutic hypothermia was administered. In contrast to other approaches previously used in newborns, ASL-PWI enables direct measurements of brain perfusion in different brain regions and does not require the use of contrast agent, as it relies upon the magnetic labeling of incoming blood flow to provide a change in contrast that is proportional to the amount of perfusion present. However, this technique has been only rarely used in newborns until now, because of the challenges to obtain sufficient signal-to-noise ratio (SNR) and spatial resolution to differentiate cortical gray matter, white matter and basal ganglia in newborns. It would probably benefit from recent improvements of ASL methods for adults.

PURPOSE: To compare two methods of ASL-PWI (i.e. pulsed arterial spin labeling (PASL) and pseudo-continuous arterial spin labeling (pCASL)) to assess brain perfusion in healthy newborns and in asphyxiated newborns treated with therapeutic hypothermia.

METHODS: We conducted a prospective cohort study of term asphyxiated newborns admitted to the neonatal intensive care unit (NICU) and meeting the criteria for therapeutic hypothermia. Three additional healthy term newborns were also included. Each of the enrolled newborns was scanned once or twice during the first 3 days of life, and again once or twice between days of life 7 and 35. Patients receiving hypothermia treatment had hypothermia maintained during the MRI without any adverse events. Any ventilatory support, pressor support, or sedation was also maintained during the MRI; additional sedation was avoided. This study was approved by the institutional review board, and parental consent was obtained.
Each MRI scan included conventional anatomical imaging, as well as PASL and pCASL PWI-MRI. All images were acquired on a 3T MR Systems with a 32-channel head coil. For PASL, we used a multislice single-shot echoplanar Imaging (EPI) sequence with signal targeting and alternating radiofrequency (EPISTAR) for labeling combined with an optimized water suppression enhanced through T1 effects technique for proper presaturation of the imaging volume, called pulsed STAR labeling of arterial regions (PULSAR) [1]. For pCASL, we used a multislice single-shot EPI sequence in combination with parallel imaging (SENSE) [2]. A registration using Statistical Parametric Mapping SPM8 was used to correct for motion artifacts after the scan was acquired. Quantification was done afterwards using a separate M0 scan and previously described formulas [3]. For comparison between ASL methods, whole-brain cerebral blood flow (CBF) was always measured on the axial slice at the level of the basal ganglia.

RESULTS: 3 healthy newborns and 10 asphyxiated newborns treated with therapeutic hypothermia were enrolled. A total number of 42 concomitant PASL and pCASL scans were obtained. However, 16 of them were excluded from the analysis, due to excessive movements even after the registration to reduce motion artifacts: i.e. 8 scans of healthy newborns and 8 scans of asphyxiated newborns, including 5 scans performed after the end of therapeutic hypothermia between days of life 7 and 35.
A total of 26 MRI scans were thus of good enough quality after motion correction for comparison between the two ASL methods. Whole-brain CBF mean ± standard-deviation was very similar between the two ASL methods: i.e. 20.84 ± 6.80 mL/100g/min when measured by PASL and 20.14 ± 7.56 mL/100g/min when measured by pCASL (*p 0.48*). Variations in CBF were related mostly to the presence or not of brain injury and the day of life at the time of the MRI scan. In addition, strong correlation was found between the CBF measured by PASL and pCASL (*r = 0.76; p value < 0.0001*) (**Figure 1**). However, pCASL perfusion maps presented a qualitatively better SNR to define smaller regions of interest and permitted more detailed identification of the injured brain areas.

Figure 1. Comparison between cerebral blood flow (CBF) measured by pulsed arterial spin labeling (PASL) and pseudo-continuous arterial spin labeling (PCASL) in healthy newborns and in asphyxiated newborns treated with hypothermia.



DISCUSSION: Both ASL techniques permitted the measurement of CBF in these newborns. CBF values were very similar between these two methods, confirming that both ASLmethods are measuring the actual brain perfusion in these newborns despite the known limitations of the quantification formulas used for each methods. However pCASL provided better image quality and thus better identification of the smaller regions of interest. pCASL should thus be chosen over PASL in newborns for more detailed assessment of brain perfusion abnormalities.
Motion artifacts remained an important limiting factor in using ASL methods in newborns, as demonstrated by the fact that we could only use 62% (26/42) of the available scans in this study despite the use of a registration to reduce motion artifacts. This was especially true for the more active newborns (i.e. healthy newborns and asphyxiated newborns after therapeutic hypothermia when recovering from their encephalopathy). More robust retrospective and prospective motion correction processes should thus be developed for newborns to allow the more generalized use of ASL methods in this population of patients.

CONCLUSION: This study demonstrates that both ASL methods are feasible and reproducible methods to assess brain perfusion in healthy newborns and in asphyxiated newborns. However, pCASL might be a better choice in newborns, as pCASL perfusion maps were of better quality and permitted more detailed identification of the injured brain areas.

REFERENCES: [1] Golay X, et al., Magn Reson Imaging (2005) 53:15-21; [2] van Osch MJP, et al., Magn Reson Imaging (2009) 62:165-173; [3] Gevers S, et al., Journal of Cerebral Blood Flow & Metabolism (2011) 31:1706–1715.