Navigator Steady State Free Precession for Renal Artery Screening - Has the Time Come?

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Introduction

This work examines Steady State Free Precession (SSFP), an emerging non-contrast technique of renal artery MRA, focusing primarily on whether it can be effectively applied to rapidly screen for renal artery stenosis (RAS) without the need for the additional expense, time, and potential discomfort of injecting contrast media. Prior work indicated a navigator SSFP sequence performed better than breath-hold variants [1]. Our hypothesis is that optimized SSFP techniques are of sufficient reliability and quality that they can screen out the approximate 80% of normal renal arteries making up a "rule out RAS" referral base, obviating the need to administer contrast and perform further imaging. As such, SSFP may make an excellent rapid screening tool for RAS.

Methods

Forty consecutive patients at a Veteran's Affairs Medical Center referred for clinical renal MRA to rule out RAS were recruited. All imaging was performed on a Philips 1.5T Intera scanner with Master gradients (30 mT/m amplitude, 150 mT/m/ms slewrate) running release 8. The renal arteries were first localized with a fast SSFP coronal scout. Following this, each patient underwent a free-breathing navigator echo 3D axial SSFP (Nav SSFP) scan with the navigator placed through the liver). Saturation bands were placed inferiorly and over the kidneys to suppress IVC and renal venous signal. Imaging specifics: 3D balanced turboFFE, turbo factor 64, selective water excitation, TR 6.4, TE 3.2, flip 80^0, 4 averages, FOV 300x105 mm, 24 x 2mm slices (zero filled to 1 mm), 5mm navigator tracking, nominal acquisition time 98 sec (Figure 1). Following this, each patient underwent routine 3D contrast-enhanced renal MRA (CE-MRA) using 20 cc standard gadolinium chelate (TR 4.1, TE 1.4, flip 40^0, SENSE factor 2.5 in phase, FOV 380x380 mm, 25 slices 2mm thick zero filled to 1 mm, acquisition time 9 sec, contrast injection rate 2.5 cc/sec). Two radiologists, blinded to the technique used, the other exam, and the results of the other reader, scored degree of stenosis for all main and accessory RA's. Degree of stenosis was determined by measuring stenotic and normal distal renal artery diameters with electronic calipers having an accuracy of $\pm$0.1 mm. A standard form was used to collect all relevant data. Kappa statistics were used to evaluate inter-observer variability. Statistical analysis of stenosis data was performed by stratifying each renal artery into positive or negative for stenosis using a 50% threshold for CE-MRA and a 40% threshold for SSFP.

Findings

The CE-MRA was completed in all patients, and the Nav SSFP sequence was successful in 38 of the 40 patients. In one patient, the Nav SSFP was not attempted secondary to severe patient anxiety and need to minimize scan time. In a second patient, Nav SSFP failed due to technical difficulty obtaining an adequate navigator. In the two cases where Nav SSFP could not be completed, a breath-hold SSFP (BH SSFP -18 sec) was substituted. Navigator efficiency ranged from approximately 20-50%, meaning total Nav SSFP acquisition time ranged from approximately 3 to 8 minutes.

Based on CE-MRA, three of the forty patients had co-dominant main renal arteries, providing a total of 83 main renal arteries for analysis. All main renal arteries were detected by SSFP. A total of twenty accessory renal arteries were detected by CE-MRA, and nineteen of these (95%) were detected with SSFP. For the purpose of analysis, we considered a renal artery stenosis of greater than 50% by CE-MRA to be positive. Using these criteria, fifteen of the forty (38%) patient studies were positive, with 21 of 83 (25%) main renal arteries being stenotic. A ROC curve was constructed which demonstrated 100% sensitivity when choosing a Nav SSFP stenosis threshold of 40%. Using this cut-off point, sensitivity/specificity was 100%/80% and 100%/81% measured per patient and per renal artery respectively. Confidence intervals were 75–99% and 59-92% per patient and 81–97% and 68-89% per renal artery respectively. Positive and negative predictive values were 75% and 100% on a per patient basis, and 64% and 100% on a per renal artery basis. The average absolute value of the difference in measured stenosis between CE-MRA and Nav SSFP was 10 $\pm$ 10%. Examining only the false positive renal arteries by Nav SSFP (n=11), this difference was 14 $\pm$ 7%. Stratifying stenosis into positive or negative (>50% for CE-MRA and > 40% for Nav SSFP), interobserver agreement for CE-MRA and Nav SSFP were both very good, with simple Kappa values of 0.77 (confidence intervals 0.91 – 0.93) and 0.70 (confidence intervals 0.54 – 0.86) respectively.

Discussion

Successful application of SSFP to the renal arteries is relatively new, with multiple recent publications demonstrating the tremendous potential of this technique [2-3]. While certainly inferior to the "gold standard" of CE-MRA [1], the navigator SSFP renal MRA protocol performed extremely well in the context of a screening test, detecting all significant main renal artery stenoses (i.e. sensitivity 100%) and having a negative predictive value of 100%. The above authors [2-3] similarly found a 100% sensitivity/100% negative predictive value for SSFP renal MRA. Thus our work, augmented by these comparable studies, strongly suggests SSFP can be used to reliably determine the absence of significant RAS. We envision using SSFP as a rapid screening technique for RAS, thereby clearing the majority of screening patients who do not have disease while accurately identifying the minority with probable stenoses. The latter can then immediately proceed with further MR imaging, including gadolinium administration for CE-MRA. This approach has the potential to considerably cut costs, eliminating contrast injection and shortening examination time in the majority of RAS screening cases.

As an example, given a typical screening population prevalence of RAS of 20% (more realistic than the 38% prevalence in this study), 80% of patients have non-stenotic renal arteries. Assuming the specificity of 80% is maintained, this translates to approximately 16% being incorrectly called positive, and therefore contrast administration and further imaging would only proceed in the true positive 20% plus the false positive 16%, or a total 36% of the screening population. This translates to a 64% savings in contrast cost and a corresponding decrease in required scanner time.

Following the lead of some institutions that now offer low cost "limited" cardiac MR screening, we suggest the time is approaching to adopt a limited lower cost renal artery "screening" SSFP exam, perhaps charging additional fees for those cases where contrast and further pulse sequences are necessary. This approach has the potential to make MR imaging more accessible and economically feasible as a widely accepted screening study. As implemented by our group, the Nav SSFP study requires only a rapid 30 sec scout scan, a 30 sec coronal SSFP renal artery localization scan, and then the 3–8 minutes for the Nav SSFP. Adding a BH SSFP adds a mere ~20 sec, and provides some redundancy in cases where the Nav SSFP fails (as it did for one of our forty patients). Total on magnet time is only 10 – 15 minutes. Furthermore, by using Nav SSFP, the patient need not breath-hold, increasing compliance and effectiveness in respiratory compromised or sedated patients.

In terms of study limitations, one accessory renal artery was missed with SSFP, and seen to have a 50% ostial stenosis by CE-MRA. Also, accessories lying outside of the imaging volume will be missed (although this did not occur in this study). In general, however, interventions are not performed on small accessory renal arteries, and therefore missing an occasional accessory renal artery with the Nav SSFP screening examination is of doubtful clinical consequence. Another potential drawback to the screening concept is that a qualified observer must examine the SSFP data in real time to determine whether a stenosis is present and whether further imaging/contrast administration should be performed. While this would ideally be performed by a radiologist, a well-trained MR technologist can likely make the call, especially considering the very good Nav SSFP interobserver agreement (kappa value 0.7) which suggests interpretation of the Nav SSFP data is not overly difficult. Finally, no patients with fibromuscular dysplasia (FMD) were included in this or other studies, and it remains unknown how well Nav SSFP will perform diagnosing FMD. But FMD is frequently missed on CE-MRA, likely at least in part due to motion-related blurring, and a navigated MRA sequence may actually be less blurry than breath-hold CE-MRA. Further testing of Nav SSFP on FMD patients is required before determining the utility of SSFP in cases where FMD is suspected.

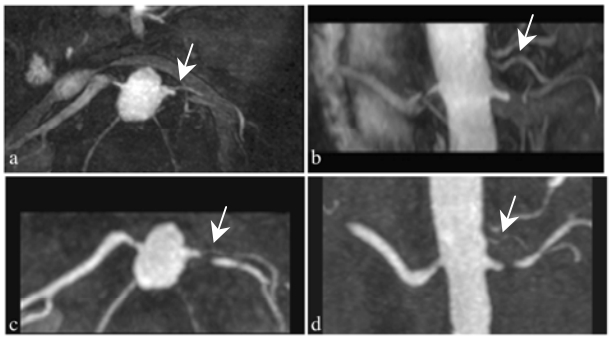

Figure 1. Axial and coronal subvolume MIP's from Nav SSFP (a,b) and CE-MRA (b,d) demonstrating agreement on a high grade left renal artery stenosis. The right renal artery is a false positive, graded 55% by Nav SSFP and 44% by CE-MRA. Note how well even a tiny left accessory artery is seen with Nav SSFP (arrows).

Bibliography

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