Measurement of Cerebral Blood Flow in Craniosynostotic Rabbits using ASL-MRI

L. M. Foley[1], W. Fellows-Mayle[2], T. K. Hitchens[1], J. Horner[1], J. E. Losee[3], M. I. Siegel[4], M. P. Mooney[4], C. Ho[1]

[1]Pittsburgh NMR Center for Biomedical Research, Carnegie Mellon University, Pittsburgh, PA, United States, [2]Department of Neurological Surgery, University of Pittsburgh, Pittsburgh, PA, United States, [3]Division of Pediatric Plastic Surgery, Children's Hospital of Pittsburgh, Pittsburgh, PA, United States, [4]Department of Anthropology, University of Pittsburgh, Pittsburgh, PA, United States

Introduction

Craniosynostosis is the premature fusion of one or more of the calvarial sutures and is estimated to occur in 300-500 per 1,000,000 live births [1]. Closure of the sutures has two implications, firstly there are cosmetic considerations such as craniofacial and intracranial anomalies [2] and secondly, neurological problems are associated with increased intracranial pressure (ICP) [3], enlarged cerebral ventricles [4], and changes in cerebral blood flow (CBF). The relationships between ICP, ventricle volume, CBF, and craniosynostosis are poorly understood. This study aimed to investigate differences in CBF in a colony of rabbits with naturally occurring early onset (~21 days fetal) coronal suture synostosis (EOCS) and age-matched controls.

Materials and Methods

The rabbits used were breed in the vivarium at the Department of Anthropology, University of Pittsburgh. Seven control rabbits at 10 (n=3) and 25 (n=4) days of age, and 7 EOCS with rabbits at 10 (n=2) and 25 (n=5) days of age were used in this study. Physiological parameters such as heart rate, and arterial CO_2 tension ($PaCO_2$), were monitored. Body temperaturewas maintained at 37 ± 0.5˚C using a warm air heating system (SA Instruments, New York, USA). The rabbits were placed on the cradle in a prone position and the head secured by ear bars and a bite bar to prevent motion during imaging.

MR studies were performed on a 4.7-Tesla, 40cm bore Bruker AVANCE-AV system, equipped with a 12 cm diameter shielded gradient insert and a 72 mm volume RF coil. For all imaging experiments, an FOV = 6.4 cm and slice thickness = 2 mm were used. Maps of T_{1obs} [5] were generated from a three-parameter exponential fit to a series of spin-echo images with variable *TR* (*TR* = 8000, 4300, 2300, 1200, 650, 350, 185, 100 msec, 2 averages, 128 x 70 matrix). Perfusion spin-echo images were acquired in duplicate using the arterial spin-labeling technique [6] (*TR*/*TE* = 2000/10, 20, 30, summation of 3 echoes, 2 averages, 128 x 70 matrix) with labeling applied ± 2.5 cm from the imaging plane. CBF (cerebral blood flow) maps were generated from: $CBF = \lambda \cdot (T_{1obs} \cdot 2\alpha)^{-1} \cdot (M_C - M_L) \cdot (M_C)^{-1}$, where M_C and M_L are the magnetization intensities from the control and labeled images, respectively. A spatially constant value of 0.9 mL · g^{-1} was assumed for the blood brain partition coefficient for water (λ). The spin labeling efficieny (α) [7] was determined in each study with gradient echo images with spin-labeling applied at ± 11 mm (*TR*/*TE* = 100/9.6 msec, 45˚ flip angle, 8 averages, 256 x 256 matrix).

Results and Discussion

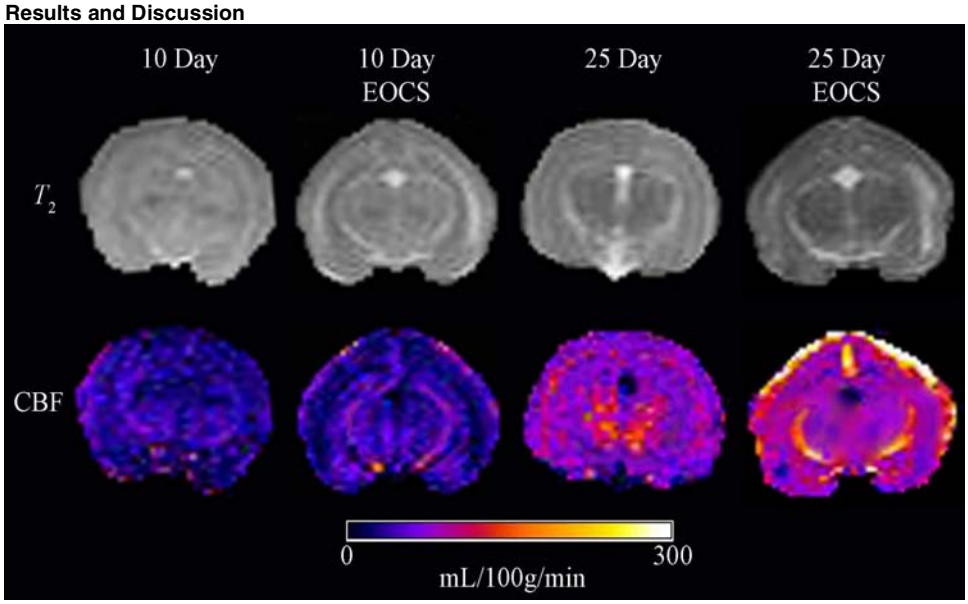

Figure 1: Representative T_2-weighted images and CBF maps from normal and EOCS rabbits at 10 and 25 days of age.

Previous results have shown that rabbits with EOCS have significantly elevated ICP when compared with age-matched controls. MRI analysis of these rabbits reveal a significant increase in the size of the lateral ventricles [8]. In the present study, the EOCS rabbits have noted differences from the controls. Firstly, the T_2-weighted images show a defined dome shape in the EOCS rabbits, and secondly, CBF in the 10 day old rabbits was approximately 30% lower than that of the 25 day old rabbits, both controls and EOCS (Figure 1). Also seen in Figure 1 are areas of increased flow around the brain cortex and in the area of the lateral ventricles. These areas are much more pronounced in the 25 day EOCS rabbits. It has been suggested that CSF circulation disorders are partly responsible for enlargement of the ventricles [9]. The increase in flow may be a reflection of differences in CSF flow.

References

1. Cohen, M. M. Jr and MacLean, R. E. *Craniosynostosis: diagnosis, evaluation, and management.* New York: Oxford University Press, (2000).
2. Martinez-Lage, J. F., Alamo, L., and Poza, M. *Childs Nerv. Sys.* **15**,11-16, (1999).
3. Fellows-Mayle, W. K., Mooney, M. P., Losken, H. W. , Dechant, J., Cooper, G. M., Burrows, A. M., Smith, T. D., Pollack, I. F. and Siegel, M. I. *Cleft Palate Craniofacial J* **37**, 370-378, (2000).
4. Cinalli, G. Sainte-Rose, C., Bollar, E.M., Zerah, M., Brunelle, F., Chumas, P., Arnaud, E., Marchac, D., Peirre-Kahn, A. and Renier, D. *J Neurosurg.* **88**, 209-214, (1998).
5. Hendrich KS, Kochanek PM, Williams DS, Schiding JK, Marion DW and Ho C. *Magn. Reson, Med.* **42**, 673-681 (1999).
6. Detre JA, Leigh JS, Williams DS and Koretsky AP. *Magn. Reson. Med.* **23**, 37-45 (1992).
7. Zhang W, Williams DS and Koretsky AP. *Magn, Reson, Med.* **29**, 416-421 (1993).
8. Fellows-Mayle, W., Hitchens, T. K., Simplaceanu, E., Horner, J., Barbano, T., Nakaya, K., Losee, J. E., Losken, H. W., Siegel, M. I. and Mooney, M. P. *Childs Nerv. Syts.* **21**, 385-391, (2005).
9. Collman, H., Sorensen, N., Kraub, J. and Muhling, J. *Childs Nerv. Syst.* **4**, 279-285, (1988).