Quantification of Mixed Perfusion using Vessel Encoded Pseudo-Continuous Arterial Spin Labeling

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Introduction

We have developed a new vessel encoded ASL technique based on pseudo-continuous tagging (1) which allows for the efficient imaging of two or more vascular territories (2). With this technique, we are able to generate quantitative maps of perfusion territories with good separation of each territory. Here we demonstrate examples of clinically relevant information one can obtain using this technique.

Methods

The vessel encoded ASL scan was performed using a tagging time of 1600ms, with other imaging parameters as in (2). Total scan time was 4.5min for 2 vessel separation and 9min for 3 vessel separation. Territories are separated according to an empirical decoding scheme based on measured tagging efficiencies. Subjects were scanned on a GE 3T system with a commercial 8 channel head coil under an IRB approved protocol with prior informed consent.

Results

Separation of left internal carotid artery (ICA), right ICA, and basilar artery (BA) territories is shown in **Figure 1**. There is good separation of territories in all four subjects. The subject at bottom right has severe right ICA stenosis, diagnosed by Doppler ultrasound and visible in this data. **Figure 2** shows separation of the right ICA territory from the combined left ICA+BA territory in a normal subject. Mixing angles are calculated from vascular territory data by computing the arctangent of signal ratios from each territory across all voxels. The mixing angles map in Figure 2 is unremarkable except for a small transition between the two territories along the interhemispheric fissure and in the right posterior part of the brain, at the posterior border zone. A scatter plot of signal intensities from the two territories is concentrated along the axes, indicating minimal blood mixing. **Figure 3** contains similar data from a subject with variant vasculature. Angiography reveals a patent anterior communicating artery (ACA) and a right posterior cerebral artery (PCA) arising mainly from the anterior circulation. The calculated territories match these findings; there is left-to-right flow across the ACA, and the right posterior territory is perfused mainly by the right ICA. The mixing of blood in these areas is seen in row 2 of Figure 3 as light blue anteriorly and orange in the posterior territory. The concentration of voxels in the scatter plot along rays other than the axes indicates 6:5 mixing of blood (40° mix angle) from left and right ICAs in the anterior area and 2:9 mixing (77° mix angle) of BA and right ICA in the right posterior area.

Discussion

Our vessel encoded ASL technique produces well-separated, quantitative vascular territory maps that are consistent with angiographic findings and medical history. Our technique allows one to image mixed perfusion and to distinguish mixing in arterial border zones from that arising from more proximal anastomoses, such as the circle of Willis.

Acknowledgements

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References

1. Garcia, et al., ISMRM 2005, p. 37.
2. Wong, ISMRM 2006, p. 668.

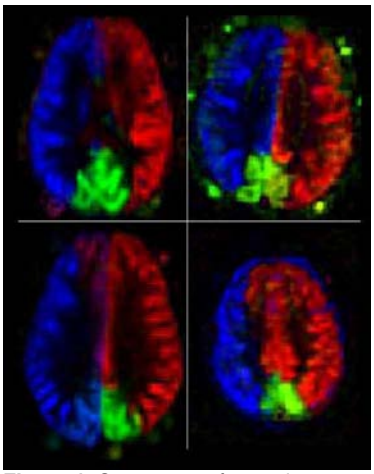

Figure 1. Separation of vascular territories in four subjects. Left ICA, right ICA, and BA are represented by red, blue, and green, respectively. Row 1 shows normal subjects and row 2 shows one subject with normal variation and one with pathology.

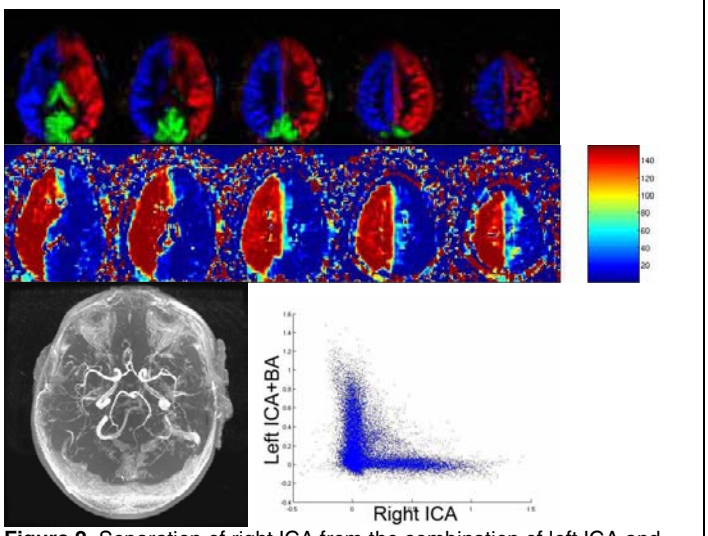

Figure 2. Separation of right ICA from the combination of left ICA and BA in a normal subject. Row 1 shows perfusion territories. Row 2 shows mixing angles between right ICA and other territories. The MRA in row 3 is normal. The scatter plot shows voxels positioned by the amount of blood derived from each territory and indicates minimal mixing.

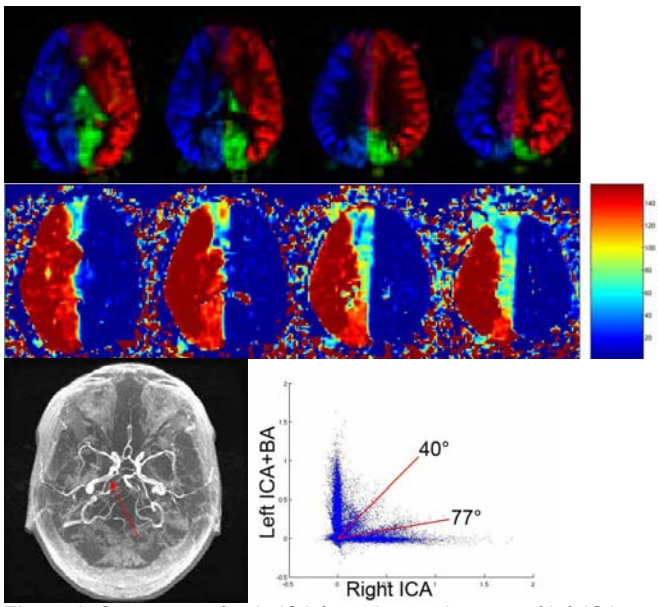

Figure 3. Separation of right ICA from the combination of left ICA and BA in a subject with flow across the ACA and a right PCA originating primarily from the anterior circulation. Row 1 shows perfusion territories and row 2 shows mixing angles. The MRA in row 3 shows variant vasculature. The scatter plot shows voxels positioned by the amount of blood derived from each territory and indicates significant mixing (40° and 77°) in two regions.