Steady State Free Precession MRA of the Renal Arteries: Breath-hold and Navigator Techniques vs. CE-MRA

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Introduction

While bright blood Steady State Free Precession (SSFP) techniques have revolutionized cardiac MRI, they also are becoming increasingly useful for MR angiography. We test the hypothesis that SSFP is a useful rapid screening technique for renal artery stenosis, determining which patients need to go on to have a standard contrast enhanced MRA. Three SSFP sequences, 2 breath-hold and 1 free-breathing navigator, were evaluated and compared to 3D contrast enhanced MRA. Navigator free-breathing SSFP performed best, appearing to be a reliable indicator of renal vascular disease.

Methods

Seven consecutive patients (males, age 50–81, mean 67) referred for renal MRA to rule out renal artery stenosis were recruited. All imaging was performed on a Philips 1.5T Intera scanner. The renal arteries were first localized with a fast SSFP coronal scout. Following this, each patient underwent three different 3D axial SSFP renal artery protocols - two breath-hold, and one using a navigator echo (navigator placed through liver) (Table 1). All SSFP scans were performed with saturation bands inferiorly and over the kidneys to suppress IVC and renal venous signal (Figure 1). Following this, each patient underwent routine 3D Gd-enhanced renal MRA. Two radiologists, blinded to the technique used, the other exam, and the results of the other reader, scored image quality, artifacts, reader confidence, and degree of stenosis for all main and accessory RA's. Analysis was performed on an offline workstation with window/level, multi-planar reformat of source images, and maximum intensity projections (MIPs) available. Image quality was scored for four vessel segments (1 - origin to 4 mm, 2 - segment 1 to first branch, 3 - segment 2 to kidney parenchyma, 4 - within parenchyma) on a 4-point scale (3-excellent, 2-good, 1-fair, 0-poor). Blurring of the segment1/2 renal artery was scored on a 4-point scale (0-none, 1-mild, 2-moderate, 3-severe). Overall reader confidence in the diagnosis was scored on a 3-point scale (2-sure, 1-moderate, 0-poor). Degree of stenosis was determined by measuring stenotic and normal distal renal artery diameters with electronic calipers having an accuracy of 0.1 mm on an offline workstation. A standard form was used to collect all relevant data. Statistical analysis was performed using the paired Student t-test.

Parameter	SSFP BH	SSFP 3BH	SSFP Nav	3D Gd
Coil	Phased Array	Phased Array	Phased Array	Phased Array
Orientation	Axial	Axial	Axial	Coronal
Technique	3D b turboFFE	3D b turboFFE	3D b turboFFE Nav	3D T1-FFE
Turbo Factor	64	64	64	NA
Fat suppresion	Water Excitation	Water Excitation	Water Excitation	None
TR/TE/α/ NEX	6.4/3.2/80/2	6.4/3.2/80/2	6.4/3.2/80/2	4.1/1.3/40/1
FOV	300 x 105	300 x 105	300 x 105	380 x 380
# Slices (true)	12	25	24	25
Matrix	240 x 240	240 x 240	240 x 240	368 x 210
SENSE Factor	NA	NA	NA	2.5 L/R
Scan Time	19 sec BH	56 sec (3 BH)	1:38	9 sec x 3 phases BH
Navigator window	NA	NA	5 mm	NA
Measured voxel	1.25 x 1.25 x 3	1.25 x 1.25 x 2	1.25 x 1.25 x 2	1.03 x 1.8 x 2.0
Recon Voxel	0.59 x 0.58 x 1.5	0.59 x 0.58 x 1.0	0.59 x 0.58 x 1.0	0.74 x 0.74 x 1.0

Table 1

Findings

Renal artery image quality in segments 1-3 was rated significantly better for navigator SSFP (Nav SSFP) as compared to the breath-hold (BH SSFP) (scores 1.56 vs. 2.07, 1.30 vs. 1.75, 0.3 vs. 0.68 respectively, all p values <0.01). In addition, renal artery blurring and reader confidence with Nav SSFP was significantly improved (1.92 vs. 1.32, p < 0.001 and 0.83 vs 1.6, p<0.0001). The 3D contrast enhanced studies (3D Gd) were uniformly rated significantly better than Nav SSFP for all renal artery segments as well as renal artery blurring (all p<0.01), and there was near significant improvement for reader confidence (p=0.052). Example images are seen in Figure 2. Considering the 3D contrast enhanced study to be "truth", there were 15 main renal arteries (1 patient had 2), and 4 accessory renal arteries. Five renal arteries were stenotic (>50%, average 75%), including one which was completely occluded. Using a threshold of 40% stenosis as positive, Nav SSFP accurately detected all five stenotic renal arteries (false negative rate 0%). Average disagreement between 3D Gd and Nav SSFP for these arteries was 6%. Average disagreement for non-stenotic arteries was 7%. Nav SSFP failed to visualize 1 of 4 accessory renal arteries, even in retrospect (Figure 2).

Discussion

Although contrast-enhanced renal MRA is rapidly becoming a preferred method of screening for renal artery stenosis (RAS), in most patient populations, the prevalence of stenosis is relatively small. To perform a contrast injection requires placing an IV, takes time, and is of considerable cost. Thus a rapid, low cost MRA may be useful in increasing utilization and accessibility of MR for renal vascular screening. We approached this project from the standpoint of determining how well SSFP would perform not to diagnose RAS, but to exclude it. This required first determining the best SSFP technique. Previous experience suggested an axial 3D approach with selective water excitation and suppression of renal veins and the IVC with saturation bands was a good starting point (Figure 1). This work further showed the navigator technique to be the best in terms of image quality, vessel sharpness, and reader confidence. Examining our small population (5 significant stenoses), if we set a threshold of 40% stenosis with Nav SSFP and consider 3D Gd stenosis >50% positive, we detect all 5 stenoses. Furthermore, we only have 1/7 false positives (14%) (Nav SSFP 55%, 3D Gd 44%). In our population, had we chosen to not proceed with contrast for all patients in whom Nav SSFP showed < 40% stenosis, we would have withheld contrast in 4/7 or 57% of patients.

In terms of limitations, one small-moderate sized accessory renal artery was missed on all SSFP sequences despite good image quality - it was seen to have a 50% ostial stenosis with 3D Gd (Figure 2). This non-visualization is felt to be due to the significant inflow enhancement properties of SSFP, and we have noticed small vessels with slow flow tend to not be visualized. For a small accessory RA this is likely to be of little clinical significance, as small accessory RA's are not typically amenable to intervention. Accessories that lie outside of the imaging volume (Figure 1) will be missed as well. Another point worth noting is that navigator sequences are lengthy, depending on navigator efficiency. We experienced efficiencies of 20-40%, meaning the nominal 98 sec Nav SSFP exam requires from 4:05 - 8:10 to perform. On the other hand, no breath-holding is required. Whether Nav SSFP can diagnose fibromuscular dysplasia, another important cause for renovascular hypertension in screening population patients, remains to be seen. Clearly this study is much too small to conclude Nav SSFP is appropriate for renal artery screening, but further investigation is warranted and underway.

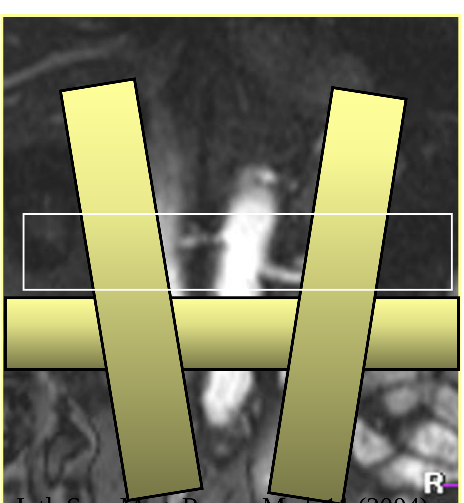

Figure 1 (left). Coronal scout SSFP showing setup for acquiring axial 3D SSFP dataset (white rectangle), as well as inferior and renal saturation bands.

Figure 2 (right). BH SSFP (a), 3BH SSFP (b), Nav SSFP (c), and 3D Gd (d) axial subvolume MIP's of a representative patient. Note the accessory right renal artery (arrow in (d)) that was missed on all SSFP sequences.