

Single Echo MRAV with Inversed Vessel-Tissue Contrast

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Introduction:

Understanding the cerebral vascular system is very important for many clinical applications, and the ideal scenario is to be able to simultaneously acquire separable arterial and venous networks. Previous efforts in obtaining MRA and MRV images simultaneously through single echo sequence [1] showed arteries with bright blood signal via time-of-flight effects and veins with dark blood signal via susceptibility weighted imaging (SWI). Compared to multi echo approaches [2, 3], obtaining MRAV images in a single echo can get rid of misregistration errors without any penalty in scan time increase. However, MRA contrast is suboptimal with the long TE and TR needed for good SWI. In this study, we introduce an alternative strategy for single echo MRAV imaging, in which inverted vessel-tissue contrast is obtained. Specifically, arteries will be of dark blood contrast via flow dephasing, while veins will be of bright blood contrast via quantitative susceptibility mapping (QSM) calculation [4]. This new method not only has the potential to provide the best contrast for MRA and MRV, but also a quantitative perspective of the oxygen saturation in major veins as a biomarker for many neurovascular diseases such as TBI or stroke, all in one single echo scan.

Method:

Two sets of *in vivo* data were collected at a Siemens Magnetom 7T scanner, using a flow dephased 3D GRE sequence [2]. The flow dephasing was achieved using bipolar gradients along all three oblique directions, with an effective VENC value of 2.5 cm/s. Other scanning parameters were: 0.5 isotropic voxels with 384*384*128 data matrix, TE = 11 ms, TR = 16 ms, FA = 12°, bandwidth = 450Hz/px.

To visualize the veins with high signal, the phase images were processed using iterative SWIM method [4]. The process included: 1) high pass filtering with 32x32 filter size and skull striping; 2) extract a venous mask from an initial susceptibility map obtained by solving the regularized inverse Green's function; 3) perform FFT on the venous mask and use its k-space data to fill in the singular cones in the inverse Green's function; 4) repeat steps 2 and 3 for three times. The final susceptibility map can then be used as the venous map to extract the final venous mask, which was further processed to improve the continuity of the veins shown. And this continuous venous mask was then applied to the original flow dephased images to mask out the venous voxels by setting them to a higher value close to the surrounding tissues. Finally, the vein masked flow dephased images were then minimally intensity projected (mIPped over 32 mm) to show the arteries only with dark blood signal.

Results:

Fig. 1 presents the single slice results of the flow dephased images and the SWIM images. From Fig. 1a we can see that all vessels are of low signal due to flow dephasing by bipolar gradients with low VENC value. And in the reconstructed susceptibility map (Fig. 1b), the veins are of higher signal than surrounding tissues due to the high susceptibility with the paramagnetic venous blood, but the arteries are still of low signal. Fig. 2 displays the minimally or maximally intensity projection results of flow dephased images that shows both veins and arteries, and separated venous/arterial maps obtained using above processing.

Discussion and Conclusions:

In this study we aim to develop a new scheme to extract both arterial and venous networks from the single echo GRE data. Routine MRA and MRV, or other proposed MRAV methods all featured in bright blood contrast for

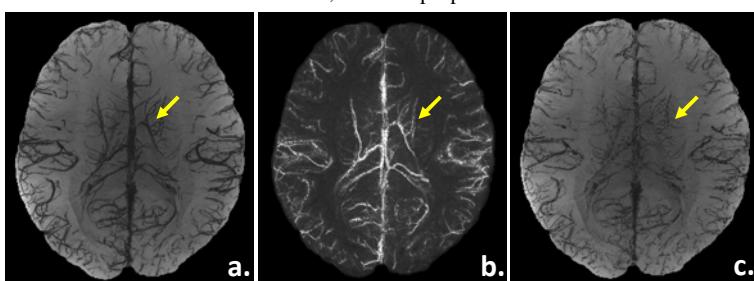


Figure 2: Intensity projection results of (a) dark blood images, (b) QSM venous map and (c) final arterial map. Note that the major arteries cannot be seen in vein map, such as that shown by the arrow.

remove veins from the original flow dephased images to show only the arteries. We have successfully demonstrated this concept with our results here, though further optimizations are needed to improve the data acquisition parameters, the extraction of venous mask from susceptibility maps, the removal of veins from the flow dephased data, and reducing the mask effect on arteries. Collecting the data at 7T offers the advantage of higher SNR and stronger gradient system, and can facilitate high resolution and better phase imaging capacities for better QSM results. Therefore it is beneficial to collect the data at very high fields. Future works will also include testing the method on a 3T scanner to evaluate its potential for routine clinical applications.

References:

[1] Barns, ISMRM (2009) 1861. [2] Ye et al. J Magn Reson Imaging (2013) online. [3] Du et al. J Magn Reson Imaging (2009) 30:449-454. [4] Tang et al. MRM (2013) 69:1396-1407.

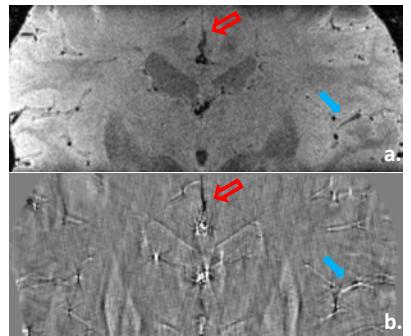


Figure 1: Coronal view of single slice: (a) flow dephased image, (b) susceptibility map. Note that the vein pointed by solid blue arrow and artery pointed by hollow red arrow can be easily classified by the two images.

arteries and dark blood contrast for veins. However, our method presents the vessel networks with an inverse contrast. Compared with bright blood methods such as TOF or contrast enhanced MRA, the dark blood contrast obtained using flow dephased approach can give very high artery-tissue contrast for whole brain coverage, without any saturation effects or the need to inject contrast agent. On the other hand, veins will show even lower signal than arteries with additional T_2^* decay, and may not be distinguished from arteries in the original images (Fig.2a). However, one important property of venous blood is that it is paramagnetic and will induce dipole effects in the phase images, while arterial blood is slightly diamagnetic and almost invisible in phase images. Therefore using the iterative SWIM method [4] to calculate the susceptibility maps from the phase images can show veins with hyper-intensity (i.e. high susceptibility value) and distinguish it from arteries. In turn this susceptibility based venous map can be used to

remove veins from the original flow dephased images to show only the arteries. We have successfully demonstrated this concept with our results here, though further optimizations are needed to improve the data acquisition parameters, the extraction of venous mask from susceptibility maps, the removal of veins from the flow dephased data, and reducing the mask effect on arteries. Collecting the data at 7T offers the advantage of higher SNR and stronger gradient system, and can facilitate high resolution and better phase imaging capacities for better QSM results. Therefore it is beneficial to collect the data at very high fields. Future works will also include testing the method on a 3T scanner to evaluate its potential for routine clinical applications.