Improved Fat Supression in Musculoskeletal Knee Imaging using 3D Radial VIPR IDEAL

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Introduction bSSFP provides high intrinsic signal but is challenging to use in areas of obscuring fat. Numerous methods utilizaing phase cycling and TR modulation have been proposed to suppress fat; however, these techniques achieve modest fat suppression. Limitations in TR lead many Cartesian approaches to demonstrate resolutions slightly less than 1 mm. To circumvent these limits, we previously modified a 3D radial "out and back" VIPR trajectory to create 4 echo times in two passes for an IDEAL implementation [1,2] at 1.5T. Here we demonstrate the high performance capabilities of this method at 3T for high 3D isotropic resolution, T2-weighted knee imaging (0.5 mm in 5 minutes and 0.33 mm in 8 minutes) and compare it to a previously described high resolution, bSSFP method, 3D radial fat-suppressed Alternating TR(VIPR FS-ATR), [3].

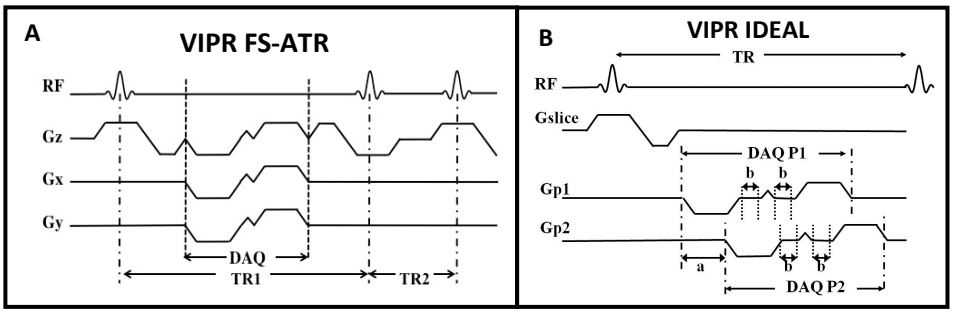

Figure 1 : Pulse sequence diagrams of VIPR FS-ATR (A) and VIPR IDEAL (B). In B, Gp1 and Gp2 represent the readout/phase encode gradients played out on all three axis for pass 1 and pass 2 respectively. The delays a and b are used to create timing offsets within or between passes to generate echo times with phase that is well spaced on the unit circle.

Methods and Theory The 3D radial VIPR IDEAL method makes use of a dual half echo, two pass sampling scheme to acquire 4 echoes, comprised of unique radial lines, during two TRs (Fig 1B). This allows for the collection of high resolution data while still keeping the TR short to avoid banding artifacts and keep fat and water centered in separate pass bands [1]. Utilizing 4 echo measurements instead of 3 in conventional IDEAL requires less precision in the echo spacing, allowing the resolution to dictate the trapezoid width and therefore the minimum spacing between echoes within a pass. The delays (a) and (b) in Fig 1B are the selected to ensure echo times do not sample phase at redundant points along the unit circle. The comparison method, FS-ATR, uses TRs of two different lengths (Fig 1A) with a ratio of TR2 to TR1 of 1:3, which when combined with RF phases cycling places a stop band over the fat resonance peak [3]. Both methods acquire the same data per effective TR and thus should have similar data acquisition efficiency.

Two volunteers were imaged with VIPR IDEAL (0.33 mm resolution 8 min scan time and 0.5 mm resolution 5 min scan time) and VIPR FS-ATR (0.4mm resolution 5 min scan time) sequences on a 3.0T Discovery MR750 scanner (GE Healthcare, Milwaukee WI), using a 16-channel knee coil over a 15 cm FOV. Echo times for IDEAL where chosen to be 0.5, 1.36, 3.2 and 4.06 ms.

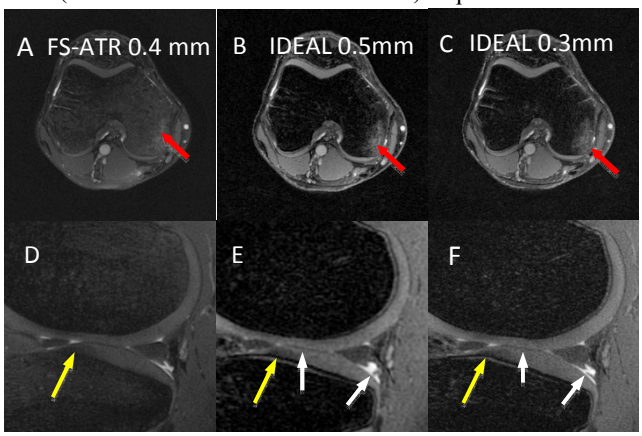

Figure 2: VIPR FS-ATR (A,D) and IDEAL (B, C, E and F) images of a knee imaged at 3T. The improved fat suppression of IDEAL allows for the visualization of bone marrow edema (red arrows) and bone cartilage interface (yellow arrows) that are obscured in FS-ATR (A and D). The increased resolution of IDEAL at 0.33 mm allows for better visualization of bone/cartilage interfaces and fluid along the cartilage surface (white arrows) as compared to 0.5mm

Results / Discussion VIPR IDEAL has superior contrast between bone and adjacent cartilage and fluid than FS-ATR due to better fat suppression as shown in Fig 2. Incomplete fat suppression obscures bone marrow edema (Fig 2A) and the bone cartilage/interface (Fig 2D) in the VIPR FS-ATR image. The value of increased resolution in the VIPR IDEAL scan is demonstrated in Fig 2 E and F. In the 0.5mm VIPR IDEAL, the cartilage-fluid interface is blurred as is the boundary between the two cartilage layers while these features are well represented in the 0.33 mm VIPR IDEAL. The 0.33mm VIPR IDEAL also improved homogeneity of the texture of the muscle and cartilage in the joint.

Conclusion Compared to VIPR FS-ATR, the VIPR IDEAL sequence offers greatly improved fat suppression, which improves visualization of bone marrow edema and the bone/cartilage interface. VIPR IDEAL is capable of producing ultra-high isotropic resolution of the knee with bright synovial fluid for studies of cartilage and whole-organ joint assessment in scan times of 5 or 8 minutes depending on the level of resolution required.

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References: [1] Moran CJ, *et al*, MRM *in press*. [2] Moran CJ, *et al*, ISMRM 2010, [3] Klaers JL, *et al* ISMRM 2010