Robust retrobulbar MRA using BORR pulse for fat suppression

Yongquan Ye[1] and E. Mark Haacke[1]
[1]*Radiology, Wayne State University, Detroit, Michigan, United States*

Introduction:

Being able to obtain a clear picture of the retrobulbar vasculature that provides the blood supply to the eye (Fig.1a, www.missionforvisionusa.org) is very important for the diagnosis to a number of sight threatening diseases, such as ocular ischemic/hemorrhagic syndrome and central retinal artery occlusion. However, every imaging modality has their drawbacks for imaging the retrobulbar vessels: CT is limited by radiation exposure, while Doppler ultrasound, optical coherence tomography (OCT) and Heidelberg retinal tomography (HRT) all have limited penetration into the eye. MRI has great potential with its high resolution, full field of view imaging of the vasculature, non-invasiveness and radiation free benefits, and thus has become the most widely used angiography imaging modality for most body parts. However, unlike in any other body parts where vessels are surrounding by brain tissues or muscles, retrobulbar vessels are buried in fatty tissues (Fig.2b). Fatty tissues have short T_1 and long T_2 values, and thus show hyper-intensity in most routine MRI scans. Fat suppression techniques such as fat saturation or inversion recovery cannot completely remove fat signals especially with high resolution, while phase based Dixon methods cannot provide detailed information of the vessels. In this study, we proposed using a new RF based fat suppression method, namely the Binomial Off-resonant Rectangular (BORR) pulse [1], to reliably reveal retrobulbar vessels and structures by total removal of fatty tissues with its broad suppression bands (Fig.2).

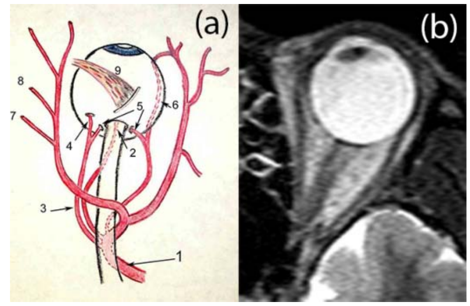

Fig.1 a) Supplying retrobulbar arteries. b) A typical T2 weighted image of the eye, where fatty tissues around the optical never are of high signal.

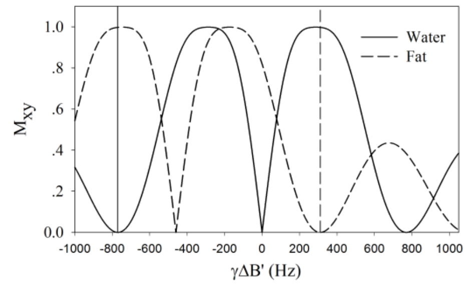

Fig.2 Frequency response of the BORR pulse.

Methods:

Five healthy volunteers (28-35 y/o) were enrolled in the study with written consents. All data were collected on a Siemens 3T Verio scanner with product 32 channel head coil. The BORR GRE sequence was scanned sagitally with TR/TE = 11/3ms, 0.5mm isotropic voxels, 224 x 224mm inplane FOV and 256 partitions, and with BORR pulse of duration τ = 1.6ms, flip angle = 12°, and frequency offset Δf = +140Hz [1]. This configuration gives whole brain coverage and excellent fat suppression for the whole brain. For comparison, 3D TOF MRA (with and without fat saturation) and Enhanced MRA [2] were also collected, using coronal imaging slabs covering only the anterior part of the brain to maximize in flow effects. Also 3D contrast enhanced (CE) MRA was collected on one subject to see its performance in revealing the ocular vessels, using an axial imaging slab covering the whole eyes. All scans were configured to have similar scanning parameters as much as possible (e.g. voxel size, bandwidth, etc.), but optimized to yield the best performance in showing the vessels (e.g. slab size and orientation). All final results will be reoriented to axial plane and processed with Maximal Intensity Projection (MIP) over a 4mm thickness.

Results:

The comparison of the above results is shown in Fig.3. Due to the different contrast mechanism and intensity levels, the display window for each shown image was adjusted separately for optimal display. The images are drawn from 3 different subjects but are at the similar slice location, each showing at least one of the following major vessels: Ophthalmic Artery (OA), Posterior Ciliary Arteries (PCA) or Lacrimal Artery (LA). The BORR sequence offered the best visualization of the retrobulbar arterial vasculature among all methods, with totally suppressed fats and crisp depiction of all major arteries.

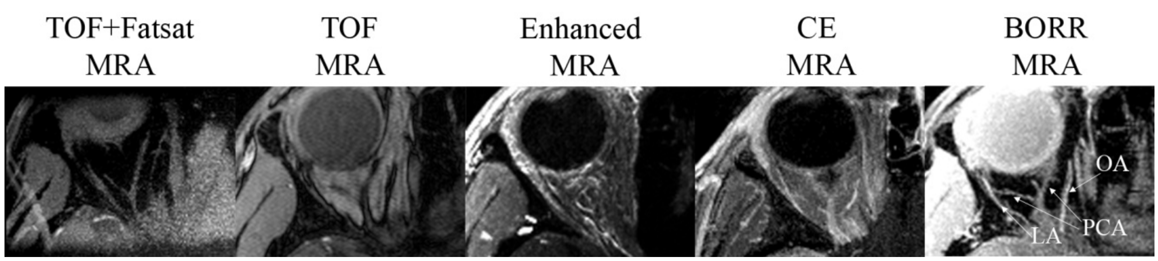

Fig.3 Comparison of different MRA methods for imaging the retrobulbar vessels of the left eye.

Discussion:

There are many contrast mechanisms in doing angiography with MRI, such as TOF, CE MRA with T_1 shortening agents, steady state free presession (SSFP) for T_2/T_1 weighted contrast, images subtractions between bright blood and dark blood images, to name a few. However, none of the above methods works well if the arteries are buried in fatty tissues, as with the case of retrobulbar vessels, because the short T_1 and long T_2 of fat make it difficult to be naturally suppressed in these scans, and thus reducing the vessel-tissue contrast as evidenced by the TOF result without fat saturation. When fat saturation was added, although the fats are suppressed to a great extent and some arteries are now shown, the SNR was not great due to the saturation leakage to the blood, and also the total scan time was lengthened to include the saturation pulse. Also shown by the Enhanced MRA (with uses subtraction to reduce background signal) and CE-MRA (using short TR and high FA to saturate background) results in Fig.3, the vessels are mostly obscured by the hyperintense fat signal. Thus it is ideal to selectively remove the fat signal and leaves good vessel signal, yet to date none has proven competent in such task [3]. By using the BORR pulse method we have demonstrated its potential in reaching this goal, due to its excellent robustness in total fat suppression. Since both water excitation and fat suppression are being done with one binomial pulse, the sequence can use very short TR to achieve short scan time but high resolution as we have shown, and has great potential for use at very high fields such as 7T with low SAR level. Further studies will evaluate the clinical potential of BORR MRA on ocular ischemic patients.

References:

[1] Ye, et al. JMRI (2013);24149; [2] Ye, et al. JMRI (2013);24128; [3] Christoforidis, *et al.* GACEO (2013) 251:271–277