Non-Contrast-Enhanced MRA of the Renal Arteries using Inflow-Enhanced, Inversion-Recovery bSSFP: Validation against DSA in a Porcine Model of Renal Artery Stenosis

T. A. Bley[1], C. J. Francois[1], M. L. Schiebler[1], O. Wieben[2], N. Takei[3], W. Sun[4], M. Miyoshi[3], J. H. Brittain[4], R. F. Busse[4], T. M. Grist[1], and S. B. Reeder[1]

[1]Radiology, University of Wisconsin - Madison, Madison, WI, United States, [2]Radiology and Medical Physics, University of Wisconsin - Madison, Madison, WI, United States, [3]MR Applied Sciences Laboratory, GE Healthcare, Tokyo, Japan, [4]MR Applied Sciences Laboratory, GE Healthcare, Waukesha, WI, United States

Introduction

Arterial hypertension is a widespread disease. Exclusion and evaluation of possible renal artery stenoses (RAS) is a fundamental step of the diagnostic workup in patients with recalcitrant hypertension. Because of recent concerns over the association between gadolinium-based contrast material and nephrogenic systemic fibrosis (NSF), there has been a renewed interest in non-contrast-enhanced MR angiography (NCE-MRA) techniques (1, 2). The purpose of this study was to evaluate the ability of the Inhance Inflow IR pulse sequence to detect and quantify renal artery stenoses in a porcine study.

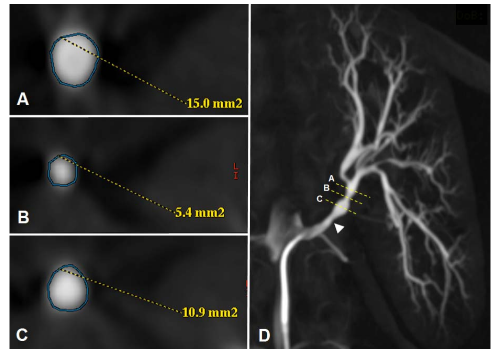

Fig. 1 – Planimetry of orthogonal sections of the renal artery was performed proximal (A), within the stenosis (B), and distal to the stenosis (C) and revealed a significant stenosis with 58% luminal narrowing. Please note vasospasm proximal to the stenosis (arrowhead in D).

Methods

Following Animal Care and Use Committee protocol approval, bilateral RAS were surgically created in 12 swine. All studies were performed under general anesthesia. 3D rotational digital subtraction angiography (DSA) was used as the gold standard for quantification of the degree of stenosis in 8 animals (Figure 1). Projectional DSA was used in the other 4 animals. NCE-MRA and CE-MRA of the renal arteries were performed on a 1.5 T Scanner (Signa HDx, GE Healthcare, Waukesha, WI, USA). The investigational version of the Inhance Inflow IR pulse sequence acquires data using a 3D balanced SSFP (bSSFP) acquisition (TR/TE/TI = 4.2/2.1/1400 msec, BW = ± 125kHz, FOV=36cm^2, 54 slices, matrix = 512 x 512 with 2.0mm slices for true spatial resolution of 1.4 x 1.4 x 2.0mm^3, interpolated to 0.7 x 0.7 x 1.0mm^3, scan time = 4-5 min), and uses a selective inversion pulse over the region of interest to invert arterial, venous, and static tissue signal. Subsequently, during the null point of venous blood, another pulse is applied to generate arterial signal. Periodic spectrally selective partial inversion pulses were used for fat-saturation, while respiratory gating compensates for respiratory motion. The net result is an angiographic image with robust background suppression and suppressed venous signal (3, 4). For comparison, CE-MRA was performed using a 3D-SPGR sequence with 2D-parallel imaging acceleration (ARC) during the intravenous administration of 0.1mmol/kg of gadobenate dimeglumine (Multihance, Bracco Diagnostics, Inc., Princeton, NJ). Fluoro-triggering was used to time image acquisition to the arterial phase. Three expert cardiovascular radiologists evaluated the degree of stenosis and the image quality independently. The severity of RAS was confirmed by planimetry using DSA data (Fig. 1).

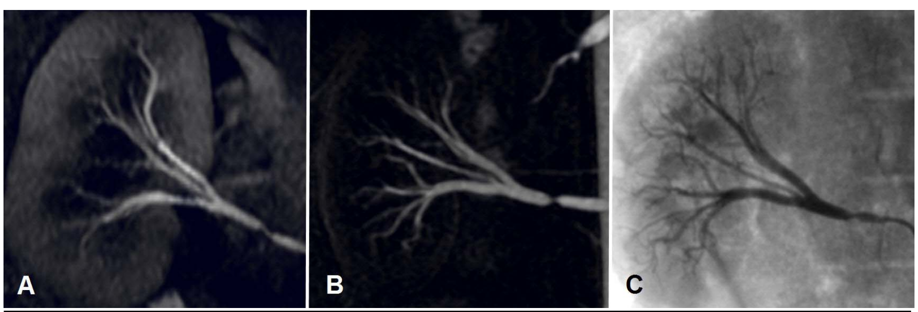

Fig. 2 – NCE-MRA (A) and CE-MRA (B) confirm the location and severity of the right renal artery stenosis (C). 70% luminal narrowing was determined by planimetry using DSA.

Results

NCE-MRA and CE-MRA images were successfully obtained in all cases (Fig. 2). Pearson correlation coefficients for the severity of stenosis in NCE-MRA vs DSA were 0.72, 0.51, and 0.76 for the three readers. The Pearson correlation coefficients for the severity of stenosis in CE-MRA vs DSA were 0.69, 0.73, and 0.84, respectively. There was a tendency to overestimate the degree of stenosis with NCE-MRA as compared to DSA (mean bias 0.11, ranging from 0.04 to 0.25). 3rd and (only) 2nd degree renal branch vessel were depicted in 87.5% and 4.2% on the NCE-MRA and in 35.4% and 48.8% on the CE-MRA. Image quality was rated excellent in both sequences, however substantial noise was found in 14% of the CE-MRA and in only 2% of the NCE-MRA studies. In no cases did noise interfere with image interpretation.

Discussion

This study demonstrates the feasibility of performing NCE-MRA using the Inhance Inflow IR pulse sequence to evaluate the severity of renal artery stenosis in an animal model. Good correlation between the severity of RAS was found between NCE-MRA (and CE-MRA) and DSA. Excellent visualization of branch vessels makes the NCE-MRA also attractive for assessment of diseases like renal arteriovenous malformations, fibromuscular dysplasia and polyarteritis nodosa, where second and third degree branch vessels may be involved. Navigator 3D SSFP based sequences are known to produce high quality 3D bright blood images with significantly increased SNR (5). However, mild overestimation of the degree of renal artery stenosis occurs (6). In our experiments, the degree of bias was very low for all readers. The NCE-MRA technique described in this study produced consistent results, with no failures, that are comparable to CE-MRA and DSA. Based on the excellent image quality and robustness of this technique in our animal study, we have implemented this sequence into clinical investigational protocols.

References

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