Automated Segmentation of Multiple Vascular Territories from Vessel Encoded Pseudo-Continuous Arterial Spin Labeling MRI Data

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Introduction

Vessel encoded pseudo-continuous ASL (VEPCASL) permits efficient imaging of cerebral vascular territories via the application of a magnetic tag to each of many vessels as they pass through a thin plane (1). Because there is continuous spatial modulation of tagging efficiency across the tagging plane, each vessel acquires a tag based on its position and the configuration of the spatial modulation in each VEPCASL scan. As such, it may be possible to use clustering methods to resolve a relatively large number of vascular territories using very few scans. Earlier attempts using clustering in tagging efficiency space generally necessitated manual segmentation of clusters (2). In this work, we describe a region-growing method that achieves reliable spatial segmentation via clustering in tagging efficiency space.

Methods

VEPCASL scans were performed on healthy human subjects in a GE 3T system using a commercial 8 channel head coil with IRB approval. Images were acquired using single shot spiral imaging at 64 x 64 matrix and FOV 22cm x 6mm, requiring 4 mins for each successive scan. Vessel encoding was performed as in (1), with labeling plane above the circle of Willis, resulting in approximately sinusoidal variation of the tagging efficiency, with a range of -1 to 1. Perfusion-weighted images were decoded into vascular territories as in (3). Using N VEPCASL images, each with distinct vessel encoding, each voxel was assigned an N-dimensional tagging efficiency vector. A region-growing algorithm was then initiated within each perfused voxel. This algorithm iteratively added neighboring voxels to the region pursuant to a maximum difference criterion between the tagging efficiency vector of the voxel to be added and the mean tagging efficiency vector of the voxels already within the region. This process was repeated until all voxels were assigned to a region. The final regions represented distinct vascular territories, each well clustered in tagging efficiency space.

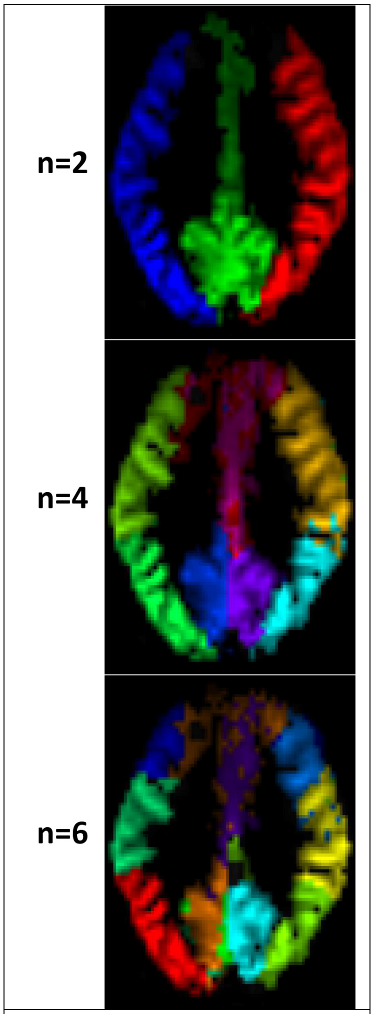

Figure 1. Perfusion territory maps from an automated region-growing algorithm using 2, 4, or 6 VEPCASL images. Including additional VEPCASL data results in improved segmentation of vascular territories. The colors in this image are chosen arbitrarily.

Results

Perfusion territory maps of the same axial section segmented using 2, 4, or 6 VEPCASL images are shown in **Figure 1**. Automated segmentation of each image with a region-growing algorithm required negligible post-processing time. In each case, the segmented territories were consistent with known arterial distributions. In the n=2 case, the region-growing algorithm was able to separate left middle cerebral artery (MCA), right MCA, and combined anterior cerebral artery (ACA) and posterior cerebral artery (PCA) territories. Clustering of data in tagging efficiency space for the n=2 case is shown in **Figure 2**. In the n=4 case, the algorithm was able to discern left PCA, right PCA, two branches each of left and right MCAs, and the ACAs. It also appeared to detect some features within the ACA territory, although the precise pattern was not immediately clear. In the n=6 case, the algorithm identified three unique branches of the left and right MCAs, left and right PCAs, lateral ACA branches, and medial ACA branches.

The data in Figure 1 also demonstrate that territorial boundaries were consistent with the inclusion of additional VEPCASL scans. For instance, the interface between the MCA branch territories in the n=4 case occurred in the same location in the n=6 case. These results suggest, as was expected, that the inclusion of additional scans simply added territorial contrast and did not affect the boundaries of territories that were already adequately separated.

Compared with previously described approaches using Hadamard encoding and a linear model (3), the technique described here permits separation of a greater number of vascular territories with a smaller number of VEPCASL images. However, in this underdetermined system, each voxel can be assigned only to a single vascular territory. As such, the ability to identify and characterize simultaneous perfusion by two or more arterial sources is lost. This consideration may prove to be important in the large proportion of subjects possessing territories with mixed supply (4).

Conclusion

Automated segmentation of VEPCASL data with a region-growing algorithm demonstrated multiple vascular territories above the circle of Willis. Definition of independent territories improved as additional VEPCASL scans were included in the segmentation. With appropriately many VEPCASL images, the technique revealed three branches of the MCA. This approach may permit identification of a large number of vascular territories with minimal scan time.

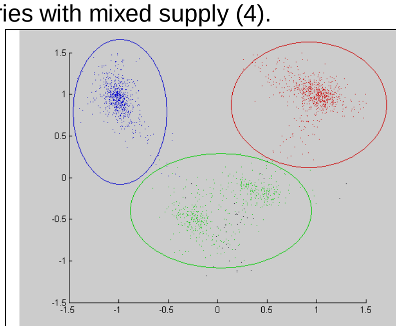

Figure 2. Automatically segmented clusters in tagging efficiency space. The colors correspond to the n=2 case. Ellipses added for clarity.

References

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