

# High Spatial Resolution Cerebral Blood Flow Imaging of Rat Brain

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**TARGET AUDIENCE** Researchers in high resolution imaging, perfusion imaging, stroke imaging.

**INTRODUCTION** Cerebral blood flow (CBF) is an important physiological parameter. CBF is tightly regulated and intricately coupled to basal metabolic function under normal physiologic conditions. Perturbations of basal CBF have been implicated in many neurological diseases such as stroke, brain tumor, and neurodegeneration. The majority of CBF studies in rat brain are  $\sim 500 \times 500 \times 2000$  microns using single shot EPI using either continuous arterial spin labeling (cASL) or dynamic susceptibility contrast techniques. In our previous study, we reported high spatial resolution CBF maps of rat brain at  $75 \mu\text{m} \times 56 \mu\text{m} \times 1 \text{mm}$ .<sup>1</sup> In this study, we further pushed the spatial resolution to  $50 \mu\text{m} \times 38 \mu\text{m} \times 1 \text{mm}$  to map the layer specific CBF of rat cortex. This approach was also used to image CBF of stroke rat brain at different time points.

**METHODS** Four normal and two 90-min transient middle cerebral arterial occlusion (MCAO)<sup>2</sup> male adult SD rats (250~300g) were anesthetized with  $\sim 1.2\%$  isoflurane in air. Body temperature, respiration rate, heart rate and blood oxygen saturation level were continuously monitored and maintained within normal ranges. MRI experiments were performed on a Bruker 11.7-Tesla/16-cm scanner. Surface coils (1.2-cm or 2.1-cm ID) with active decoupling were used for brain imaging and a neck coil for perfusion labeling.

Quantitative CBF was measured using the continuous arterial spin-labeling technique<sup>3</sup> with four-shot, gradient-echo EPI. MRI parameters were: FOV= $12.8 \text{mm} \times 9.7 \text{mm}$  for small coil or  $19.2 \text{mm} \times 14.4 \text{mm}$  for large coil, matrix= $192 \times 144$  and reconstructed to  $256 \times 256$ , TR=3s, TE=9ms, labeling duration=2.65s and post-labeling duration=250ms.

CBF of cortex were flattened<sup>4</sup> and layer I to VI were assigned according to thickness reported in literature<sup>5</sup>.

**RESULTS** Figure 1(A) and (B) showed the CBF maps of a representative rat showed in gray scale (A) and spectrum (B). Distinct CBF contrast can be seen between gray and white matter. Columnar (bright and dark stripes) and the layer structure of microvascular distribution in cerebral cortex can be clearly seen. Flattened cortex CBF is shown in Fig.1(C). And group averaged (N=4) successive depth profile is shown in Fig. 1(D). Cortical layer I to VI were assigned based on the thickness reported in literature.<sup>5</sup>

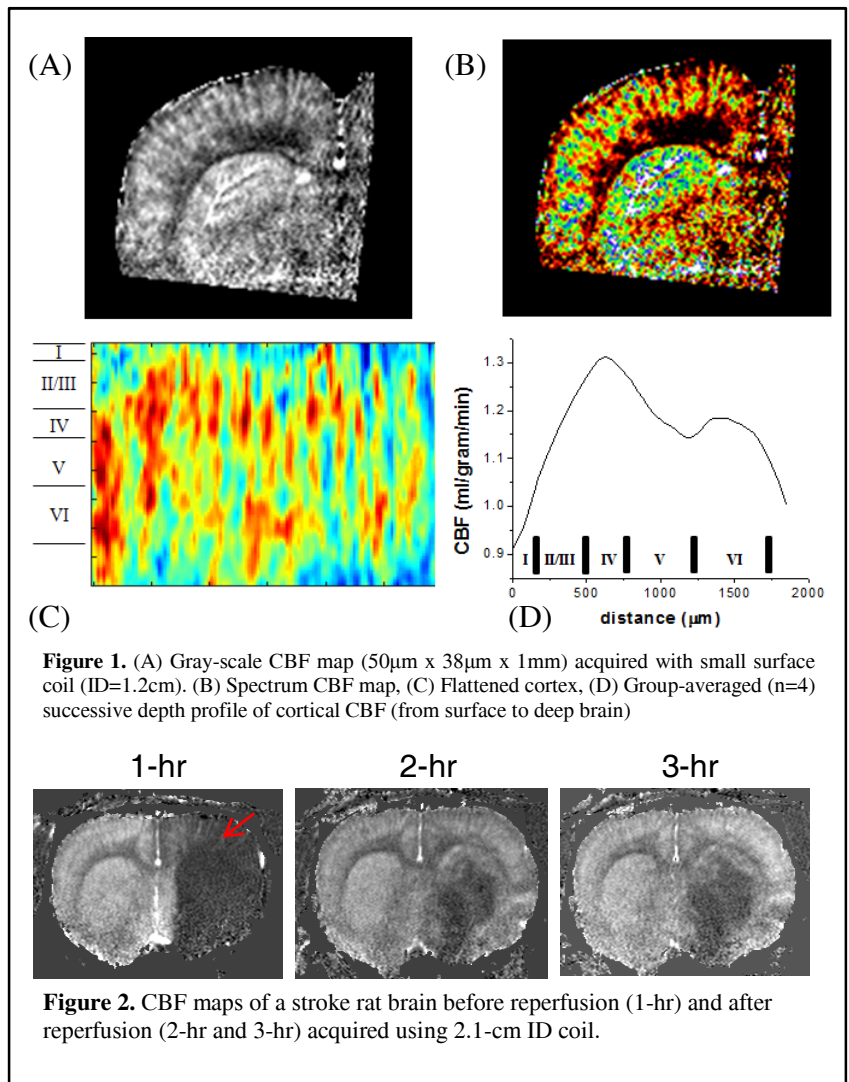
Figure 2 showed CBF maps of a 90-min MCAO stroke rats before reperfusion (1-hr post-occlusion) and after reperfusion (2-hr and 3-hr post-occlusion).

**DISCUSSIONS** High resolution CBF map (Fig. 1) showed columnar and layer specific characteristics in cortex. Layer IV and VI showed higher CBF, likely associated with higher basal metabolic needs. Our results are consistent with the vascular density distribution previously reported using confocal laser scanning technique.<sup>6</sup>

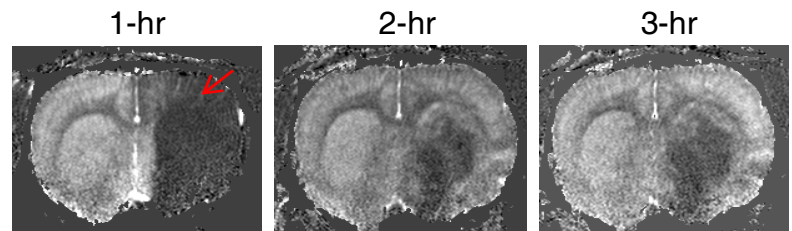
Clear CBF gradient can be seen in the stroke rat CBF map before reperfusion. Mild CBF drop can be noticed in the cortical area of right hemisphere (as shown by the arrow). After reperfusion, cortical CBF was recovered. By contrast, striatum CBF was still low. CBF changes in different regions (structures) were clearly delineated.

**CONCLUSION** This study presents very high spatial resolution CBF imaging of rat brain, with columnar and laminar resolutions. We found that the vascular density distribution peaked at layer IV and VI, consistent with previously reported. We demonstrated an application in stroke rat. This study sets the stage for investigating CBF dysfunction for a wide range of neurological diseases at very high spatial resolution.

**REFERENCE:** 1) Shen Q, et al. ISMRM 2012: 1064. 2) Shen Q, et al, J Cereb Blood Flow and Metab 2011;31:2076. 3) Duong TQ, et al., MRM 2000; 43: 338. 4) Cheng H, et al., PNAS 2006 103;17525. 5) Silva AC, et al., J Neurosci Meth 2008;167:246. 6) Masamoto K, et al., Brain Research 2003; 995 : 66.



**Figure 1.** (A) Gray-scale CBF map ( $50 \mu\text{m} \times 38 \mu\text{m} \times 1 \text{mm}$ ) acquired with small surface coil (ID=1.2cm). (B) Spectrum CBF map. (C) Flattened cortex. (D) Group-averaged (n=4) successive depth profile of cortical CBF (from surface to deep brain)



**Figure 2.** CBF maps of a stroke rat brain before reperfusion (1-hr) and after reperfusion (2-hr and 3-hr) acquired using 2.1-cm ID coil.