Vessel Wall Edge Enhancement in High Resolution 3D Turbo Spin Echo Imaging

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TARGET AUDIENCES For those who are interested in 3D high-resolution vessel wall imaging and in investigating associated pathologies

PURPOSE Vessel wall imaging has gained increased interest and clinical significance as the absence of timely diagnosis and consequent treatment of associated pathologies such as atherosclerotic disease of primary feeding arteries to the brain and intracranial arteries may result in increased morbidity and mortality. Hence, diagnosis and treatment are crucial for these vascular diseases. However, it is challenging to image the vessel wall due to its small dimension which is typically sub-millimeter. High-resolution 3D imaging is desirable to sufficiently cover tortuous anatomy with isotropic resolution. Recently, 3D turbo spin echo (TSE) sequence with variable flip angles[1] (vendor names: SPACE, VISTA, CUBE) has been utilized to provide high-resolution image quality within a feasible scan time[2]. However, these techniques usually involve long echo trains during which the spin magnetization decays and the signal is modulating, which can lead to blurring or ringing artifacts[1]. The vessel wall edge enhancement along both the phase-encoding and partition-encoding directions depends on the echo train length, the k-space filling scheme, and different T1 and T2 values of the vessel wall and adjacent tissues. This wall edge enhancement effect needs to be carefully accounted for and should not be confused with actual vessel wall in clinical practice. This paper reports and discusses the effect of vessel wall edge enhancement when using high-resolution 3D TSE-based sequences.

METHODS Two normal volunteers were scanned on a wide-bore 3T (Skyra, Siemens) with a 20-channel head coil. The basilar artery was imaged to demonstrate the wall edge enhancement effect for simplicity since it is contained in the pontine cistern filled with cerebrospinal fluid (CSF). The protocol parameters for 3D SPACE were as follows: TE/TR= 28/1700 msec, 0.55 mm isotropic voxels, 140 mm^2 FOV, 80% slice resolution, 6/8 slice partial Fourier, GRAPPA 2, radial k-space reordering (Fig. 1a, color bar in the right indicates echo numbers in TR) with elliptical scanning, 399 Hz/pixel receiver bandwidth, 5.41 msec echo spacing, and echo train length=60. Axial imaging has been performed twice on the same subject, with the phase-encoding and readout directions swapped for the second imaging scan. The vessel wall edge of the basilar artery was compared between the two acquisitions. Simulation has also been performed to illustrate the effect of wall edge enhancement. T1 and T2 values of vessel wall and CSF were 1000/80 msec and 3100/160 msec in the simulation, respectively. Signal evolution along 60 echoes on the k-space trajectory (Fig. 1a) was simulated then, point spread function (PSF) was calculated.

RESULTS Fig. 1b shows simulated vessel wall edge enhancement along the phase-encoding direction. There observes the enhancement and broadening of vessel wall. Fig. 2 shows the basilar artery of one subject acquired axially (b, e) and reformatted into coronal planes (a, d). Fig. 2a and 2b show edge enhancement and broadening along the phase-encoding direction (red arrow) similar to that shown in the simulations in Fig 1b while Fig. 2d and 2e do not show that effect at the same location as it was acquired along the readout direction. Fig. 2c and 2f are actual measurements of vessel lumen/wall along the blue line shown in Fig. 2b and 2e, respectively. Fig. 2c shows broader and enhanced vessel wall than Fig. 2f as PSF along the phase-encoding direction is much broader than that of the readout direction.

DISCUSSION The intracranial vessel wall is a structure that is very thin relative to typical MR voxel sizes and consequently, imaging usually requires long acquisition time to obtain high quality images. The echo train length typically ranges from 50 to 60 to reduce scan time. However, this long echo train, along with different variable flip angle schemes can cause vessel wall enhancement and broadening along either the phase-encoding or partition-encoding directions. This also depends on how k-space is acquired and filled along each direction. These wall edge enhancement effects can vary depending on vessel size, surroundings, and vessel tortuosity with regard to the two phase-encoding directions and can be confused with an actual vessel wall. Hence, vessel wall reading should carefully consider details of the imaging protocol and anatomy locations. Simulation helps to estimate these effects prior to in vivo imaging and clinical reading.

CONCLUSION In this paper, we report the effect of vessel wall enhancement and broadening along phase-encoding directions when using high-resolution 3D TSE sequence. This can confuse the actual vessel wall reading. Consequently, care should be taken in imaging and reading with regard to imaging protocol and vessel locations.

REFERENCES

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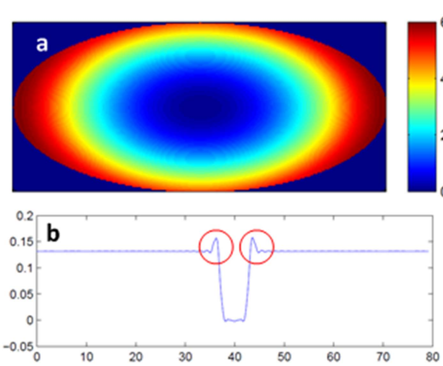

Figure 1. Radial k-space reordering (a, horizontal: phase-encoding and vertical: partition-encoding dir) and simulated wall edge enhancement (b)

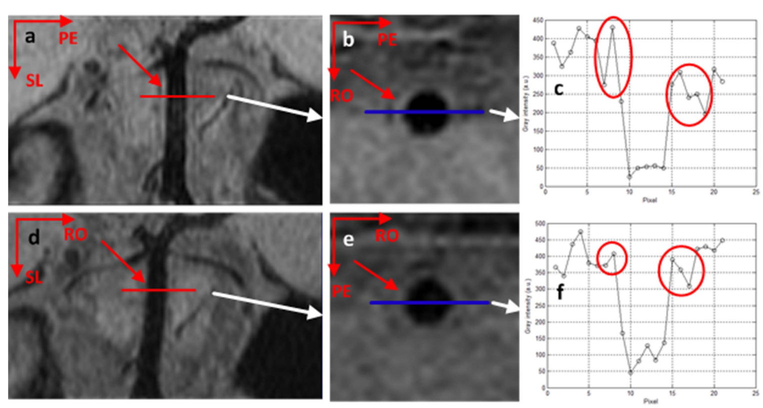

Figure 2. Basilar artery of one subject: coronal view (a,d) and axial view (b,e) taken from a slice shown in coronal views. C and f show actual measurements of the vessel wall along the blue lines in b and e, respectively.