Renal Artery Stenosis: Diagnostic Performance of Balanced Fast Field Gradient Echo MRA

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Objective: *To compare the diagnostic performance of new B-FFE MR angiography with contrast-enhanced MR angiography in diagnosis of renal artery stenosis.*
Material and Method: *One hundred and fourteen patients suspected of having renal artery stenosis underwent MR angiography with 2D B-FFE technique and 3D post contrast enhancement.*
Results: *Compared with contrast enhanced MR angiography, B-FFE MR angiography correctly depicted significant stenotic renal arteries (≥ 50% stenosis) in 13 and 12 renal arteries from 21 renal arteries, reviewed by first and second radiologists, respectively. The overall sensitivity, specificity, negative and positive predictive values of B-FFE MR angiography in diagnosis of significant renal artery stenosis (≥ 50% stenosis) reviewed by first and second radiologists, were 57.1-61.9%, 91.9-93.6%, 96.1-96.4%, and 81.3-92.3%, respectively.*
Conclusion: *B-FFE MR angiography of renal arteries can be promising technique for screening patients who are suspected of having renovascular disease without requirement of intravenous contrast injection, especially the kidney disease patients.*

Keywords: *MR angiography, Renal artery stenosis, B-FFE technique*

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The accurate diagnosis of renal artery stenosis is important because of renal ischemia leading to an elevation of blood pressure that is often difficult to control with medical therapy. Over time, the stenosis progresses in severity and leads to occlusion and a permanent reduction of renal function[1]. The correction of the stenosis by percutaneous transluminal angioplasty, renal stent placement, or surgery is necessary and can prevent or limit renal insufficiency thus, can result in cure or better control of hypertension[2].

Conventional angiography has been considered as the gold standard for identification of renal artery stenosis. However, it is an invasive procedure involving direct catheterization into arterial vessels and uses iodinated contrast material that may be nephrotoxic. MR angiography has a number of advantages over conventional angiography. It is noninvasive and uses gadolinium-based contrast material, which has a lower risk of nephrotoxicity, and provides sufficient vascular enhancement[3]. Recently, nephrogenic systemic fibrosis (NSF) has been described with increasing frequency and strongly associated with intravenous injection of double-dose gadodiamide for MRI and MR angiography in patients with acute or chronic renal insufficiency[4-6]. In these patients, if MR angiography is needed to exclude renal artery stenosis, non-contrast MR angiography is more suitable. Balanced fast field gradient echo technique (B-FFE) has become available without requirement of any intravenous contrast injection. This sequence is characterized by a complex T2 and T1contrast, and provides homogeneous high blood vessel signal intensity relatively independent of flow. It also can be performed in very short acquisition times[7]. However, until now only one article has reported its feasibility of diagnosis in renal artery disease with small sample size. The aim of the present study was to compare the diagnostic performance of new B-FFE MR angiography

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with contrast-enhanced MR angiography in diagnosis of renal artery stenosis.

Material and Method

Patients

Between January 2004 and September 2006, 164 patients who had clinical symptoms that suspected renal artery stenosis (poor control of hypertension with medical therapy, progression of renal insufficiency), underwent MR angiography of renal artery. The patients who were younger than 12 years old or status post renal stent placement were excluded.

MR imaging

All examinations were performed with a 1.5 T MR scanner (Philips, ACS-NT, maximum gradient performance, 30-mT/m amplitude; slew rate, 150 T/m per second) using a phase-array body coil. Localizer sequences were performed in transverse, sagittal, and coronal planes. A breath-hold coronal 2D B-FFE sequence was performed to cover the whole kidneys by using the following parameters; repetition time 3.4 msec/echo time 1.7 msec; flip angle, 80°; matrix = 192 x 192, slice thickness 5 mm/gap 1 mm. Next, a breath-hold transverse 2D B-FFE sequence was performed, which was characterized by the following parameters; repetition time 3.8 msec/echo time 1.9 msec; flip angle, 80°; matrix = 192 x 192, slice thickness 6 mm/gap 2 mm. Coronal 3D gradient echo sequence (repetition time 5.2 msec/echo time 1.5 msec; flip angle, 40°; slice thickness 2.4 mm/gap 1.2 mm) was performed before and after the intravenous administration of contrast agent (Magnevist; Schering, Berlin) at a dose of 0.2 mmol/kg The contrast was tracked by a bolus-tracking technique and was administered by injector at a rate of 3 ml/sec and followed by 20 ml of saline flush.

Image analysis

B-FFE MR angiography and contrast-enhanced MR angiography were interpreted by two genitourinary radiologists, who were unaware of each other's interpretation, and other clinical information. Detection of the number of renal arteries and degree of stenosis was done on contrast-enhanced MR angiography, which was used as the standard reference. Each patient's subtracted 3D data set of the arterial phase were evaluated and consensus was achieved. A final interpretation of all disagreed contrast-enhanced MR angiography was done. The evaluation was performed with maximum-intensity-projection algorithms, multiplanar reformatting algorithms, and cine-loop display of source images on the computer workstation. The renal arteries were assessed from the aorta to the renal hilum. The images were assessed for main renal artery and accessory renal artery abnormalities. Each renal artery was analyzed for the presence of stenosis, which was graded on the basis of the most severe reduction of arterial diameter compared with an uninvolved renal artery segment proximal or distal to the stenosis. The renal artery was graded as normal (grade 0), mild stenosis (< 50%, grade 1), moderate to severe stenosis (50-99%, grade 2), and total occlusion (grade 3). Because stenoses of 50% or more were considered hemodynamically significant, grades 0 and 1 stenoses were considered as negative tests for renal artery stenosis, and grades 2 and 3 stenoses as positive tests for renal artery stenosis.

Statistical analysis

Sensitivity, specificity, positive, and negative predictive values of B-FFE MR angiography as a diagnostic test for renal artery stenosis were calculated using contrast-enhanced MR angiography as the method of reference. Agreement in degree of renal artery stenosis between two radiologists was assessed using weighted kappa with quadratic weight

Results

One hundred and fourteen patients were included in the present study. Fifty patients were excluded due to being under 12 years old of age (3 cases), no available clinical data (9 cases), incomplete MR angiography data (24 cases), no contrast-enhanced MR angiography (5 cases), poor quality of MRA (6 cases), and status post renal stent placement (3 cases). In 114 patients, 56 were female and 58 were male, with a median age of 66 (range, 13 to 90 years). Systolic blood pressure ranged from 100 to 240 mmHg (median = 150). Diastolic blood pressure ranged from 50 to130 mmHg (median = 80). Serum creatinine ranged from 0.4 to 16 mg/dL (median = 2.5).

Contrast-enhanced MR angiography of 114 patients revealed 228 main renal arteries and 27 accessory renal arteries. The diameter of renal arteries ranged from 1 mm to 6.8 mm (median = 4.15). 214/255 (83.9%) renal arteries were no evidence of stenosis, 20 renal arteries (7.8%) were mild stenosis (< 50% stenosis), 16 renal arteries (6.3%) were moderate to severe stenosis (50-99%), and five renal arteries (2%) were total occluded. In 255 renal arteries, B-FFE MR angiography demonstrated 239 and 241 renal arteries, reviewed by first and second radiologists, respectively. There were 16 and 14 from 255 renal arteries (= 4.7%) reviewed by first and second radiologists respectively, which were not demonstrated on B-FFE MR angiography. All of them were accessory renal arteries without significant stenosis. The diameter of these renal arteries range from 1 mm to 2.7 mm (median = 2.25). First and second radiologists correctly depicted 195 and 192 normal renal arteries (grade 0) (Fig. 2) from 214 arteries respectively (Table 1) (91.1% and 89.7% respectively). Both radiologists correctly detected five from 20 (25%) mildly stenotic arteries (grade 1, < 50% stenosis) and accurately depicted eight from 16 (50%) moderately to severely stenotic arteries (grade 2, 50-99% stenosis) (Fig. 3). In five grade 3 occluded renal arteries (Fig. 4), four arteries (80%) were accurately identified by both radiologists. The comparison results of stenosis grading seen on B-FFE MR angiography and on contrast-enhanced MR angiography reviewed by first and second radiologists are shown in Table 1 and 2.

Because of stenosis of 50% or more was considered hemodynamically significant, so grade 0 and 1 renal artery stenoses were considered as negative while grade 2 and 3 were considered as positive for significant renal artery stenoses. From the present study, 234 renal arteries were classified as negative and 21 renal arteries were positive for renal artery

Table 1. Comparison of renal artery stenosis grading seen on B-FFE MR angiography (by first and second radiologists) and on contrast-enhanced MR angiography

Grade on B-FFE MR angiography by first & second radiologists	Grade on contrast-enhanced MR angiography								Total	
	Grade 0 Normal		Grade 1 < 50%		Grade 2 50-90%		Grade 3 > 99%			
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Grade 0 Normal	195	192	12	12	6	5	0	1	213	210
Grade 1 < 50%	3	10	5	5	1	3	1	0	10	18
Grade 2 50-99%	0	0	3	1	8	8	0	0	11	9
Grede 3 > 99%	0	0	0	0	1	0	4	4	5	4
Not detected	16	12	0	2	0	0	0	0	16	14
Total	214	214	20	20	16	16	5	5	255	255

1st = first radiologist
2nd = second radiologist
Not detected = no demonstration of renal artery on B-FFE MR angiography

Table 2. Comparison of negative and positive test in diagnosis of renal artery stenosis seen on B-FFE MR angiography (by first and second radiologists) and on contrast-enhanced MR angiography

Grade on B-FFE MR angiography by first & second radiologists	Grade on contrast-enhanced MR angiography				Total	
	Grade 0, 1 (negative test)		Grade 2, 3 (positive test)			
	1st	2nd	1st	2nd	1st	2nd
Grade 0, 1 (negative test)	215 (91.9%)	219 (93.6%)	8 (38.1%)	9 (42.9%)	223	228
Grade 2, 3 (positive test)	3 (1.3%)	1 (0.4%)	13 (61.9%)	12 (57.1%)	16	13
Not detected	16 (6.8%)	14 (6%)	0 (0%)	0 (0%)	16	14
Total	234	234	21	21	255	255

1st = first radiologist
2nd = second radiologist
Not detected = no demonstration of renal artery on B-FFE MR angiography

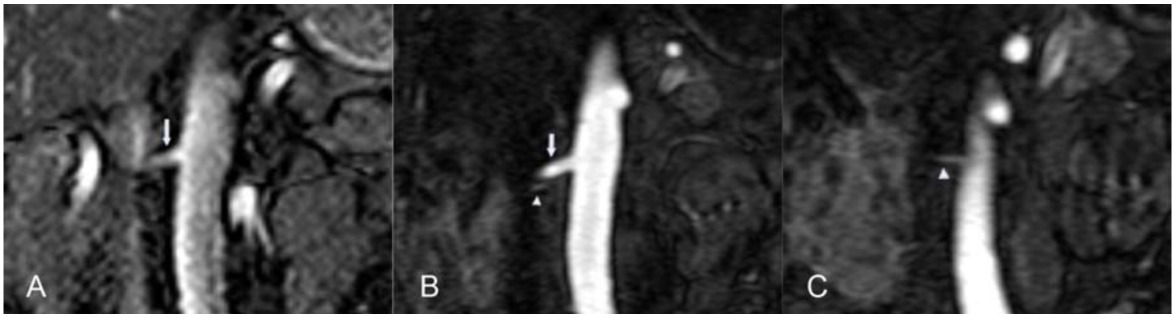

Fig. 1 A 64-year-old woman with renal insufficiency. (A) Coronal b-FFE MR angiography shows a single right renal artery (arrow). (B) and (C) Coronal contrast-enhanced MR angiography reveal a main right renal artery (arrow) and a smaller caliber accessory right renal artery locating inferiorly (arrow head), with the diameter of 4.3 mm and 1.1 mm, respectively. This accessory renal artery was not detected on b-FFE sequence

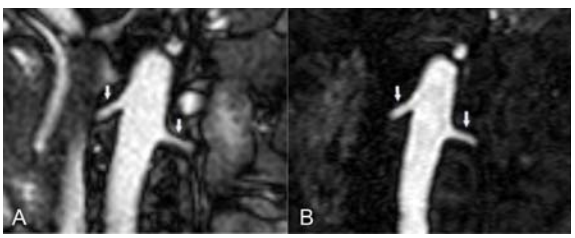

Fig. 2 A 59-year-old man with renal insufficiency. (A) Coronal b-FFE MR angiography and (B) contrast-enhanced MR angiography demonstrate normal right and left renal arteries

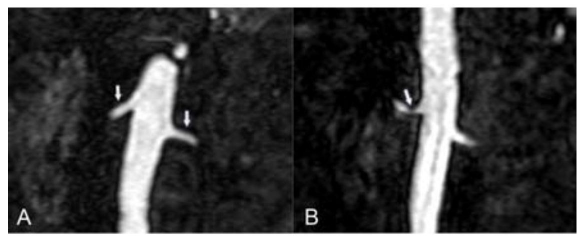

Fig. 3 An 80-year-old woman with progressive renal insufficiency. (A) Coronal b-FFE MR angiography demonstrates exceeding 50% stenosis of right renal artery (arrow). Left renal artery appears normal. (B) Contrast-enhanced MR angiography confirms the diagnosis

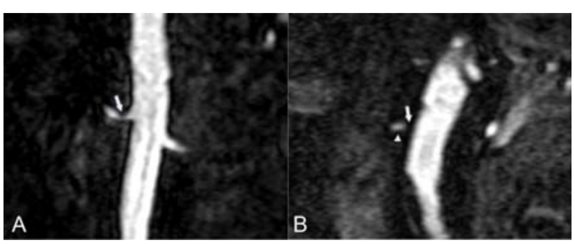

Fig. 4 A 73-year-old male with poor control of hypertension. (A) b-FFE MR angiography shows no demonstration of origin and proximal part of right renal artery (arrow) classified as a grade 3 stenosis. Distal to stenotic part of right renal artery is also demonstrated (arrow head). (B) Contrast-enhanced MR angiography demonstrates the similar findings

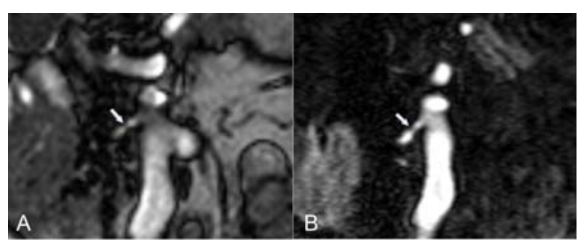

Fig. 5 A 72-year-old female with rising serum creatinine. (A) b-FFE MR angiography demonstrates overestimated right renal artery stenosis with a1.5- mm in diameter (more than 50% stenosis) (arrow). There is chemical shift artifact at the stenotic area. However, (B) Contrast-enhanced MR angiography shows a 3.5-mm right renal artery stenosis (mild stenosis), less than 50%, at the same area seen on (A)

stenoses from 255 renal arteries. There were three from 255 renal arteries (1.2%) that were overestimated to be positive for renal artery stenoses on B-FFE MR angiography, with the diameter ranged from 2.8 to 5.7 mm (median = 3.4) (Fig. 5). Two radiologists agreed in one renal artery and the other two renal arteries were detected by only the first radiologist. Ten from 255 renal arteries (3.9%), were underestimated to be negative for renal artery stenoses on b-FFSP MR angiography, with the diameter ranged from 2.4 to 4.7 mm (median = 3.8) (Fig. 6). Both radiologists agreed on the same seven renal arteries, one renal artery was detected by only the first radiologist and the other two arteries were detected by only the second radiologist.

The overall sensitivity, specificity, negative and positive predictive values, and their 95% CIs of B-FFE MR angiography in diagnosis of significant renal artery stenosis ($\geq$ 50% stenosis) reviewed by first and second radiologists were as follows: 57.1% (38.4, 81.9) vs. 61.9% (34.0, 78.2) sensitivity, 91.9% (87.6, 95.0) vs. 93.6% (89.7, 96.4) specificity, 96.1% vs. 96.4% negative predictive value and 81.3% vs. 92.3% positive predictive value. Agreement between the two radiologists in grading of renal artery stenosis was good, with Kw = 0.78 (95% CI = 0.67, 0.91).

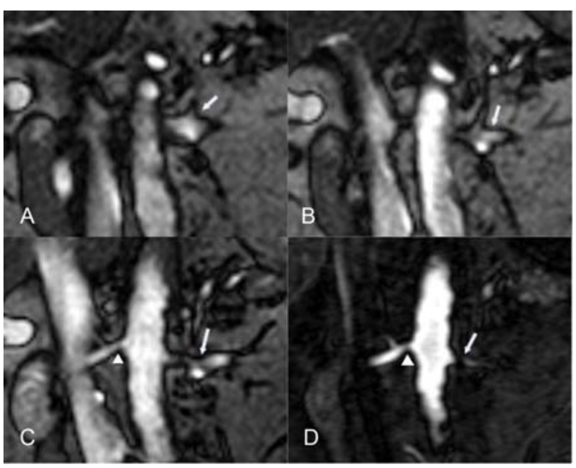

Fig. 6 A 76-year-old woman with poor control of hypertension. (A), (B) and (C) Coronal b-FFE MR angiography show superimposed left renal vein along the course of left renal artery (arrow), causing limitation to evaluate absence or presence of renal artery stenosis. b-FFE MR angiography shows no evidence of significant stenosis of left renal artery. Approximately 50% stenosis of right renal artery is also demonstrated (arrow head). (D) Coronal contrast-enhanced MR angiography shows nearly occlusion of left renal artery (arrow) and about 50% stenosis of right renal artery (arrowhead)

Discussion

The contrast-enhanced MR angiography was widely used as the standard diagnosis of renal artery stenosis with high quality of images (95% accuracy, 92% sensitivity, and 96% specificity) and by now replaces the conventional angiography, which was blamed to be the invasive technique[8]. However, the recent articles[9-11] reported the gadolinium (Gd)-induced nephrogenic systemic fibrosis in chronic renal insufficiency patient with the severe morbidity and mortality. In addition, most of the suspected renal artery stenotic patients had a history of chronic renal insufficiency, which made the criteria serious for using intravenous Gd injection for MR diagnosis, especially high-dose MR angiography.

The 2D time of flight and phase contrast MR angiography of the renal arteries have been successfully used as the non-enhanced technique of choice for a rather long time[1,12-14]. However, both techniques have been reported to be of only limited value for assessing the entire course of the renal arteries, often with only the origin reasonably displayed[15].

Recently, the new B-FFE sequence is an extremely fast gradient-echo sequence that provides displaying of abdominal vasculature including renal artery with high conspicuity in combination with high spatial and temporal resolution. The B-FFE sequence generates the high blood pool signal intensity without using Gd injection. The present results agree with Herborn CU et al. who demonstrated that the B-FFE sequence is a feasible alternative to standard angiography MR protocol for renal artery evaluation[7] with excellent overall specificity (91.9-93.6%) and overall positive predictive value (81.3-92.3%). However, overall sensitivity in the present study (57.1-61.9%) is not as good as the prior study[7]. Although, overall performance of B-FFE sequence appear to be an underestimate in the group of significant stenosis (> 50%), which had the significant change in the clinical management but is relatively low (10 from 255 renal arteries = 3.9%). In addition, the authors found a small number of accessory renal arteries (12 from 255 renal arteries = 4.7%) that could not be detected by B-FFE, but all were rather small ones, ranging from 1 mm to 2.7 mm (median = 2.25), without definite stenosis. However, they do not change any clinical decision. Because the spatial resolution of B-FFE sequence may be inferior to contrast-enhanced MR angiography, the authors propose the quality of B-FFE images in evaluation of renal artery stenosis. They can replace the contrast-enhanced MR angiography, yielding images that are not of the diagnostic quality or if the placement of a venous cannula for contrast material administration is not possible.

In the present study, the authors found many difficulties on interpretations in the small vessels with chemical shift artifact, superimposed renal vein/inferior vena cava. However, the good evaluation of both axial and coronal planes can improve the visualization and confirm the detectability of abnormality. The authors recommended to do contrast-enhanced MR angiography in the groups that cannot be well evaluated by both axial and coronal planes such as small renal arteries (mean size < 3.6 mm, calculate in the groups of underestimate) and normal visualization of main renal arteries with still suspected accessory renal artery stenosis.

There are some limitations in the present study. First, the authors defined the contrast-enhanced MR angiography as the standard reference, which is regarded as fairly controversial[7], even though we know that the conventional angiography is the standard reference that is indicated for more accurate correlation. It is not practical to do invasive angiography in the large group of suspicious renal artery stenosis to confirm a small group of significant renal artery stenosis. Second, the authors used manual measurement on the renal arteries thus, can make some errors on the evaluation of stenotic grading, especially on the small ones.

Conclusion

In conclusion, the B-FFE MR angiography of renal arteries is a promising technique for screening patients who were suspected of having renovascular disease without requirement of intravenous contrast injection, especially renal insufficiency. However, in the case of small size of renal arteries (< 3.6 mm) or incomplete assessment of renal arteries on both planes of B-FFE technique, the contrast-enhanced MR angiography is still the best additional technique to perform.

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ความแม่นยำในการวินิจฉัยภาวะหลอดเลือดแดงของไตตีบ โดยใช้เทคนิค balanced fast field gradient echo MRA

พรพิมพ์ กอแพร่พงศ์, พิชญ์วดี รงค์วราโรจน์ (โตวณะบุตร), กอบกุล เมืองสมบูรณ์

วัตถุประสงค์: *เพื่อศึกษาความสามารถของการ ตรวจ MRA โดยใช้ เทคนิคใหม่ balanced fast field gradient echo ในการวินิจฉัยภาวะหลอดเลือดแดงของไตเปรียบเทียบกับ MRA แบบมาตรฐาน*

วัสดุและวิธีการ: *ได้ทำการศึกษาผลการตรวจ MRA ของผู้ป่วย 114 คน ที่มีอาการทางคลินิกน่าสงสัย ภาวะหลอดเลือดแดงของไตตีบโดยใช้เทคนิค balanced fast field gradient echo เปรียบเทียบกับ การตรวจ MRA แบบมาตรฐานโดยใช้การฉีดสีเข้าหลอดเลือดดำ*

ผลการศึกษา: *พบว่าการตรวจ MRAโดยเทคนิค balanced fast field gradient echoสามารถใช้วินิจฉัยภาวะหลอดเลือดแดงของไตตีบมากกว่าร้อยละ 50 ได้ด้วย ความแม่นยำสูงถึงร้อยละ 91.9-93.6 เมื่อเปรียบเทียบกับการตรวจ MRAแบบมาตรฐานโดยมีการฉีดสีเข้าหลอดเลือดดำ*

สรุป: *การตรวจ MRA โดยใช้เทคนิค balanced fast field gradient echo น่าจะเป็นเทคนิคที่ สามารถนำมาใช้ในการวินิจฉัยภาวะหลอดเลือดแดงของไตตีบในกลุ่มผู้ป่วยที่มีอาการน่าสงสัยทางคลินิก และอาจเป็นทางเลือกใหม่ในกลุ่มผู้ป่วยโรคไตซึ่งไม่สามารถได้รับการตรวจ MRA โดยการฉีดสีตามปกติได้*