Comparison between Breath-hold and Navigator-gated Magnetization-Prepared 3D Steady-State Free Precession for Nonenhanced Renal Magnetic Resonance Angiography

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INTRODUCTION: Cardiac and navigator-gated, magnetization-prepared nonenhanced MRA techniques can accurately depict the renal arteries without the need for contrast administration (1). However, the scan time and effectiveness of navigator-gated techniques (Nav SSFP) depend on the subject's respiratory patterns, at times resulting in excessive scan time or suboptimal image quality. To address those issues, we implemented a 3D SSFP technique to acquire the entire imaging data in a single breath-hold (BH SSFP). The purpose of the study was to optimize the imaging parameters for BH SSFP, and to evaluate the image quality in comparison with Nav SSFP.

METHODS: The pulse sequence diagram of BH SSFP is illustrated in Figure 1, which consists of a 3D balanced SSFP acquisition sequence, center-to-out partial Fourier k-space trajectory along phase and slab encoding directions, single-shot acquisition along the phase encoding direction, slab-selective axially-oriented inversion pulse for background suppression, and cardiac triggering to ensure inflow during systole and data acquisition during diastole. A parallel saturation band is applied inferior to the imaging plane to suppress venous flow. Chemical-shift selective suppression pulse is applied to eliminate fat signal, followed by an RF catalyzation sequence with linearly increasing flip angles. The inversion time (TI) of BH SSFP is required to be sufficiently long in order to achieve adequate SNR due to the long echo train length within each RR interval. To reduce the dependency on inflow effect, a targeted dual inversion scheme (2) was also tested for magnetization preparation.

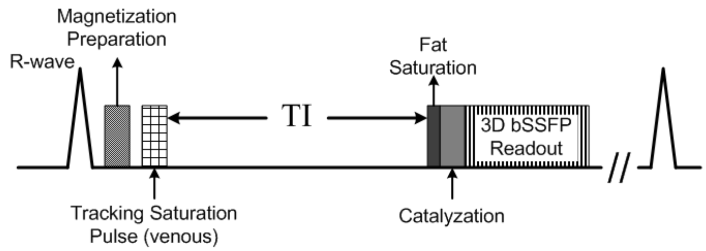

Figure 1. BH SSFP pulse sequence diagram.

A total of fourteen healthy volunteers (ages 20 – 56, 10 male and 4 female) and seven patients (ages 63 – 90, 5 male and 2 female) were recruited for this study with the approval from our IRB. Imaging was performed on a 32-channel 1.5T scanner (Siemens MAGNETOM Avanto, Erlangen, Germany). The imaging parameters included: asymmetrical echo readout; TR / echo time = 3.3 ms / 1.4 ms; field of view = 450 x 248 mm; slab thickness = 48 mm; isotropic resolution = 1.1 x 1.1 x 1.1 mm^3; receiver bandwidth = 781 Hz/pixel; slice resolution = 58%, 5/8 and 6/8 partial Fourier sampling along the phase and slab encoding directions respectively; a reverse center-to-out trajectory along both directions; parallel acceleration = 2. Technical optimization was performed on the following parameters: (a) TI, (b) acquisition excitation flip angle, (c) cardiac synchronization, (d) magnetization preparation. For comparison, Nav SSFP MRA images were acquired using the commercially available navigator-gated NATIVE TrueFISP sequence. SNR and CNR were computed as quantitative analysis. The image quality in volunteers was scored by two experienced radiologists.

RESULTS: Examples of BH and Nav SSFP MRA are illustrated in Figure 2. On average the scan time was 20s for BH SSFP and 177s for Nav SSFP for matching slab coverage. Both techniques provided excellent depiction of the extra- and intra-renal arteries in healthy volunteers and patients. The optimized protocol for BH SSFP included: 90° flip angle, maximum allowable TI, targeted dual inversion preparation, and ECG gating. For extra-renal and intra-renal arteries in volunteers, BH SSFP had SNR of 46.17 ± 5.11 and 32.98 ± 4.18 with CNR of 41.00 ± 5.25 and 22.23 ± 5.45, respectively. For Nav SSFP, the comparable values were SNR of 48.77 ± 5.69 and 33.87 ± 5.97 with CNR of 44.13 ± 5.27 and 24.34 ± 8.81. No statistically significant difference was found between the two techniques in terms of SNR and CNR ($P > 0.05$). Qualitative image scores from radiologist one reported no significant difference between the two techniques ($P > 0.05$), while scores from radiologist two showed preference to Nav SSFP ($P < 0.05$).

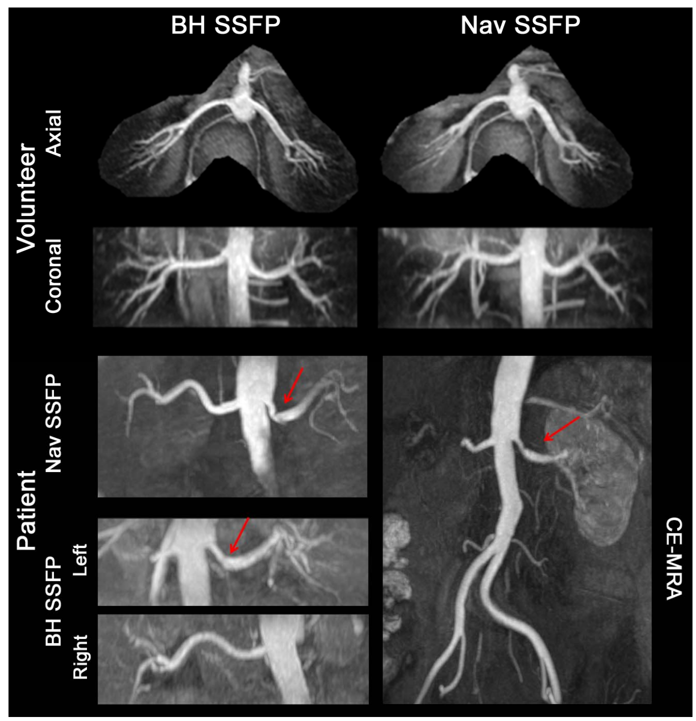

Figure 2. Maximum intensity projection images of BH and Nav SSFP from a healthy volunteer and a patient with moderate left renal stenosis (arrow). The acquisition parameters for BH and Nav SSFP were identical except for an 8 fold reduction in scan time with BH SSFP. For the patient, Nav SSFP was prescribed 96 slabs encodings of 0.9mm thickness with no partial Fourier encoding.

DISCUSSION: The single-shot BH SSFP demonstrated comparable image quality, SNR, and CNR to Nav SSFP technique. However, BH SSFP reduced scan time by a mean eight-fold. These initial results suggest a potential clinical role for BH SSFP in the evaluation of suspected renal artery disease. Given the short scan time, BH SSFP can be repeated in a single session in the event of image artifacts or patient motion. In addition, the targeted dual inversion preparation scheme reduced the dependency on inflow effect. Further study is warranted to determine the clinical accuracy of BH SSFP renal MRA.

REFERENCES: 1. Miyazaki M, et al. Radiology 2008. 2. Schmitt P, et al. ISMRM 2011.