

## From optimized Vessel Encoded PCASL (opt-VEPCASL) to randomly-encoded VEPCASL (re-VEPCASL)

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### Introduction:

In vascular territory imaging, Hadamard type encoding [1-3] and other methods [4] encode different vessels with different inversion efficiencies, such efficiencies are then used to decode the vascular territories. Optimized Vessel Encoded Pseudo-Continuous ASL [5] (opt-VEPCASL) provides higher SNR efficiency and make the prescription easier especially when more than 3 vessels are encoded, but the actual tagging profile in the tagging plane may be affected by resonance offset, and an angiogram is required to locate the vessels. Another potential strategy is to encode the vessels randomly, and decode using clustering methods, however the SNR efficiency will be lowered. Here we compare the opt-VEPCASL and Randomly Encoded VEPCASL (re-VEPCASL) methods.

### Theory:

The tagging profile in each encoding step in VEPCASL can be modeled as shown in [5]. Given encoding gradients, the actual SNR efficiency can be calculated. In opt-VEPCASL, SNR efficiencies are close to 1 assuming no gradient amplitude constrains or resonance offsets, but the SNR efficiency [1] will be lowered if a random encoding strategy is applied. To explore this effect, we generated randomly located vessels, distributed around centers representing typical vessels locations: e.g., LCA(-30, 25), BA(0, 0), RCA(40, 30), tagging profiles with random encoding gradients were simulated with constraints on gradient amplitude, and relative tagging efficiencies were calculated to give SNR efficiencies.

In theory, encoding gradients separate the tagging plane into segments (Fig. 1), each segment is mapped into a N-dimensional relative tagging efficiency space by different encoding steps, each dimension representing one encoding step, where N is the number of encoding steps other than global tag and control conditions in conventional ASL experiments. To decode the data, if there is a small number of vessels, 2-D Gaussian fitting [1] can be used to estimate the relative tagging. For a large number of vessels, clustering methods [6] can be used to segment the territories. Here, the clustered centroids which represent the actual relative tagging efficiencies are used to decode the data linearly and give quantitative estimates of contribution from individual source vessel. This decoding method can be used in both opt-VEPCASL and re-VEPCASL.

### Methods:

In the simulation, randomly distributed vessel locations were used, and the effect of the number of random encoding steps upon the SNR efficiency change is examined. Experiments with conventional 6-step VEPCASL and 8-step opt-VEPCASL were tested on a healthy human subject scanned on GE 3T system with 8-channel head coil. The imaging parameters were: 5 axial slices, FOV=220mm\*8mm, skip 2 mm, tagging time=1.6s, post-labeling delay=1s, TR=3s, TE=3ms, 96 repetitions, gradient echo with spiral readout.

### Results:

As shown in Fig. 2, the SNR efficiencies were slightly higher in opt-VEPCASL. Also of note is that the signal from external carotids was smaller in opt-VEPCASL, this may be caused by subject movement or by chance location of these vessels in regions with lower relative efficiencies, as darker regions shown in Fig. 1. Fig. 3 shows that the simulated SNR efficiencies is lower than 1 for re-VEPCASL, and that it fluctuates greatly when a small number of encoding steps is used. However as the number of the encoding steps increased, the SNR efficiencies converges to  $\sqrt{2}/2$ , since we sampled the tagging plane more uniformly with larger number of encoding steps.

### Discussion:

By simulation, the SNR efficiency of re-VEPCASL is  $\sqrt{2}/2$  compared to opt-VEPCASL. However, the re-PCASL method may prove following advantages: 1) no planning or angiogram is needed; and 2) it is potentially insensitive to resonance offsets. These advantages may benefit clinical users.

### Reference:

1. Wong, MRM 2007, 58:1086.
2. Zimine et al, MRM 2006, 56:1140.
3. Gunther et al, MRM 2006, 56:671.
4. Wong, ISMRM 2008, 182.
5. Guo et al, ISMRM 2009,
6. Kansagra et al, JMIRI 28:762-766 (2008)

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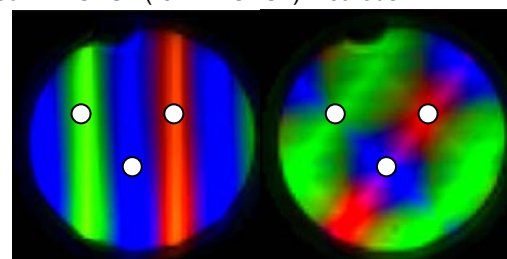
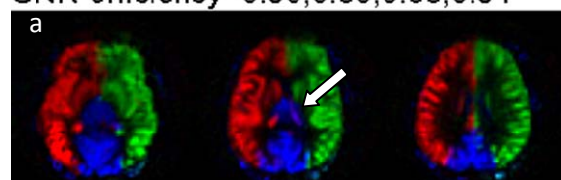


Fig. 1 Different segmentation by different encoding strategies, white dots are imaginary "vessels".

SNR efficiency=0.90,0.80,0.66,0.94



SNR efficiency=0.92,0.83,0.67,0.88

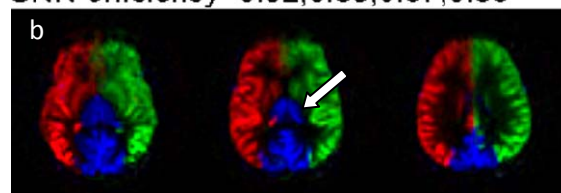


Fig. 2 Conventional VEPCASL (a) and opt-VEPCASL (b). Note the mixing part in (a) (with arrow)

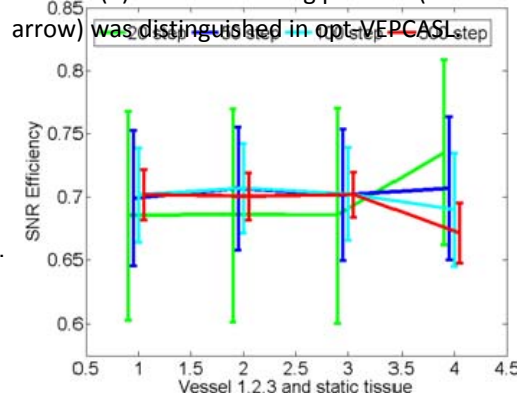


Fig. 3 Simulated SNR efficiency of re-VEPCASL v.s. number of encoding steps.