Blind Detection of Source Vessel Locations and Resonance Offsets using Randomly Encoded VEASL

E. Wong[1], and J. Guo[2]
[1]Radiology/Psychiatry, UC San Diego, La Jolla, CA, United States, [2]Bioengineering, UC San Diego, La Jolla, CA, United States

Introduction: In vessel encoded ASL (VEASL) (1), pseudo-continuous ASL tagging is used with additional gradient pulses applied across the tagging plane to encode the data with information about the location of the feeding arteries. In most implementations, prior information on the locations of feeding arteries in the tagging plane have been used to optimize the encoding process. However, in some cases, the relevant supplying arteries are not known ahead of time, as there may be variant or collateral circulation. In addition, the resonance offset in the tagging plane is known to affect the tagging efficiency, and can effectively be estimated and corrected using multiphase pcasl (2). We introduce here an efficient method for estimating both the location and resonance offset of all feeding arteries in VEASL from randomly encoded data, allowing for identification of source vessels without prior knowledge of thier locations.

Methods: In the original implementation of VEASL, gradient pulses of alternating sign were used between RF pulses to provide vessel encoding. In the presence of resonance offsets in the tagging plane, this approach results in decreased tagging efficiency. We note here that using unipolar gradient pulses for vessel encoding provides the same encoding functionality, results in a simple shift of the encoding response with resonance offset without a loss of tagging efficiency, and we are currently using this method. 60 pairs of encoding steps, with random orientation and wavelength λ (3), in addition to 2 pairs of non-vessel encoded steps, were used with imaging parameters otherwise as in (1). Each pair of encoding steps was 180° out of phase with one another, such that a difference signal between the pair removes static tissue signal and leaves a symmetrical dependence of the ASL signal upon vessel location, as shown in Figure 1. The response calculated by Bloch simulation is shown as blue circles, and a fit to the response, using three Fourier components is shown in red. The fitted curve was used in the data analysis. For an array of assumed vessel locations with 2mm spacing, and resonance offsets with 11-22Hz spacing, the expected ASL signal across encoding steps was calculated. This maps X and Y vessel coordinates and Frequency (XYF) space into 61 dimensional signal space. ASL data was acquired in healthy volunteers, and mapped from signal space back to XYF space. Clustering or other detection methods can be performed in either space, but in these examples clusters were identified in XYF space to determine the location and resonance offset of source vessels. These cluster centers were then used to generate the encoding matrix for a conventional linear analysis of the contribution of each vessel to the perfusion of each voxel (1).

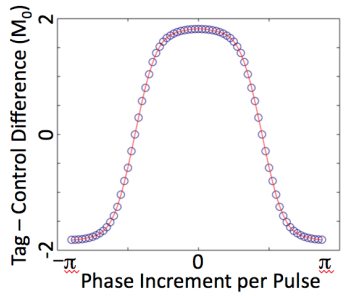

Figure 1: Simulated response to unipolar VEASL tagging. After subtraction, paired encoding steps result in a dependence of arterial magnetization on the gradient related phase rotation as shown above.

Results: Two examples are shown in , using tagging planes through the vertebral arteries and pons, respectively. In the first example, separate clusters are detected for the left and right vertebral arteries (green and blue), suggesting incomplete mixing in the basilar artery, with more mixing higher in the posterior circulation (teal color, yellow arrows). Residual signal not accounted for by the four identified arteries follow a large artery distribution, suggesting cardiac pulsation as a dominant source of those components. At the level of the pons, only two of the three major arteries had a clear cluster in XYF space. Choosing any of the small clusters in the vicinity of the blue arrow results in a correct map (c), but detection of these clusters is not straightforward. A prominent cluster (yellow arrow), which does not correspond to a vessel location, dominates the residual signal (d), and is consistent with vascular pulsations. The resonance offsets at this level were large (58-166Hz). With conventional single phase PCASL, at our tagging pulse spacing of 1.4ms, the higher of these offsets would result in a tagging efficiency near zero.

Discussion: We have demonstrated that it is possible in most cases to identify vessel locations without prior knowledge despite large resonance offsets, using a random encoding strategy that provides unbiased sampling of the tagging plane and resonance offset space. This may be important for the detection of collateral supplies, which can flow through the tagging plane at unpredictable locations. At the level of the pons, the carotid and basilar arteries form a consistent triangle which appears amenable to 3 vessel encoding, but PCASL tagging at this location is usually problematic because of large resonance offsets. In the current method the tagging is effectively multiphase pcasl at every location, but each location with a different random phase pattern. This results in consistent tagging efficiency and we suggest that this location may be a good default tagging location for VEASL of the left/right/posterior circulation. However, in our data, not all vessels appear as distinct clusters, and some spurious clusters seem to represent vascular pulsations. We are currently investigating methods such as gating and longer post-labeling delays to reduce these fluctuations, and post-processing methods to identify and remove these non-localized fluctuations.

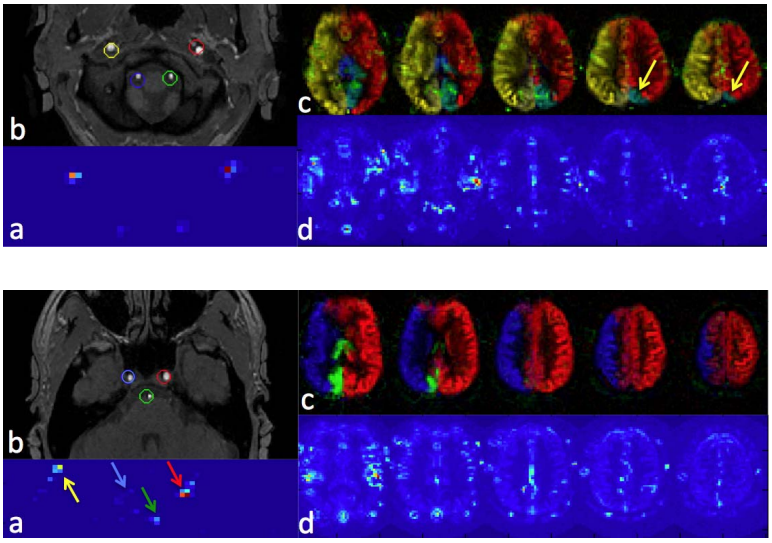

Figure 2: a) vessel locations detected by decoding ASL signal; **b)** vessel locations overlaid on angiogram of tagging plane; **c)** vascular territory maps generated using detected vessel locations; **d)** residual ASL signal not accounted for by detected vessels. **Top:** Tagging at inferior border of cerebellum. The resonance offsets detected at the vessel locations (L-R in Hz) were: 41, 33, 70, 42. **Bottom:** Tagging at mid-pons. Resonance offsets (L-R in Hz): 126, 58, 166. (see text)

References

1. Wong, EC, MRM, **58**(6): 1086-1091, 2007.
2. Jung, Y, Wong, EC, Liu, TT, MRM **64**(3): 799-810, 2010.
3. Guo, J, Wong, EC, ISMRM p.4069, 2010.