Application of Restore Pulse for Improved Intracranial Black Blood Angiography

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Introduction

In an attempt to overcome limitations of TOF-MRA (white blood MRA) black-blood FSE-MRA has been developed [1-2]. In black-blood imaging, contrast between blood in the vessels and the stationary soft tissue is achieved by suppressing signal from flowing blood and maintaining a strong signal from the stationary tissues. Serious trade-off between vessel/surrounding tissues contrast and scan time exists for intracranial black blood 3D FSE-MRA. The optimal contrast in such studies can only be achieved with long TR resulting in unacceptable long imaging time. A technique to resolve this problem is proposed in this work.

Theory and Methods

Vascular structures in the brain are surrounded by gray matter (GM) and CSF. To achieve optimal contrast between vessels and surrounding tissues in intracranial black blood FSE-MRA, blood signal should be completely suppressed and GM and CSF signals maximized. The first requirement is easily achievable, but to completely satisfy the second requirement the TR of the pulse sequence should be kept very long. The main reason for this is the long T1 relaxation time of CSF. We have proposed to use FSE with -90 degree restore RF pulse to achieve optimal contrast between vessels and CSF and acceptable scan times for intracranial black blood 3D FSE-MRA. Application of the restore pulse at the end of echo train (ET) readout results in flipping the residual transverse magnetization into the longitudinal direction. For typical ET readout (100-200 msec) of black blood FSE pulse sequences, the residual transverse magnetization of white matter (WM) and GM is close to zero due to the short T2 relaxation times of the tissues (for 1.5 Tesla, T2 of GM is about 100 msec, and T2 of WM is about 90 msec). However, the transverse magnetization of long T2 tissues such as CSF (for 1.5 Tesla, T2 of CSF is about 500 msec) continues to have significant value at the end of ET readout. Thus, the magnetization recover for short T2 tissues is similar for FSE pulse sequences with and without restore pulse. However, in the case of FSE with restore pulse magnetization recovery for long T2 tissues starts not from zero as in the case of the standard FSE but from a substantial value resulting in significant speed-up of magnetization recovery. In the case of FSE pulse sequence with restore pulse the steady-state solution of Bloch equations for the longitudinal magnetization is given by

$$M_z = M_o \frac{1 - e^{-(TR-TA)/T1}}{1 - e^{-(TR-TA)/T1} e^{-TA/T2}}$$

where TR is the repetition time, TA is the time interval between the 90 degree excitation RF pulse and the -90 degree restore RF pulse. From this equation, it is quite obvious that signal from tissues with long T1 and long T2 such as CSF can be significantly increased if FSE with restore pulse is used instead of the standard FSE.

Results

Figure 1 shows the results of the steady-state solution of Bloch equations for the longitudinal magnetization of various brain tissues for FSE pulse sequences with and without the restore pulse. It is obvious that application of the restore pulse increases the rate of magnetization recovery to thermal equilibrium for all brain tissues. However, for the standard TR of 1.5-3 seconds of intracranial black blood 3D FSE-MRA, a significant gain in signal intensity is only achievable for CSF.

Black blood images of healthy volunteers were acquired on a 1.5T SIGNA Lx 8.4 scanner (GE Medical Systems, Milwaukee, WI) with NV/CVi gradients using 3D FSE pulse sequence with and without the restore pulse. Acquisition parameters were: TR=1800 msec, TE=13 msec, FOV=230x172.5 mm, acquisition matrix=384x192, ETL=8, Rbw=+/-31,5 kHz, 24 slabs, 6 slices/slab, 0.9 mm slice thickness The acquired data volumes were zero-filled interpolated to achieve isotropic voxels of 0.3x0.3x0.3 mm^3. Figure 2 demonstrates typical slices from the image volumes acquired in this study. The image appearance agrees with results of the theoretical analysis. In both image sets gray and white matters have comparable intensities. However, CSF intensity is significantly higher for images acquired with the restore pulse in comparison with CSF intensity for images acquired without the restore pulse. Black blood angiograms are shown in Fig. 3 demonstrating improved vessel visualization for the proposed technique.

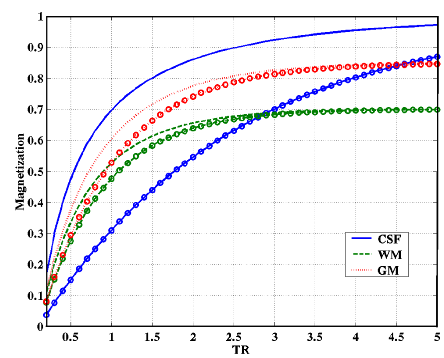

Figure 1. Dependence of longitudinal magnetization of CSF, WM, and GM on TR for FSE pulse sequence without (lines with symbol) and with (lines without symbol) the restore pulse.

Discussion

Application of -90 degree restore pulse to improve the quality of intracranial black blood 3D FSE-MRA has been proposed. The proposed technique gives significantly improved contrast between vascular structures and the surrounding CSF resulting in better vessel visualization.

Acknowledgements

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References

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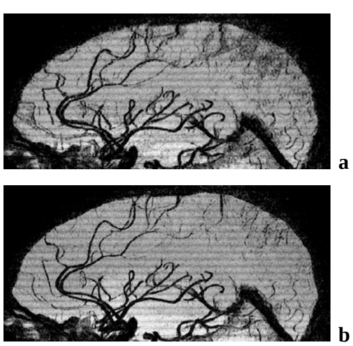

Figure 3. Angiograms reconstructed by minimum intensity projection algorithm from the image volumes acquired by black blood 3D FSE without (**a**) and with (**b**) the restore pulse.

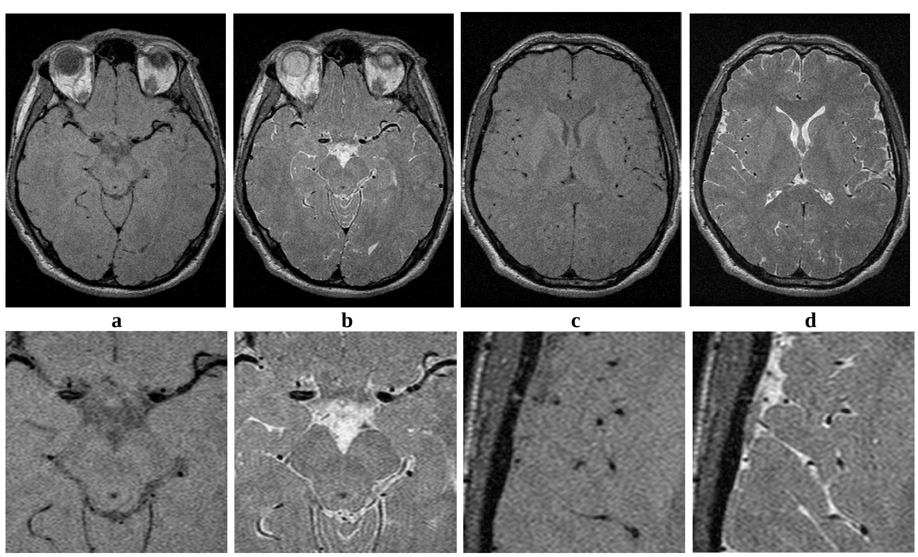

Figure 2. Brain images acquired by 3D FSE pulse sequence without (**a**, **c**) and with (**b**, **d**) the restore pulse.