Proof of Concept for 3D iCones: Single Petal, Rosette-like Sampling with a Tight TR Constraint

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TARGET AUDIENCE: Imaging scientists interested in non-Cartesian sampling and clinicians interested in high resolution, volumetric scans needing bSSFP contrast or multi-echo acquisitions.

PURPOSE: Out-and-back 3D radial trajectories have demonstrated a leading position in generating high resolution T2-weighted knee and breast imaging[1], producing resolution as high as 0.3 mm in an 8 minute knee exam[2]. Bipolar gradients allow rapid acquisition of very high spatial resolution within TR constraints used to generate fat/water separation (2.4 to 4.6 ms in various applications). Coverage of k-space with the bipolar trajectory is inefficient as k-space velocity must slow to zero before reversing directions. We investigate a 3D rosette-like trajectory that covers k-space more efficiently than a out-and-back 3D radial trajectory while maintaining a tight TR constraint. As each TR covers a single petal shaped similarly to an ice cream cone, we have termed the trajectory iCones.

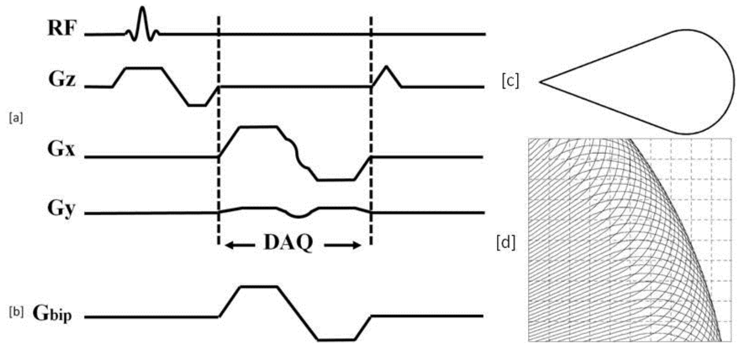
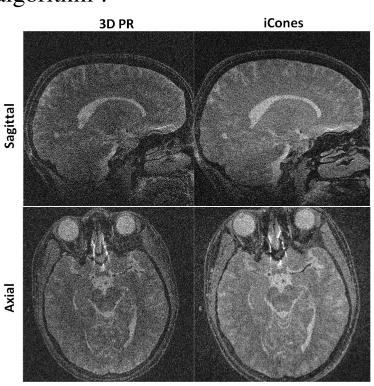


Figure 1: (a) FSPGR implementation of iCones pulses and (b) bipolar gradient for comparison. The iCones gradients generate a sampling trajectory (c) similar to one leaf of a rosette sampling pattern. A 2D depiction (d) of the overlapping trajectory is provided for illustration.

THEORY AND METHODS: In a fashion similar to TwiRL[3]—a variant of 2D PR made for improved high frequency sampling but without TR constraints—we have designed iCones (Fig 1), a dual half-echo trajectory with greater freedom to change k-space direction as it nears the edge of k-space over a wider curvature. In addition, the design can utilize the tight TR or echo spacing constraints often used in SSFP imaging and/or robust fat/water separation methods. In iCones, a single rosette leaf, achieved by a pair of fully balanced gradients (Fig1), is rotated in k-space once for each TR. G_x is similar to a bipolar trapezoid, but with a modified bridge, so that with G_y the trajectory curves along a semi-circle before reaching the periphery of k-space to maintain high velocities while sampling high frequencies. The iCones pulse sequence waveforms are generated numerically using considerations based on the desired resolution, undersampling factor, allowable overlap, peak gradient amplitude and slew-rate limitations. Trajectory and B_0 phase corrections are performed via the Duyn method, with the most prominent effects observed primarily for the more rapidly changing Gx iCone pulse. Images are produced by FFT after gridding, where density compensation is achieved with an iterative algorithm[4].



To simplify reconstruction for proof of concept, a 3D spoiled grass acquisition was acquired with a single channel head coil using the conventional out and back trajectory and iCones trajectory. To emphasize any reduction in aliasing artifact with iCones, each sequence was given only 2:30 to produce isotropic resolution of 0.5 mm in a 4 ms TR, equivalent to a high acceleration factor of 8

RESULTS AND DISCUSSION: Reduced mottling relative to 3D radial is evident through increased nasal tissue-air contrast, improved edge enhancement at the skull, and increased conspicuity of white matter (Fig 2). iCones efficiency grows as the allowable overlap shown in Fig grows, with scan time reductions of up to 33% possible .

CONCLUSION: Proof of concept has been achieved with observed reduction in undersampling. Future work includes accelerating high quality, multicoil bSSFP and IDEAL sequences, and fixing a small system instability.

REFERENCES: [1] Moran CJ *et al*. MRM 2013; doi: 10.1002/mrm.24633 [2] Al saleh H et al. MRM 2013; doi: 10.1002/jmri.24425 [3] Nielsen H *et al*, MRM. 1997 Feb;37(2):285-91 [4]Zwart NR, MRM 2012 Mar;67(3):701-10 [5]Griswold MA et al, MRM 2000 Oct;44(4):602-9

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gure 2: Sagittal and Axial reformats of iCones and 3D Radial quisitions of the brain. Increased sampling of high frequencies by 'ones reduces mottling observed in 3D Radial, improving edge ınspicuity as well as air-tissue contrast in the nasal region.