Reduced field-of-view imaging with 3D variable flip angle Fast Spin Echo-feasibility in MRI of orbits

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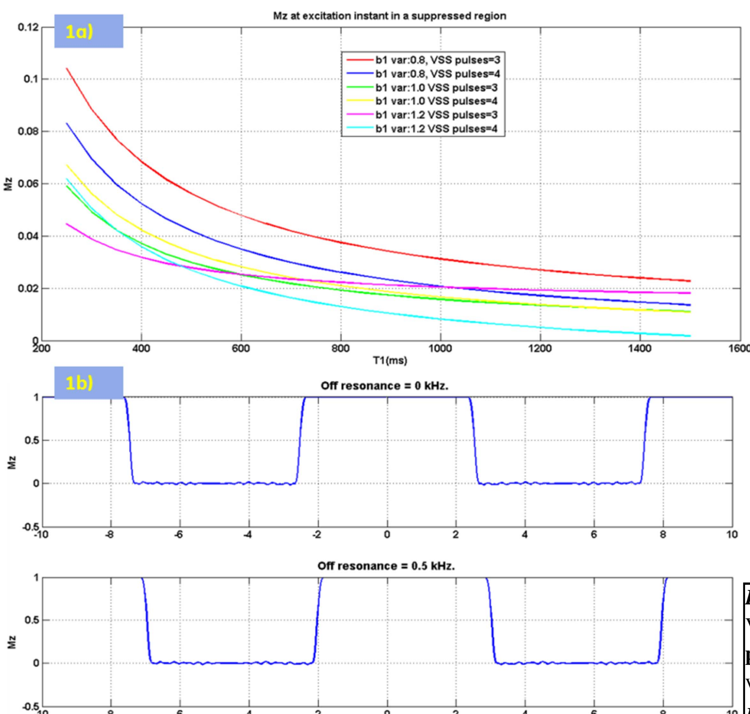
Audience: Neuroradiologists, MR physicists interested in reduced field of view imaging

Purpose: The field of MRI has been gravitating toward entirely volumetric protocols in the interest of scan time efficiency and workflow simplification. 3D scans acquired at near isotropic resolution can be reformatted at any obliquity, adjusting for the shape, size and other anatomical variations between subjects, obviating the need for multiple 2D acquisitions in different imaging planes. Reduced field-of-view (rFOV) capability can enable focused 3D high resolution imaging, even of deep-seated regions, within a short scan time by reducing the number off phase encodes at a given resolution. In this work we look at rFOV volumetric imaging using outer volume suppression (OVS) with variable flip angle 3D fast spin echo (VFA-3DFSE) [1] and demonstrate its performance for MRI of the orbits. The human optic nerve is a very small white matter bundle (< 3mm) embedded inside layers of cerebrospinal fluid, meninges, fat, muscle, and bone, close to the large sinuses-so high resolution is essential to reducing partial voluming [2]. MRI is used as a diagnostic tool for optic disorders such as optic neuritis related with inflammatory demyelination of the optic nerve and the onset of multiple sclerosis. We hypothesize that rFOV high resolution 3D VFA-FSE acquisition can improve visualization by allowing oblique reformats, as well as reduce scan times considerably compared to existing 2D FSE protocols.

Method: Previously rFOV imaging with 3DFSE has been demonstrated with 2D spatially selective RF excitation [3], inner volume [4] and outer volume suppression (OVS) techniques [5]. There are technical challenges associated with each method such as blurring due to increased echo-spacing or reduced signal due to loss of CPMG condition in case of 2D spatially selective excitations, or poor edge profile with conventional OVS pulses. We incorporated quadratic phase RF pulses (time bandwidth: 40, bandwidth: 5 KHz) to achieve sharp edge profile and a broader bandwidth at a given peak B1 power [6-7] in the 3D VFA-FSE sequence, CUBE, on the GE platform. Variable rate selective excitation (VERSE) algorithm was used to further reduce peak B1 [8]. These very selective saturation (VSS) pulses were cosine modulated [9] to simultaneously saturate regions on either side of the field-of-view in the phase encoding direction. A linear phase 90° RF excitation (2.6 ms , time bandwidth = 6) provided selectivity in the slab direction. The OVS module was positioned close to the excitation, after inversion or chemical saturation modules, when fluid attenuated inversion recovery (FLAIR) and/or fat suppression was prescribed by the user. Previous works have proposed playing out a series of OVS pulses for B1 and T1 insensitivity [5]. As seen from Fig 1a), 3-4 VSS pulses can make the suppression technique fairly insensitive to B1 and T1 variations, suppression being more B1 insensitive at longer relaxation times. Edge profile of the suppressed region is still very sharp even at an off-resonance of 500 Hz for a 5 KHz VSS pulse (Fig 1 b), but saturation band position and thickness need to be adjusted to account for the slight shift in the suppression volume.

Two subjects were scanned at 3T (GE MR750, Waukesha, WI) using a 32 channel head array (NovaMedical, Wilmington, MA) after informed consent. Scan parameters were as follows: rFOV CUBE with chemical fat saturation: TR/TE (ms):2000/79.8, FOV: 16x11.2x cm^2, matrix:320x224, resolution: .5x.5x1mm^3, 120 partition encodes, scan time: 2min 15 s, 2D FSE IDEAL [9]: TR/TE (ms):8515/80, FOV: 16x13cm^2, 320x224,slice thickness: 1 mm, 120 slices, scan time: 8mins 57 s.



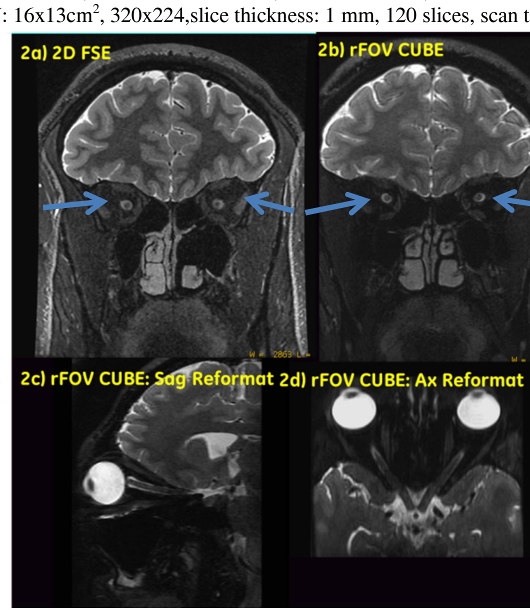


Figure 1a: **B1 & T1 insensitivity of outer volume suppression** using 3-4 VSS pulses. ***Figure 1b***: **Simulated suppression profile with a 5 KHz VSS pulse on resonance and at 500 Hz off-resonance.** The edge profile is still very sharp but suppression region is shifted, as expected, at off-resonance.

Figure 2: Coronal images of the optic nerve acquired with an **8 min 57 s 2D FSE scan** ***(a)***, **2 min 15 s rFOV CUBE scan** ***(b)*** and its sagittal ***(c)*** and axial ***(d)*** reformats are shown.

Results and Discussion: Coronally acquired 2D FSE and rFOV CUBE images had very comparable visualization of the optic nerve, even though the 3D scan time was less than 25% of 2D (Fig 2a,b). Additionally, sagittal (Fig 2c) and axial (Fig 2d) reformats of the rFOV- CUBE image volume clearly show the optic nerve exiting the globe and coursing posteriorly to the optic chiasm. In some cases of considerable B0 shift within a thick slab, slight aliasing from the shifted suppressed volume was observed-VSS pulses with larger bandwidth will be employed in the future to prevent such artifacts.

Conclusion: Reduced field-of-view 3D VFA-FSE using OVS was demonstrated for high resolution 3D MRI of the orbits, and shows potential for focused volumetric imaging within a short scan time.

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