ASL Labeling Efficiency in Healthy Children

Dustin Kenneth Ragan[1] and Jose A Pineda[1]

[1]*Department of Pediatrics, Washington University School of Medicine, St. Louis, MO, United States*

Target audience Scientists and clinicians interested in studying cerebral blood flow (CBF) in children using arterial spin labeling (ASL)

Purpose CBF is a fundamental aspect of cerebral metabolism and is frequently altered by disease, making it an attractive target of investigation. Most techniques for measuring CBF are invasive or use ionizing radiation, rendering them unsuitable for studying the pediatric population. ASL uses blood plasma as an endogenous tracer. The fraction of spins labeled is the labeling efficiency and must be accounted for in order to achieve proper quantification. The labeling procedure makes strong assumptions about the dynamics of blood flow, and labeling efficiency can be decreased when blood flow in the labeling arteries is outside of the normal adult range. Because children, particularly those with brain injury, may have more rapid and unstable blood flow we studied the effects of labeling protocol in a children from neonates to early adolescence.

Methods We modeled the labeling process by numerical integration of the Bloch equations for a pseudocontinous ASL sequence[1]. Maximum gradient = 0.6 G/cm, average gradient = .07 G/cm, 80 RF pulses, pulse length = 500 ms, pulse gap = 800 ms. Modeling was performed for pulse rates between 60 and 150 beats per minute. Blood velocity was varied from 20 to 100 cm/s.

We compared several ASL labeling protocols in a group of 11 healthy children. We varied the labeling maximum gradient strength from 0.4 to 0.7 G/cm. Other acquisition parameters were TE/TR=22/4070 ms, FOV = 22x22 cm, matrix size = 96x96. Immediately before the CBF measurement, velocity in the carotid artery at the site of labeling (CBFv) was measured using a phase-contrast technique. Immediately after scanning was completed (within 5 minutes), pulse rate, blood hemoglobin, and oxygen saturation were measured using a Masimo Rad-57 oxymeter.

Results Consistent with prior reports, we found a relationship between CBFv and labeling efficiency in our simulations (not shown). In addition, we found that labeling efficiency strongly decreased with increasing pulse rate. This is contrast to the previous study by O'Gorman [2], which found a weak relationship between labeling and pulse rate.

We analyzed the effects of physiological parameters on labeling efficiency by studying the relationship between CBF values and the parameters. In addition, we analyzed the relationship between physiology and the sensitivity of CBF values to the labeling protocol (measured as the ratio of the largest and smallest CBF values measured). Large changes with the labeling protocol indicate that the labeling efficiency is highly sensitive to this parameter, even if the absolute efficiency is unknown. No relationship was found between CBF and blood oxygen saturation (r^2=0.002) or hemoglobin concentration (r^2=.17). We found that there was little relationship between CBFv and labeling sensitivity, however, CBF showed a striking increase in protocol sensitivity with increasing pulse rate (r^2=0.5, p=0.02).

Discussion Reliable CBF measurement from ASL in children is important for its clinical and research use [3]. However, the labeling process is developed from a model of constant linear blood flow. Children, particularly neonates, can have radically different hemodynamics than expected. Although most investigations into labeling variations have focused on blood velocity, we determined that pulse rate played a more significant role in the sensitivity of ASL labeling, as was evidenced by the large sensitivity of the CBF labeling to pulse rate.

Conclusion Use of adult protocols can significantly underestimate CBF when the patient has an elevated heart rate. This may be relevant when studying tachycardic patients as well, which may be common in some disease states, such as brain injury after cardiac arrest.

References

[1] Dai, et al. Magn Reson Med., 60(6):1288-1497.
[2] O'Gorman, et al. Magn Reson Med., 55(6):1291-1297.
[3] Detre, et al., J Magn Reson Med., 35(5):1026-1037.

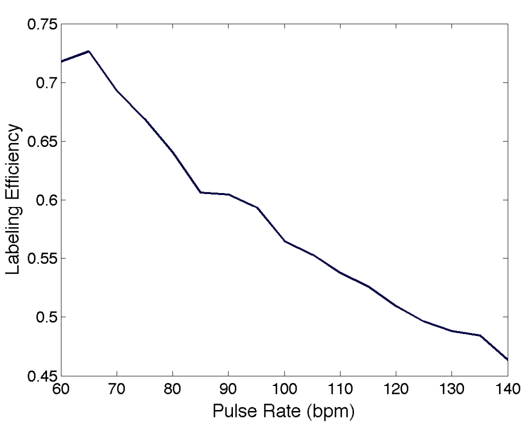

Fig 1. Simulations of labeling show a large sensitivity to pulse rate

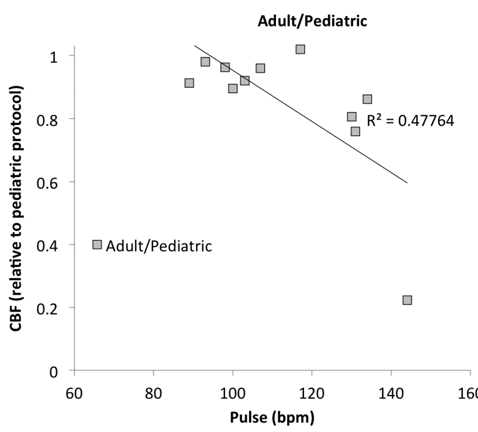

Fig 2. In vivo data shows that relatively high pulse rates, common in neonates, can result in significantly lowered labeling efficiency