Orthogonal TrueFISP Acquisitions using Paired Reverse Centric Phase Encoding

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Introduction: Orthogonal acquisition planes are used routinely as anatomical localizers (1). They can also be useful for MRI guided interventions (2) and imaging freely moving subjects (3). It is well known that significant saturation artifacts at intersections of the orthogonal imaging planes can occur (1,3) (saturation banding; not TrueFISP off-resonance banding). To date, most of these localizers have used spoiled steady state methods. Our previous experience in interventional MRI has provided motivation for use of TrueFISP acquisitions for multi-planar guidance. We hypothesize that by delaying the acquisition of the center of k-space by using reverse centric phase encoding that banding artifacts can be significantly reduced in multi-plane TrueFISP acquisitions. Further, we sought to eliminate other TrueFISP artifacts associated with eddy currents by pairing adjacent k-space lines (4).

Methods: TrueFISP (TR = 4.4 ms, 512 pulses) Block equation simulations were performed in Matlab (Mathworks, Natick, MA) for a range of flip angles (10˚-180˚ in steps of 10˚) for 6 tissues typically found in the abdomen. Saturation banding artifact was calculated for linear and reverse centric traversals of k-space for different base resolutions (res):

$$\%banding_{Linear} = \frac{S\left(\frac{res}{2}\right) - S\left(\frac{3\cdot res}{2}\right)}{S\left(\frac{res}{2}\right)} \times 100\% \quad [1]$$

$$\%banding_{ReverseCentric} = \frac{S(res) - S(2\cdot res)}{S(res)} \times 100\% \quad [2]$$

Orthogonal (transverse, coronal and sagittal) TrueFISP acquisitions were performed in a doped water phantom and in the abdomen of an asymptomatic human volunteer using linear, reverse centric and paired reverse centric phase encoding in a 1.5 T Espree magnet (Siemens, Erlangen, Germany). Paired reverse centric TrueFISP was used in conjunction with real-time three plane visualization (5) to guide and monitor the insertion of an RF electrode to the adrenal glands in porcine (0.72 sec/slice).

Results: Saturation banding artifact magnitude is plotted as a function of base resolution for liver tissue in 1. Phantom imaging results are presented in figure 2. Note elimination of orthogonal plane excitation artifact and eddy current artifacts using paired reverse centric phase encoding. Axial human abdominal images are presented in figure 3 for linear and paired reverse centric phase encoding. Three orthogonal images during the course of the MR guided RF electrode insertion are shown in figure 4.

Discussion: The results demonstrate a decrease in banding artifact using reverse centric phase encoding. Pairing of the reverse centric phase encoding lines is essential to avoid eddy current artifacts. The contrast in the reverse centrically ordered images approximates the steady state contrast more closely than the linearly acquired data.

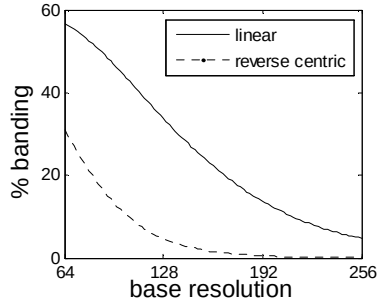

Fig. 1. Orthogonal plane saturation or banding artifact magnitude for interleaved orthogonal TrueFISP plotted for simulated liver tissue (FA = 80˚, T1 = 590 ms, T2 = 56 ms). Note marked reduction in banding by using reverse centric phase encoding across a range of base resolutions.

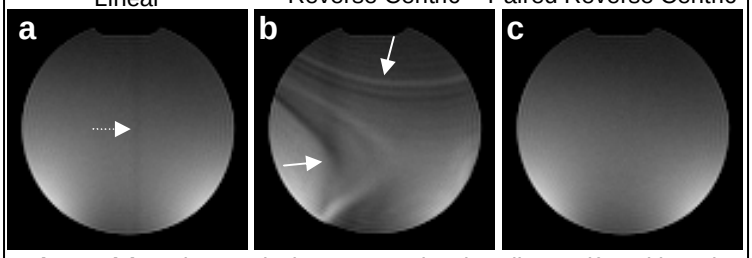

Fig. 2. (a) Orthogonal plane saturation banding artifact (dotted arrow). **(b)** Eddy current artifacts (arrows). **(c)** Artifact free image using paired reverse centric phase encoding.

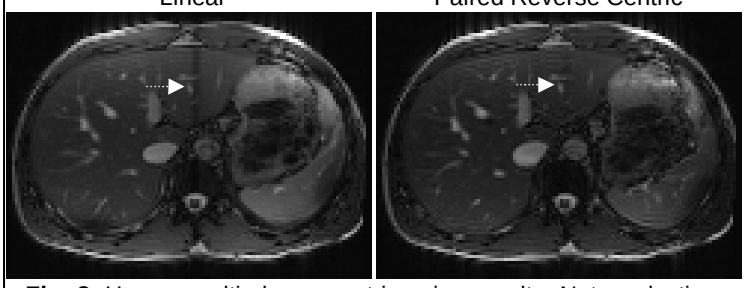

Fig. 3. Human multi-plane scout imaging results. Note reduction in saturation band (arrows) using paired reverse centric PE.

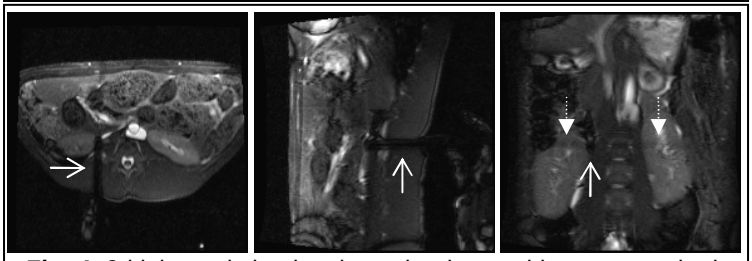

Fig. 4. 3 high resolution interleaved orthogonal images acquired during RF electrode guidance to porcine adrenal gland using paired reverse centric TrueFISP (0.72 sec/slice). Open arrows indicate RF electrode artifact. Dotted arrows indicate small remaining orthogonal plane saturation artifacts.

Conclusion: This work uses a new way of collecting interleaved orthogonal TrueFISP images to minimize saturation banding artifacts. Paired reverse centric TrueFISP allows the collection of fast, high CNR multi-plane images with minimal saturation banding artifacts and is shown to be useful for anatomical localization and dynamic imaging during interventional MRI.

References: [1] Wright S.M. et al., MRI 6:105-112 (1988) **[2]** Silverman S.G. et al., Radiology 197:175-181 (1995) **[3]** Neustadter D.M. et al, MRI 22 :329-343 (2004) **[4]** Bieri O. et al., MRM 54:129-137 (2005) **[5]** Derakhshan J.J. et al., Proc ISMRM. 15:487 (2007)