Quantification of Cerebral Blood Flow and Vascular Territories in Normotensive and Hypertensive Rats

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INTRODUCTION

Arterial spin labeling (ASL) is a well-established method to obtain quantitative maps of perfusion non-invasively [1, 2]. In combination with other MRI techniques such as angiography (MRA), diffusion-weighted MRI (DWI) and T_2-weighted MRI, ASL has proven useful for the diagnosis of a variety of cerebrovascular diseases [3]. Animal models of cerebral ischemia play an important role in the study of stroke and other cerebrovascular diseases. Spontaneously hypertensive (SHR) rat is a strain that exhibits spontaneous elevated blood pressure that has been widely used as an experimental model of hypertension and stroke [4]. However, a detailed characterization of resting cerebral blood flow and angiographic morphology has not been yet performed in SHR rats. In the present study, a three-coil system comprised of a small figure-8 shaped labeling coil, a homogeneous volume excitation coil and a receive-only quadrature surface coil was employed to obtain cerebral blood flow and perfusion territory maps of the major feeding arteries to the brain [5] in normotensive and hypertensive rats. In addition, MRAs were acquired to assess major differences in the vasculature between the two groups as well as variations in the formation of the Circle of Willis that are related to the vascular perfusion territories.

MATERIALS AND METHODS

Sprague-Dawley (SD) (N=6) and SHR (N=6) rats, weighing 300-350g, were anesthetized under isoflurane and scanned in a horizontal 7T/30cm magnet (Bruker-Biospin, Billerica, MA) equipped with gradients capable of 450mT/m amplitude (Resonance Research Inc, Billerica, MA). A home-built, transmit-only birdcage volume RF coil, 12cm internal diameter, and a commercially-built, receive-only quadrature surface coil (RAPID Biomedical GmbH, Rimpar, Germany), were used for all image acquisition. A small figure-8 shaped labeling coil [6] was positioned under the neck of the animal, approximately 2cm away from isocenter. All coils were equipped with active decoupling circuits to minimize coil-to-coil interferences during the labeling and imaging phases of the experiment, and to avoid off-resonance saturation of water in the acquisition region [6]. Multi-slice, single-shot echo-planar images were obtained during continuous ASL achieved with flow-driven adiabatic inversion using TR/TE=5115/38ms, FOV=2.56x2.56cm, matrix=96x96, slice thickness=1.5mm, 10 slices and 32 averages. Whole brain MRAs were acquired by using a 2D flow compensated gradient echo sequence with the following parameters: TR/TE=30/4.5ms, flip angle=90°, FOV=1.92x1.92cm, matrix=192x192, 218 slices, slice thickness=1mm and interslice distance=0.1mm, resulting in an effective isotropic resolution of 100 μm. Angiograms were obtained by generating maximum intensity projections (MIPs).

RESULTS AND DISCUSSION

Figure 1 shows representative multislice CBF maps obtained from an SHR rat. Figure 1b shows the CBF map for labeling both common carotid arteries (CCAs), whereas Figs. 1c-d show the CBF map of the vascular territories obtained labeling the right and left, respectively. Whole brain CBF values in SHR rats (1.47±0.25 ml/g/min, N=6) were significantly higher than in normotensive rats (1.12±0.15 ml/g/min, N=6, $p<0.05$). Regional variation in CBF in both groups is shown in Fig. 2. Regional CBF values obtained in SHR rats were significantly higher in the sensory-motor cortex, but not in caudate putamen.

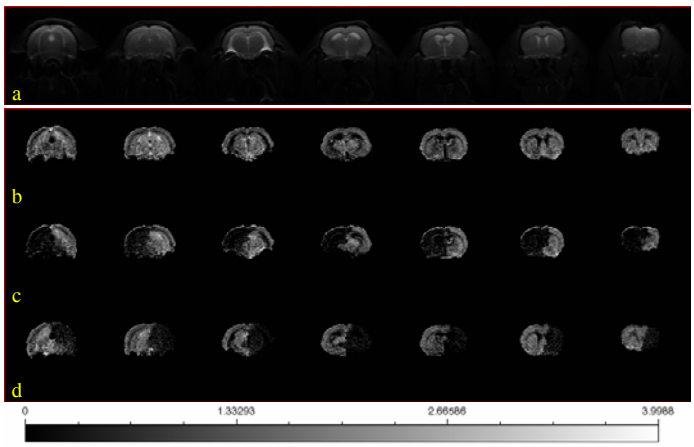

Figure 1: (a) Representative coronal images obtained from a hypertensive rat. (b) Corresponding whole brain CBF maps and (c) right and (d) left vascular territories. Color bar shows CBF values in ml/g/min.

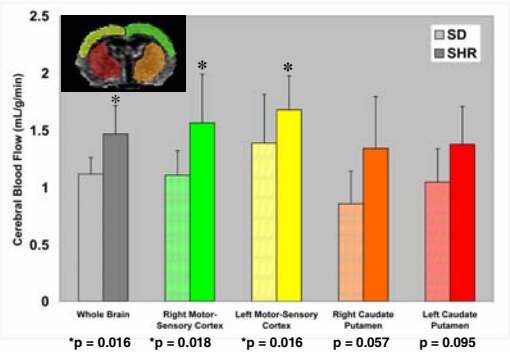

Figure 2: Regional variation of CBF measured in normotensive (SD) and hypertensive (SH) rats.

Asymmetry in the cingulate cortex corresponding to the territory of the anterior cerebral artery (ACA) is shown in Fig. 1c-d. CBF contrast in both sides of the cingulate cortex was obtained by labeling the right CCA, but not the left. Fig. 3a shows a whole-brain MRA in this rat, where a dominance in the left A1 was observed (Fig. 3b), which explains the asymmetric pattern observed in the perfusion territories (Fig. 3c-d).

CONCLUSIONS

In this study we used CASL with a dedicated labeling coil to compare resting whole-brain CBF in normotensive and hypertensive rats. Higher CBF values were found in hypertensive rats, and asymmetric perfusion territories could be explained by higher lateral dominance of arteries in the the circle of Willis. The characterization of whole brain CBF in SHR rats will allow future studies of vascular reactivity and stroke in these animals.

REFERENCES

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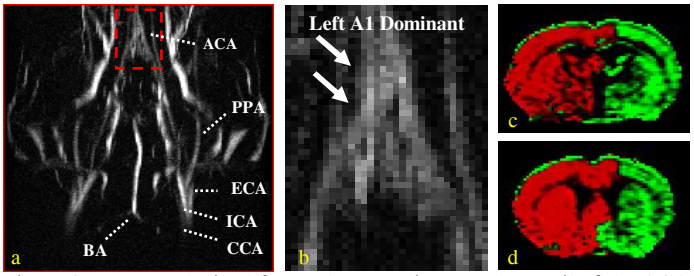

Figure 3: (a) MIP obtained from a hypertensive rat. (b) Detail of the ACA region showing the left A1 dominance. (c,d) Color-coded representation of the vascular territories in two adjacent slices show asymmetric perfusion of the cingulate cortex.