Non-Contrast Enhanced Renal Artery Angiography with a Respiratory Gated 3D Radial Linear Combination SSFP Sequence

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INTRODUCTION

The recent discovery of the link between Nephrogenic Systemic Fibrosis (NSF) and Gd based contrast agents has brought renewed interest in non-contrast enhanced MR angiography (NCE MRA) methods, especially for use in patients with renal insufficiency. Several variations of the balanced steady state free precession (bSSFP) acquisition have been proposed to provide renal angiograms without the injection of a contrast bolus due to the preferably bright fluid signal [1-4]. However, these sequences are sensitive to banding artifacts and errors from fat signal. To combat these effects, we have developed an ultrashort TR dual-echo 3D radial Linear Combination SSFP (LCSSFP) sequence, which has been utilized for non-contrast enhanced imaging in static vascular territories [5]. Blurring due to respiratory motion has previously inhibited use of this sequence for NCE MRA in the chest and abdomen. Here we report the initial results of this approach used in conjunction with a real-time adaptive expiratory respiratory gating for high resolution renal NCE MRA.

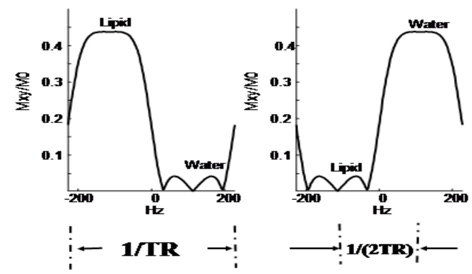

Figure 1. Different linear combinations of SSFP scans generate either broad water (a) or fat (b) stopbands.

METHODS

As depicted in Figure 1, optimal fat/water separation using LCSSFP occurs in a 2.4ms TR at 1.5T, which is not possible in Cartesian imaging without an unacceptable reduction in resolution. To achieve this TR and maintain acceptable resolution, an out and back, fully balanced, dual echo readout was utilized that completely avoids prewinders or rewinders, as shown in Figure 2. Full sampling is achieved by rotating the readout such that the projection endpoints are uniformly distributed on the surface of a sphere [7].

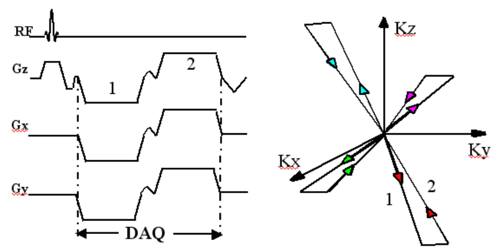

***Figure 2**. Pulse sequence (left) and trajectory (right) of dual echo SSFP with VIPR. The out and back nature results in the absolute minimum TR for a given resolution.*

All imaging was performed on a 1.5T clinical scanner (Excite HD, GE HealthCare, Milwaukee, WI). MR angiograms of the renal arteries were acquired on 3 volunteers without a contrast agent. The real-time adaptive expiratory respiratory gating was used based on a respiratory bellows reading. Projections are continuously acquired and only reacquired if the bellows reading is outside an acceptance window defined by the previous 10s of bellows readings. A robust off-center gradient and receiver calibration sequence was acquired during prescan to correct errors associated with eddy currents and system delays [8]. The two passes required for LCSSFP were acquired back to back using TR=2.7, α=35°, BW=125kHz, Resolution=1.3x1.3x1.3mm, FOV=34x34x20cm. The mean scan time of all volunteers was 6:15 min, with only 3:20 min of data collection.

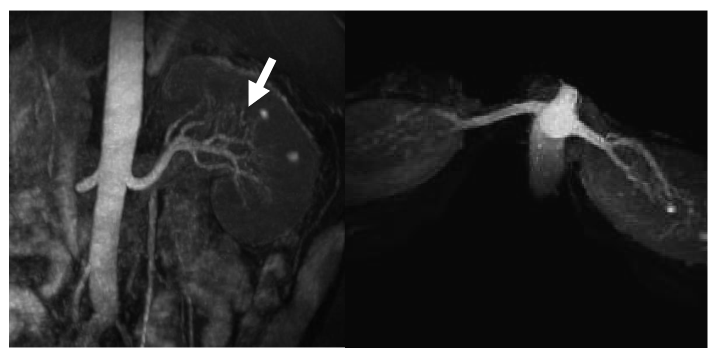

***Figure 3**. MPR (left) and VR (right) images demonstrating left renal artery and multiple smaller branches.*

RESULTS

Multiplanar reformatted (MPR) and volume rendered (VR) images shown in Figure 3 excellently depict the renal arteries, including branch vessels, not typically seen in contrast enhanced exams. Representative axial and coronal reformatted images are given in Figure 4, demonstrating consistent fat/water separation across the image volume and improved vessel conspicuity in the water-only images. Banding artifacts are minimal and only present at the very edges of the large FOV.

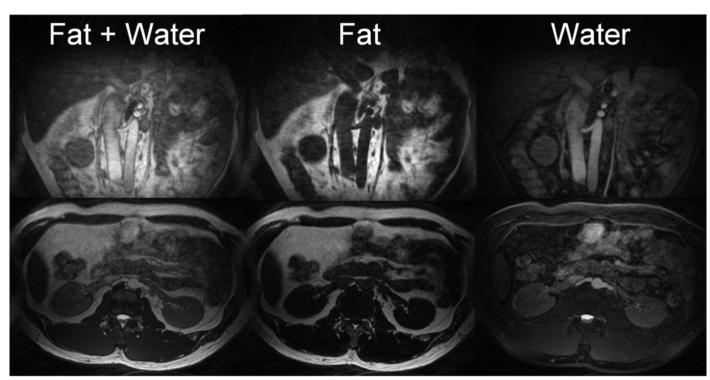

***Figure 4**. Example fat+water, fat-only and water-only signals. Excellent fat/water separation is achieved without banding artifacts, allowing much improved depiction of vessels.*

DISCUSSION AND CONCLUSION

Respiratory-gated LCSSFP with a dual-echo 3D radial trajectory is a promising method for NCE MRA. Excellent depiction of the renal arteries has been demonstrated without the use of contrast agent. Banding artifacts and errors from fat signal present in typical SSFP sequences have been eliminated. Compared to CE MRA, higher resolution and improved respiratory compensation is possible due to the large acquisition window. These promising initial results warrant further investigation in a larger study involving healthy volunteers and patients with various degrees of pathology including renal artery stenosis and kidney transplant patients.

REFERENCES

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