Visualization of arteries and veins using carbogen-challenged dual-echo MRA (CD-MRA)

Chien-Hsiang Huang[1,2], Chiao-Chi V. Chen[1], Yi-Hua Hsu[1], and Chen Chang[1]

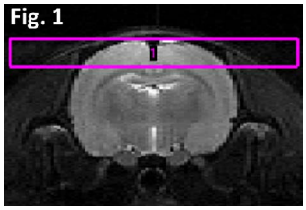
[1]*Institute of Biomedical Sciences, Academia Sinica, Taipei, Select, Taiwan,* [2]*Institute of Biomedical Engineering, National Taiwan University, Taipei, Taipei, Taiwan*

Introduction

Identifying the arteries and veins is critical for diagnosis and prognosis in certain brain diseases. Arteries are characterized by fast blood flow that results in large inflow effect, while veins are characterized by high deoxyhemoglobin concentration. A dual-echo sequence has been proposed to detect both inflow and BOLD effects so as to visualize the arteries and veins simultaneously [1]. The inflow effect of arteries is revealed by the first echo whereas the BOLD effect of veins is detected by the second echo. As a strategy to improve the sensitivity of arteries and veins in the dual-echo sequence, carbogen (95% O_2 + 5% CO_2) challenge was used so as to enhance both the contrasts arising from the blood flow and vascular oxygenation. This newly proposed technique is named carbogen-challenged dual-echo magnetic resonance angiography (CD-MRA).

Materials and Methods

All images were acquired in a 7-T PharmaScan 70/16 MR scanner. One normal and one stroke rats were used in the present study. The stroke model was induced by permanent occlusion of right middle cerebral artery (MCA) and 20-min transient occlusion of both carotid arteries. The stroke rat was scanned at 1 h, 1 day, and 3 days after stroke. The dual-echo sequence was acquired by 3D multi gradient-echo (MGE) with a repetition time (TR) of 45 ms, first echo time (TE) of 5 ms, second TE of 20 ms, field of view (FOV) of 2.56×2.56×0.25 mm^3, and matrix size of 256×256×16 (zero-filling to 512×512×32) . The image slab was placed in the cortical region as shown in Fig. 1. The arterial angiography is reconstructed based on the hyperintensities in the first-echo images under the carbogen inhaling condition. The venography is reconstructed based on the ΔR_2* between air and carbogen as calculated by $\ln(S_{Carbogen}/S_{Air})$, where the $S_{Carbogen}$ and S_{Air} are the signal intensities in the inhaling conditions.

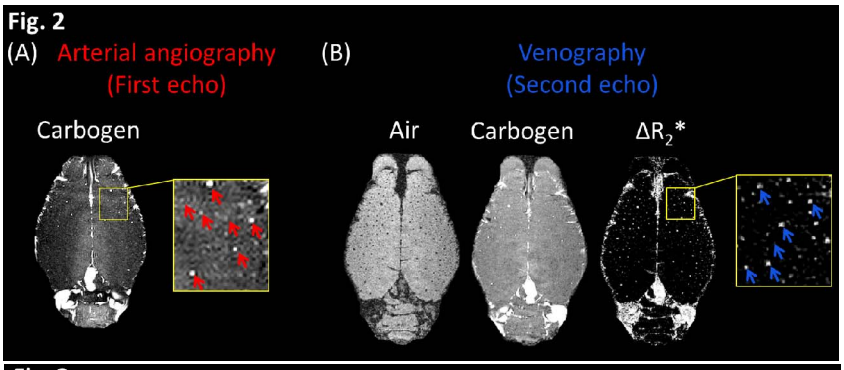


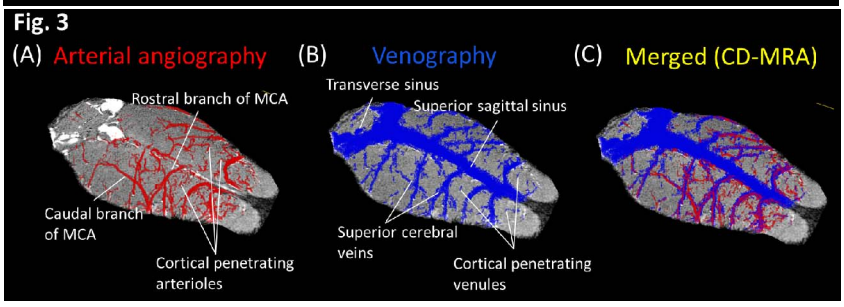
Results and Discussion

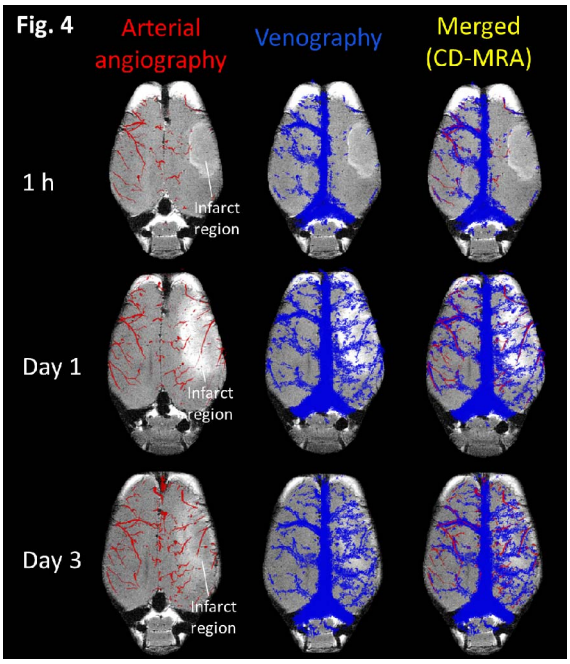
Fig. 2A shows the arterial angiography by first-echo images. Numerous hyperintensities caused by large inflow effect reflecting arterial vessels were observed in carbogen inhaling condition as indicated by red arrows. Figure 2B shows the venography by second-echo images. Many hypointensities were observed in air inhaling condition, reflecting the accumulation of deoxyhemoglobin. The hypointensities vanished in carbogen inhaling condition, and the derived ΔR_2* maps show many high-contrast venous dots as indicated by blue arrows. After 3D reconstruction, the arteries including branches of MCA and cortical penetrating arterioles were clearly identified by the arterial angiography (Fig. 3A), and veins including the surface venous structure and cortical penetrating venules were revealed by the venography (Fig. 3B). The arterial angiography and venography can be merged to demonstrate the spatial distribution of both arteries and veins (Fig. 3C). The CD-MRA was acquired at 1h, 1 day, and 3 days after stroke. Arteries and veins in CD-MRA were severely reduced in the infarct region at 1 h after stroke. On day 1 and 3, the arteries and veins were recovered, implying the postischemic vascular remodeling process.

Conclusion

The CD-MRA allows high-resolution visualization of arteries and veins, and its ability in revealing the remodeled vessels in a pathological condition was demonstrated by a stroke model.







Reference: 1. Du et al., *MRM*, 59:954–958, 2008.