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Accuracy of unenhanced magnetic resonance angiography for the assessment of renal artery stenosis

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ABSTRACT

Purpose: To evaluate the accuracy of unenhanced magnetic resonance angiography (U-MRA) using balanced steady-state free precession (SSFP) sequences with inversion recovery (IR) pulses for the evaluation of renal artery stenosis.

Materials and methods: U-MRA was performed in 24 patients with suspected main renal artery stenosis. Two radiologists evaluated the quality of the imaging studies and the ability of U-MRA to identify hemodynamically significant main renal artery stenosis (RAS) defined as a stenosis ≥50% when compared to gold standard tests: contrast-enhanced magnetic resonance angiography (CE-MRA) (18 patients) or digital subtraction arteriography (DSA) (6 patients).

Results: A total of 44 main renal arteries were evaluated. Of them, 32 renal arteries could be assessed with U-MRA. When CE-MRA or DSA was used as the reference standard, nine renal arteries had hemodynamically significant RAS. U-MRA correctly identified eight out of nine arteries as having ≥50% RAS, and correctly identified 22 out of 23 arteries as not having significant RAS, with a sensitivity of 88.8%, a specificity of 95.65%, positive and negative predictive value of 88.8% and 95.65%, respectively, and an accuracy of 93.75%. Renal artery fibromuscular dysplasia (FMD) was observed in the two misclassified arteries.

Conclusion: U-MRA is a reliable diagnostic method to depict normal and stenotic main renal arteries. U-MRA can be used as an alternative to contrast-enhanced magnetic resonance angiography or computer tomography angiography in patients with renal insufficiency unless FMD is suspected.

1. Introduction

Renal artery stenosis (RAS) is a well-known cause of hypertension (HTA) and is associated with progressive, decreased kidney function and renal failure. RAS has a prevalence of about 6.8% in the elderly population [1]. It is well established that the prevalence of RAS is higher in elderly patients, particularly in those with comorbid conditions such as diabetes, coronary artery disease (CAD), aortoiliac occlusive disease, or HTA [2]. Although controversial, there is general consensus that interventions to prevent the loss of renal function should be performed before there is a clinically evident decline of the renal function [3,4].

The successful implementation of this strategy requires an efficient and accurate method of screening for RAS in patients at risk. Noninvasive tools such as Doppler ultrasound, computed tomography angiography (CTA) or contrast enhanced magnetic resonance angiography (CE-MRA) have been widely applied in clinical practice for several years for the evaluation of the renal arteries and veins [5–8]. The main limitation of CTA is radiation exposure and the necessity of administration iodinated contrast media in patients with decreased renal function or previous severe allergic reaction [9,10]. In addition to the general limitations of MRI, there is a potential risk of nephrogenic systemic fibrosis (NSF) that has been associated with some gadolinium-based contrast media in patients with markedly reduced glomerular filtration [11,12]. Invasive imaging with digital subtraction angiography (DSA) is the traditional gold standard for imaging renal artery anatomy but this technique is reserved when the results of noninvasive imaging tests are inconclusive or when a renal artery revascularization is indicated [4].

Recently, unenhanced magnetic resonance angiography (U-MRA) has been re-explored as an alternative to CE-MRA for the assessment of renal artery stenosis [13–15]. Few studies have

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evaluated the usefulness of balanced steady-state free precession (SSFP) combined with arterial spin labeling (ASL) for the depiction of renal vasculature [16–22]. This technique seems a good alternative to be used in cases where contrast administration is not safe.

The main goal of this study is to determine the imaging quality and accuracy of U-MRA using balanced SSFP acquisition with inversion recovery (IR) pulses (Inhance 3D inflow IR [*GE* ®]) and compare them with a gold standard tests (CE-MRA or DSA) for the evaluation of renal artery stenosis.

2. Material and methods

2.1. Patients

From February 2012 to December 2014, all of the patients who were referred for a CE-MRA of renal arteries were included in this study. A U-MRA sequence in addition to the conventional CE-MRA images was added. The Hospital Ethics Committee approved the study and informed consent was obtained from all participants. A total of 24 patients, 14 men and 10 women, were included (mean age 56 ± 18 years). The 24 patients were referred to MRA due to Doppler Ultrasound findings: 22 of them (12 patients had uncontrolled HTA, 6 patients had deterioration of the renal function) because of suspected stenosis of the main renal artery, one patient for follow up of a renal artery aneurysm not properly visible by ultrasound, and one patient for suspected RAS of a kidney graft. Participants formed a random series.

2.2. Imaging protocols

2.2.1. U-MRA parameters

All examinations were performed with a 1.5T General Electric Hdxt MR system. An 8 channel phased array body coil was used for signal reception and respiratory-triggered 3D SSFP with fat saturation pulses was also used. MRI studies were performed feet first with the patient's arms above the head. Respiratory gating technique was used to mitigate the effects of respiratory motion. SSFP U-MRA imaging was performed in the transverse plane with to cover approximately 12 cm to visualize both kidneys and anticipating that the kidneys will move up 1–2 cm during free breathing. Inversion pulses are used for background suppression by saturation of arterial and venous blood and fat. After inversion, fast imaging with steady-state data acquisition occurs. This allows the background and venous blood to reach a null point, while the fresh inflowing arterial blood that is not affected by the inversion pulse has full magnetization. The arteries generate a significantly bright signal due to the in-flow effects of the fresh blood. The technique called SPECIAL (Spectral Inversion At Lipid) was implemented to achieve good fat saturation. Parallel imaging (array spatial sensitivity encoding technique, ASSET) was used in the in-plane phase-encode direction. The scanning parameters were TR = 4.6; TE = 2.3; flip angle = 90°; TI = 1200 ms; matrix = 256 × 256; FOV = 36 × 40 cm; slice thickness = 2 mm; slice number = 50, readout bandwidth = 125.00 kHz, Nex1; and the average scan time = 1 min and 50 s.

2.2.2. CE-MRA parameters

The CE-MRA sequence was a 3D fast-spoiled gradient echo (FSPGR). The imaging sequence was performed in the coronal plane with an anatomical range that covered both kidneys and the aorta. Automatic triggering (Smart prep) was used to start the MR data acquisition when the contrast agent reached an optimal concentration in the renal arteries. This was detected by positioning a tracker in the aorta, just superior to the renal arteries. The maximum monitoring period was 40 s. Breathing suspension was required for the duration of MR data acquisition. Parallel imaging (ASSET) was used in the in-plane phase-encode direction with an acceleration factor of 2. The MR imaging parameters were as follows: TE = 1.5 ms; TR = 4.4 ms; flip angle = 30°; receiver band width 41 Hz/pixel; FOV = 36 × 40.0; slice thickness = 2.8 mm; locations per slab = 38; frequency matrix = 320; phase matrix = 224; the phase FOV is reduced dependent on the patient's size, being a 0.8 phase FOV generally adequate. Acquisition time = 16–20 s breath-hold. Gadobutrol (GADOVIST 1.0, BAYER, Berkshire, UK) (0,1 mL/kg) was injected at a rate of 2 mL/s followed by 20 mL of saline while the smart preparation function monitored the change of signal that indicates the arrival of contrast agent.

U-MRA and CE-MRA were post-processed in a Volume Share 2 Advantage Workstation 4.4 (General Electric) using the Volume Viewer 3.1 application. Axial and coronal MIP reformations were performed in all cases.

2.2.3. Digital subtraction angiography protocol

DSA was performed with a monoplane C-arm angiography system (AXIOM Artis Forchheim, Germany). An interventional radiologist performed the study through the right femoral arterial route in all the patients. The standard protocol included an abdominal aortography using a 5F pigtail catheter and the injection of 30 mL of iodinated contrast medium at a flow rate of 15 mL/s. A selective angiography of the renal artery with suspected significant stenosis was performed with a 5F Simmons 1 or Cobra catheter or a 4F Hook catheter ands injecting 12 mL of iodinated contrast medium at a flow rate of 4 mL/s in the anteroposterior and oblique planes.

2.3. Image analysis

Two radiologists with 9 and 11 years of experience in abdominal MRI (BP and RS) independently evaluated the ability of U-MRA to visualize the renal arteries and to demonstrate main renal artery disease. Each radiologist independently reviewed source images and MIP reconstructions of the U-MRA studies. We chose to use non-automated methods for reader quantification. Reference standard tests were not available for the readers.

CE-MRA was used as a gold standard in 18 patients and DSA in 6 patients. Since the study was done in a clinical setting, DSA was chosen as the reference standard when available. DSA was performed in 6 patients with inconclusive noninvasive imaging tests (2 patients) or when a renal revascularization due to significant stenosis was indicated (4 patients). One radiologist with 15 years of experience in abdominal MR imaging evaluated the CE-MRA, and one radiologist with 16 years of experience in angioradiology evaluated the DSA. Index tests were available to the readers of the reference standard tests.

A hemodynamically significant RAS was defined as a moderate (50% to 69%) stenosis with ≥10 mmHg mean or ≥20 mmHg systolic translesional gradient, or a severe stenosis with a visually estimated diameter stenosis of 70% [4].

With the objective to evaluate the ability of U-MRA to identify hemodynamically significant stenosis the cut-offs for the index tests and the reference standard tests were graded as follows:

- No main renal artery stenosis (0)
- Main renal artery stenosis <50% (1).
- Main renal artery stenosis ≥50% (2).

In case of discrepancies between readers of the U-MRA studies, decisions were made by consensus.

The quality of the U-MRA images to visualize the renal arteries was assessed using the following subjective categories: