Visualisation of renal arteries using Time-SLIP and contrast-enhanced MR angiography technique

Sabina Prevljak, Sandra Vegar-Zubović, Melika Bukvić, Adi Behmen, Fuad Julardžija, Jasenko Šito, Merim Jusufbegović, Adnan Šehić

Abstract— The purpose of this study was to compare unenhanced MR angiography with contrast-enhanced MR angiography and visualisation of renal arteries with its segment branches using both techniques. We performed renal MRA on 22 patients using a 1.5T MRI unit. For renal MRA, a three dimensional balanced type steady-state free precession (SSFP) sequence (Time-SLIP, Canon) was used with respiratory gating and conventional CE-MRA sequnce. For analysis, two radiologists independently evaluated the visual quality of the axial images and axial maximum intensity projection images (MIP) of Time SLIP and CE MRA. Visualisation of aorta and main stem of the renal arteries were satisfactory on both techniques, and there was no statistically significant difference. The score of segmental renal artery appeared superior with Time-SLIP and showed a statistically significant difference (P<0.05). Visualisation of segmental renal arteries, interlobar renal arteries and kidneys parenchyma was significantly superiorwith Time-SLIP technique. We compared visualisation of renal arteries and its branches using unenhanced MRA, Time-SLIP, in comparison with contrast-enhanced MRA. Although it is slightly time-consuming and its clinical utility is necessary to further investigate, unenhanced MRA provides superior visualization of peripheral branches even in this study. Further improvement of the technique would make it even more sensitive in detecting small vessel abnormalities and it is promising for clinical use.

Index Terms— magnetic resonance angiography (MRA), renal artery, unenhanced technique, magnetic resonance imaging (MRI), Time-SLIP.

1 Introduction

Unenhanced MR angiography (MRA) recently provides an option for safer, effective and promising technique in vascular imaging. Previously there have been several reports on the visualization of the renal artery [1–6]. Contrast-enhanced MR angiography (MRA) is a useful technique that offers excellent results in analyzing renal arteries, but it has been limited by low spatial resolution in its ability to depict arterial segmental branches and showing motion-related blurring in the distal renal arteries [7–10]. Studies have shown association between gadolinium contrast agents and nephrogenic systemic fibrosis (NSF) so unenhanced MR angiography has gained enermous interest as an alternative to contrast-enhanced MRA [11]. Especially in renal MRA because of the development of NSF in patients with deficient kidney function, a reliable and practical non-contrast MRA technique is preferred. In this study, we used an unenhanced MRA technique, time spatial labeling (Time-SLIP), to delineate renal arteries. The aim of this study was to confirm the effectiveness of the unenhanced MRA Time-SLIP sequence in comparison with contrast-enhanced MRA in its ability to present the renal arteries and also to determine whether Time-SLIP can be used as an alternative for contrast-enhanced MRA for screening for renal artery diseases in patients with hypertension. Unenhanced MRA sequences has been used regularly to image the cerebral vasculature and carotid arteries for long time, such as time of flight and phase contrast sequences, but it has been used less often for imaging of the renal blood vessels [12–14]. Recently, screening for renal artery disease with unenhanced MRA has become more and more popular because of safety issues, especially for patients with renal functional impairment. Time-SLIP is a stedy-state free precesion sequence (SSFP) on Canon MR scanner (Canon Medical Systems, Otawara, Tochigi, Japan) that produces high-resolution non-contrast MRA with a respiration triggered free-breathing three-dimensional (3D) consistent steady-state free recession (SSFP) sequence, which hase become increasingly important in clinical evaluations of the renal artery [15-19]. The visibility of the artery relies on flow dynamics.

- *Sabina Prevljak, MD, PhD, Docent, Clinical Center University of Sarajevo E-mail: sabinarad@yahoo.com*

2 Materials and Methods

This study was approved by our institutional review board and written informed consent was obtained from all patients. Table 1 shows demographic data and characteristics. Total of 22 patients (5 men and 17 women; age range, 26-84; mean age 58,7 years; body weight range, 52-79; mean, 78,7). The subjects included in this study did not submit any clinical history of renal disease or dysfunction. All patients, from April 2019 to May 2019, who were referred for a CE-MRA of renal arteries were included in this study using a 1.5T MRI unit (Vantage Titan 1.5T, Canon Medical Systems, Otawara, Tochigi, Japan) in Clinical Center University of Sarajevo. An 16 elements Atlas

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SPEEDER body coil was used with spine coil. Additional squence, stedy-state free precession (SSFP) sequence (Time-SLIP, Toshiba), was added to the conventional CE-MRA images. For respiratory gating we used MSIP – CRM – PMO - WirelessSpO2 (Assembled for Invivo, a division of Philips Medical System, Orlando, USA) .

TABLE 1
Demographic and Characteristics of Study Population

Characteristics	Value
Sex, no. (%) of patients	
Male	5 (22.7)
Female	17 (77.3)
Age (y)	
Mean ± SD	58,7 ± 13,6
Range	26-84
Height (cm)	
Mean ± SD	170,6 ± 7,4
Range	160-188
Weight (kg)	
Mean ± SD	78,7 ± 11.9
Range	52-79

For all MRA studies, a single three-dimensional slab was placed in a coronal plane. We obtained selective arterial images by subtracting black-blood tagged images from bright-blood non-tagged images. The bright-blood images are the same as those of the commonly used non-contrast MRA technique, depicting the arterial flow entering the imaging slab as high signal. After the 180-degree pulse, the background static tissue recovers and its longitudinal magnetization decreases toward the null point. To suppress the fat tissue signal, an additional frequency selective fat saturation pulse was applied just before data acquisition. The black-blood images were acquired in an identical manner, except for additional suppression of arterial inflow by applying a tagging pulse covering the heart.

TABLE 2
Imaging parameter for stady-state free precession

TR/TE/FA	5.2/2.6/120
TI	OFF
receiver bandwidth	781 Hz/pixel
slab thickness	
slice thickness	3 mm
field of view	280 x 350 mm
resolution	3 x 1.09 x 1.21 mm
parallel imaging factor	1.3

All data were analyzed on two postprocessing workstations (IMPAX 6.5.2.114 2011, AGFA HealthCare N.V., Mortsel, Belgium) by two radiologist with over 4 years of expirience in abdominal MRI independently evaluated the ability of Time-SLIPE and CE-MRA to visualize the renal arteries. Each radiologist independently reviewed source image and MIP reconstruction of Time-SLIPE and CE-MRA. For image analisys five segments were defined: aorta, renal artery, segmental renal artery, interlobar renal artery and kidney parenchyma. Image quality for each segment was gradet by its visualisation as 0 not visible and 1 visible. For statistical analisis were used a commercial available software package (IBM SPSS Statistics V23.0). Statistical comparison was made with Wilcoxon rank test. A P-value less than 0.05 was considered statistically significant.

TABLE 3
Statistical evaluation of visualization score

Anatomy part	Aorta	Renal artery	Segmental renal artery	Interlobar renal artery	Kidney parenchyma
Time-SLIPE	22	19	19	9	14
CE-MRA	21	18	8	1	3
P value	NA	NA	<0.001	<0.005	<0.001

3 RESULTS

Visualisation of aorta and main stem of the renal arteries was satisfactory on both techniques, and there was no statistically significant differece. The score of segmental renal artery appeared superior with Time-SLIP. Table 2 shows the results of statistical evaluation of visualization score. Visualisation of segmental renal arterys, interlobar renal arterys and kidneys parenchyma was significantly superiorwith Time-SLIPE technique (Fig. 1). Actual imaging of Time-SLIP was around five minutes, depending on breathing of the patient while CE-MRA took 24 seconds to complete.

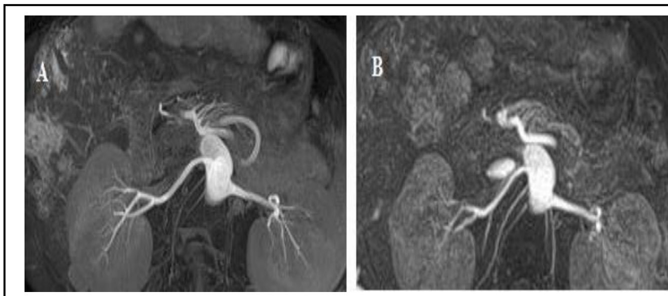

Fig 1. (a) U-MRA and (b) CE-MRA depicted normal renal arteries in MIP axial reformatted images. Visualization of intraparenchymal arteries is easier by U-MRA because there is no parenchymal enhancement associated.

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4 DISCUSSION

A major branch of the aorta is renal artery, and a rarity of vascular lesions may devolop in this vessel. Renovascular hypertension is most frequent cause of secondary hypertension, and clinical diagnosis of the disease is very important [20]. Atherosclerotic renal artery stenosis tends to induce a narrowing of the main stem lumen while fibromuscular dysplasia usually involves the distal part of main stem [21,22]. Polyarteritis nodosa occurs in the peripheral branches of the renal artery [23]. Because of that it is very important to visualize the entire renal artery, including the small intraparenchymal branches.

Three-dimensional fast gradient echo with contrast media has been common for renal MRA. However, since nephrogenic systemic sclerosis (NSF) associated with the use of gadolinium contrast agents has been widely reported, it is practically out of the question to use contrast agents in patients with renal deterioration [24,25]. Although renovascular hypertension caused by renal artery stenosis does not as a consequence lead to renal failure, atherosclerosis is the most common disease of the systemic arteries, making it a frequent cause of renal deterioration.

Unenhanced MRA appears interesting as a solution of these problems. Recent developments of unenhanced MRA techniques are remarkable. In addition to the conventional time-of-flight and phase contrast techniques, use of the ECG-gated partial-Fourier fast spin echo technique for evaluating the upper and lower extremity arteries has become clinically widespread [26,27]. In renal MRA, the steady-state data collection described above, combined with respiratory gating, can provide high-resolution blood vessel images without respiratory movement [28,29–32]. In this study, although the proximal renal arterial segments were readily demonstrated on the conventional technique, smaller peripheral branches were more confdently evaluated on subtraction images. The results were considered to be due to superior background suppression and resulting higher contrast on subtraction MRI. Non-contrast MRA depends on the flow velocity of target vessels, but renal artery flow tends to be slower in patients. Furthermore, the success rate of navigator gated MR images tends to lower in patients and the elderly. The timing of inversion pulse application was not optimized on this study. Although we used the same imaging parameters for bright blood and images. The bright blood technique requires increased signal of distal branches, so a longer TI time may be suitable. Detailed optimization would be necessary for actual clinical use, and we are currently investigating sequence optimization. Due to small sample size it is recommended to repeat the research on a higher number of subjects.

5 CONCLUSION

We tried to compare visualisation of renal arteries and its branches using unenhanced MRA, Time-SLIP, with contrast-enhanced MRA. Although it is slightly time-consuming and its clinical utility is necessary to further investigate, it provides superior visualization of peripheral branches even in this study. Further improvement of the technique would make it even more sensitive in detecting small vessel abnormalities and promising for clinical use.

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6 CONFLICT OF INTERESTE

None

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