Cerebral Blood Flow MRI in Rats Using Cardiac Spin Labeling Technique

Q. Shen[1], E. Muir[1], and T. Q. Duong[1]
[1]Yerkes Imaging Center, Emory Unviersity, Atlanta, GA, United States

INTRODUCTION Cerebral blood flow (CBF) measured by the continuous arterial spin labeling (cASL) technique with a separate labeling neck coil is generally more sensitive compared to the single-coil ASL technique (1, 2), but the two coils need to be actively decoupled to avoid coil-to-coil electromagnetic interaction. Therefore additional decouple circuits, trigger equipments and software modification are needed. Even when the two coils are decoupled, saturation effect is still observed in the slices close to the label coil. Furthermore, the veterbal arteries which supply the cerebellum can't be efficiently labeled by beck coil, the CBF of cerebellum and brain stem is difficult to be imaged. We report herein a new approach to overcome these limitations by placing the labeling coil at the heart position. We termed this approach the **Cardiac Spin Labeling (CSL)** technique. We applied this approach to image blood flow and physiologically evoked blood flow changes in normal rats.

METHODS Four male SD rats (250-300 g) were imaged under ~1.5% isoflurane and spontaneous breathing conditions. Respiration rate and rectal temperature were monitored, and temperature was maintained at ~37^{o} C. MRI was performed on a 7T/30cm scanner using a surface brain coil and a circular heart coil (ID = 2.3 cm) for spin labeling placed in the heart position. CBF images were acquired using gradient echo EPI (3) with a 2.56x2.56 cm FOV, 64x64 matrix (single shot), seven 1.5-mm slices, 2.78 s labeling pulse, 3.0 s TR, and 14 ms TE.

Hypercapnic challenges involved 3 mins air and 3 mins of 5% CO_2 in air. CBF images (ml/g/min) were calculated by, $S_{BF} = \lambda/T_1 \bullet (S_c - S_L)/(S_L + (2\alpha - 1)\, S_c)$, where S_C and S_L are signal intensities of the non-labeled and labeled images, respectively, T_1 is 1.8 s at 7T, λ is the water brain-blood partition coefficient (0.9). α, the labeling efficiency, was measured to be 0.67 (n = 2).

RESULTS Figure A shows the heart image acquired using the label coil, which demonstrates that the coil is positioned directly on the heart and is large enough to label the heart. Quantitative blood-flow images (**Figure B**) show excellent and heterogeneous blood-flow contrast. Blood flow in the corpus callosum (white matter) is low compared to the gray matter as expected. The CBF values of posterior slices are not higher than those of anterior slices, which demonstrates the absence of the saturation effect of the label coil. No coil-to-coil electromagnetic interaction was observed, and similar CBF maps were derived with and without decoupling between the two coils. **Figure C** shows a time course of responses to 5% hypercapnia. After giving CO_2, the intensity difference between control and label images increased, signifying that the blood flow increased, modulated by the CO_2.

DISCUSSION Compared to neck labeling cASL, the CSL technique offers the following advantages for CBF imaging: 1) The distance between the heart and the brain (~5 cm) in rats is sufficiently large that it results in negligible saturation of the brain. 2) Active decoupling is not necessary any more, which simplifies the experimental setup. 3) Finally, this approach also offers whole body blood-flow imaging for organs that are within reasonable transit time, such as kidney, brain stem and cerebellum. The latter two are often not studied by the conventional neck labeling approach because the vertebral arteries are generally not effectively labeled and/or these structures are susceptible to saturation effect due to their close proximity to the neck labeling coil. The disadvantage of CSL compared to neck labeling cASL is the decreased labeling efficiency because of the longer transit time.

CONCLUSIONS This study demonstrates that quantitative CBF in rat can be measured using a separate labeling coil positioned at the heart. This approach simplifies the experimental setup and offers the potential to image the blood flow of kidney, brain stem and cerebellum, which is difficult using the neck labeling technique.

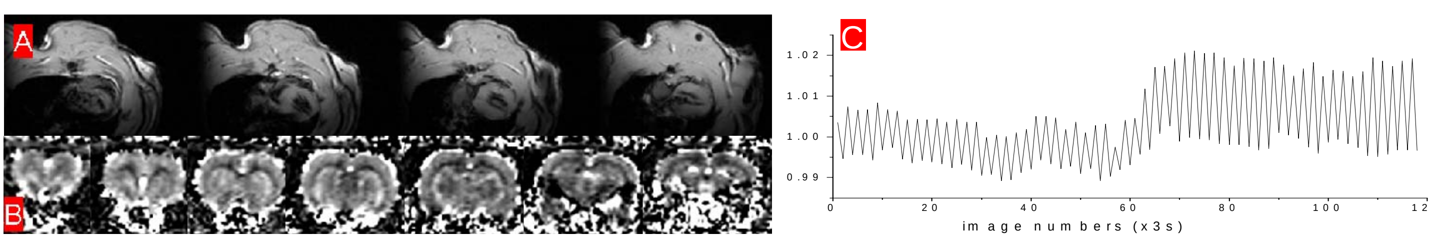

Figure (A) Heart image (B) CBF map (**C**) time course of 5% CO_2 from one representative animal.

REFERENCES 1) Silva et al, JCBFM 1999, 19:871. 2) Duong et al, MRM 2000, 43:383. 3) Sicard & Duong, NI 2005, 25:850. Support in part by a Venture Grant via P50 AG025688.