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Comparison of diagnostic accuracy of Doppler USG and contrast-enhanced magnetic resonance angiography and selective renal arteriography in patients with atherosclerotic renal artery stenosis

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Background: There are many systemic complications of conventional selective renal arteriography (SRA), such as contrast-mediated nephropathy. Contrast-enhanced magnetic resonance angiography (CE-MRA) and renal artery Doppler ultrasonography (DUSG) have been used increasingly for renal artery stenosis (RAS). The aim of this study was to evaluate the accuracy of CE-MRA and DUSG as used for diagnosis of RAS.

Material/Methods: We divided 130 consecutive patients investigated for resistant hypertension into 2 groups based on age: group 1 was patients <60 years old and group 2 was patients >60 year. DUSG, CE-MRA, and SRA were performed in group 1 and group 2 patients.

Results: Seventy-two patients (24 males [M], 48 females [F]) in group 1, and 58 patients (26 M, 32 F) in group 2 were included in the study. In the evaluation of clinically significant renal artery stenosis with DUSG, in group 1 the overall sensitivity was 83.33% and overall specificity was 81.82%, and in group 2 they were 69.23% and 0%, respectively, when compared with SRA. In the evaluation of clinically significant renal artery stenosis with CE-MRA, the overall sensitivity and specificity were 92.31% and 36.36%, respectively, in group 1 and 100.00% and 73.33%, respectively in group 2, when compared with SRA.

Conclusions: CE-MRA is an accurate, non-invasive method for the diagnosis of RAS in patients above 60 years of age and DUSG may be the choice of diagnostic method for RAS in patients under 60 years of age.

Key words: hypertension • vascular disease • renal disease • atherosclerosis

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Background

Atherosclerotic renal artery stenosis (RAS) has become an important cause of end- stage renal disease in the elderly. Selective renal arteriography (SRA) is still the gold standard method in diagnosis of renal artery stenosis [1]. However, since it is an invasive test and has contrast-mediated nephropathy risk, it cannot be performed in some patients with suspected RAS [2]. Hence, there is a need for a diagnostic method for renal artery stenosis that is both correct and safe. In this sense, the search for a non-invasive method that can be used for high risk subjects still continues. Doppler ultrasonography (DUSG), magnetic resonance imaging (MRI) without contrast, and contrast-enhanced magnetic resonance angiography (CE-MRA) are the most investigated methods regarding this issue [3].

CE-MRA is non-invasive, does not requirement ionizing radiation, and is potentially valuable for imaging renal arteries [4]. A limited number of studies have tried to find an answer to this question [5]. However, we still do not know in which patients its use would be most feasible. However, the reality that this technic cannot be used in subjects with metallic prosthesis and the long acquisition time are important disadvantages.

The overall prevalence of RAS in hypertensive patients is between 3% and 10% [6]. Definite sub-groups of patients are reported to have a higher incidence. For instance, 25–45% all of hypertensive patients with peripheral vascular disease were found to have important (>50%) RAS at angiography [7]. In addition, RAS is expected to be the cause of hypertension in up to 33% of patients over age 60 years [8].

Important advantages of DUSG are the lack of need for contrast administration, the relatively cheap cost, and being a non-invasive technique. However, the requirement of experienced personnel during the assessment and its insufficiency when examining obese and non-cooperative patients are important disadvantages [9]. Recent studies have suggested that CE-MRA and SRA are better than DUSG for detecting RAS because some indexes used during Doppler assessment are controversial [10]. Nevertheless, some authors propose use of DUSG as a screening test and declare that CE-MRA and SRA should be used only as second-line tests [11].

The aim of our study was to evaluate the evidence on DUSG, CE-MRA, and a combination of DUSG plus CE-MRA (co-DUSG-CE-MRA) images for use in diagnosis of RAS, and to compare with accuracy of SRA in patients under age 60 years old and those age 60 years and older.

Material and Methods

We prospectively assessed 130 consecutive patients investigated for clinically suspected renovascular hypertension and diagnosed definitively as having RAS. The patients were divided into 2 groups: group 1 was composed of patients less than 60 years of age, and group 2 was composed of patients age 60 and older. Informed consent was obtained from all patients, and the study protocol was approved by the institute's ethics committee on human research.

After ruling out the possible causes of resistant hypertension such as renal parenchymal diseases and disorders, endocrinological and neurological disorders, and drugs, renal artery evaluation was performed to rule out RAS. For this purpose, priority was given to DUSG, not only because there is no use of contrast agent, but also because of its non-invasiveness. CE-MRA was used in obese patients with whom renal artery evaluation could not be done with DUSG. Some patients with uncertain DUSG results also underwent CE-MRA evaluation.

DUSG was used on 24 subjects in group 1 and 16 subjects in group 2 and CE-MRA was used on 24 patients in group 1 and 22 patients in group 2. Overall, co-DUSG-CE-MRA was used on 24 patients in group 1 and 20 patients in group 2. After the DUSG, CE-MRA, and co-DUSG-CE-MRA procedures, all subjects underwent SRA (n=65).

We excluded from the study subjects who could not monitor their blood pressure with standardized devices, as well as patients with breathing problems, chronic obstructive and restrictive lung diseases, hypersensitivity against gadolinium and iodine-based contrast agents, acute or chronic renal failure, exposure to gadolinium-based contrast within the previous 60 days, and pregnant or breast-feeding women. Patients with diabetes mellitus, vasculitic syndromes, fibromuscular dysplasia, and patients with relative or absolute contraindications to CE-MRA and claustrophobia were also excluded.

Blood pressure measurement above 140/90 mmHg with standardized devices (OMRON M6 comfort, Kyoto, JAPAN) at home under the regular and optimum treatment of 3 different types of antihypertensives (1 of them diuretics) were accepted as resistant hypertension.

In our study, 24 subjects in group 1 were assessment with only DUSGs, another 24 were assessed with only CE-MRA, and the remaining 24 were assessed with co-DUSG-CE-MRA. In group 2, 16 subjects had only DUSG and 22 subjects had only CE-MRA. The other remaining 20 patients had co-DUSG-CE-MRA.

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Imaging techniques

All of the Doppler US assessments were done with a colored Doppler US device (Aplio, Toshiba Tokyo/Japan) with the use of a 3–6 MHz broadband convex probe (PLT 3.75 Toshiba, Tokyo, Japan) by the same radiologist. The measurements included peak systolic velocities within main renal arteries, renal aortic ratio (RAR), and intrarenal blood flow measurements. Peak systolic velocities <100 cm/sec were considered normal, those between 100–200 cm/sec were suggestive of mild stenosis (<50% narrowing), and those >200 cm/sec were suggestive of severe stenosis (50–99% narrowing). RAR greater than 3.0 is evidence of significant RAS. Intrarenal vessel evaluation was performed with the patient in the lateral decubitus position. An acceleration time greater than 0.07 seconds with a tardus-parvus waveform was considered diagnostic of severe stenosis of the extrarenal arteries.

CE-MRA of the renal arteries was performed using a 1.5-T GE unit (General Electric, Milwaukee, Wis., USA). Then, a sagittal localizer (a 3-D TOF sequence) was achieved in the axial plane to cover the location of renal arteries. A 3-D FLIPR Membrane Potential (FMP) Systematizing Person-Group Relations (SPGR) sequence was used with the following imaging parameters: TR: 26 ms, TE: 6.9 ms, flip angle 40, field of view (FOV) 36.36 cm matrix 256. 256, 1 excitation (NEX). Next, 1.5-mm-thick partitions were acquired in 3 min, 32 s. In order to maintain optimum catch up of contrast at renal artery level, with the help of the software programme "smart pep" an indicator was put intraluminally to the abdominal aorta at the level of superior mesenteric artery in the axial plan. Just after the arrival of contrast to the renal arteries, the subjects were told to hold their breath. Contrast for (Magnevist® [(Berlex Lab., Wayne, NJ] brand of gadopentetate dimeglumine, 0.2 mmol/kg) CE-MRA was administered in all procedures. Contrast agent administration was performed through a power injector at a rate of 2 mL/s, followed by a 20-mL saline flush at a similar rate.

Biplane angiography was used in all SRA assessments. With the help of Seldinger technic and transfemoral approach, the femoral artery was catheterized. A flush aortic injection of 45 ml of iohexol (Omnipaque 300, Nycomed, Oslo, Norway) at 15 ml/s speed was practical and images were taken in the anteroposterior plane. A 5-F pigtail catheter was placed (William Cook, Europe, Verskof BF, Denmark) in the aorta at the level of the renal arteries. Then, selective renal artery images were gathered. All of the DSA examinations were performed within 30 days after the CE-MRA examination.

For all imaging methods, a filling defect more than 50% at any level of the renal artery was assessed as "stenosis". If a filling defect was ≤50%, the renal artery was assessed as "no stenosis or normal" [12].

The findings gathered by DUSG and CE-MRA were compared with SRA results to determine the sensitivity and specificity in detecting RAS. Sensitivity (the percent of vessels detected as stenotic with DUSG and/or CE-MRA among the ones evaluated as stenotic with DSA), specificity (the percent of vessels found to be not stenotic with DUSG and MRI among the ones reported to be not stenotic with DSA), positive predictive value (PPV) (the real number of vessels found to be stenotic with DSA that were found to be stenotic with DUSG and CE-MRA), negative predictive value (NPV) (the real number of vessels found to be not stenotic with DSA that were found as negative with DUSG and CE-MRA), and accuracy (the percentage of true decision of the test (positive + negative / negative) were assessed by the comparison of DUSG and CE-MRA with SRA. It was accepted as important if specificity and sensitivity were ≥70%.

Laboratory tests

Serum creatinine, fasting blood glucose, total cholesterol (TC), high-density lipoprotein cholesterol (HDL), and triglyceride (TG) levels were evaluated (Olympus AU 640, Japan). Low-density lipoprotein cholesterol (LDL-C) level was assessed with Freidwald formula, which can be formulated as LDL =TC – (HDL) – (TG/5) [13]. GFR was evaluated with "Modification of Diet in Renal Disease" MDRD formula, which can be shown as MDRD:

GFR=170 × [Scr] – 0.999 × [age]– 0.176 × (0.762 if the subject is female) × (1.180 if the patient is black) × [BUN] – 0.170].

GFR and serum creatinine levels were measured before and after imaging. After contrast administration for SRA, serum creatinine and GFR levels were measured within the first 48 hours.

BMI was calculated as weight in kilograms divided by height in meters squared.

Statistical analysis

To evaluate the comparison between different methods, Cohen's Kappa "coefficient" was calculated. To assess the independency status between 2 categoric variables, statistical analysis was performed using the chi-square test with $p<0.05$ considered statistically significant.

For the determination of the ruling-out potential of the methods, various diagnostics test evaluation criteria such as false positive (FP), false negative (FN), specificity, sensitivity, PPV, NPV, and accuracy were calculated. FP (the number of vessels detected not to be stenotic with DSA that were evaluated as stenotic with DUSG and CE-MRA) and FN (the number of vessels detected to be stenotic with DSA that were evaluated as not stenotic with DUSG and CE-MRA) values were assessed.

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Table 1. Mean basic demographic and mean biochemical data of group 1 and group 2.

Parameter(s)	Group 1 (n=72)	Group 2 (n=58)	p
Age	42.15±12.1	68.75±22.34	<0.05
Gender (M/F)	24/48	26/32	>0.05
Body Mass Index(kg/m²)	30.34±5.27	30.06±4.23	>0.05
Systolic blood pressure (mmHg)	150	155	>0.05
Diastolic blood pressure (mmHg)	100	105	>0.05
Fasting Plasma Glucose (mg/dl)	88.38±17.29	91.56±19.34	>0.05
Serum creatinine (mg/dl)	0.8±0.24	0.9±0.32	>0.05
GFR (ml/min/1.73 m²)	106.66±14.45	94.75±5.21	>0.05
Total cholesterol (mg/dl)	168.20±34.40	184.16±43.00	>0.05
Triglyceride (mg/dl)	170.90±94.63	183.99±126.03	>0.05
LDL cholesterol (mg/dl)	98.02±28.32	108.57±37.74	>0.05
HDL cholesterol (mg/dl)	45.62±12.01	43.76±10.99	>0.05

M – male; F – female; LDL – low density lipoprotein; HDL – high-density lipoprotein; GFR – glomerular filtration rate.

All values of at least 70% except FP and FN values were accepted to be a good parameter in distinguishing the healthy subjects from others with DUSG and/or CE-MRA. The performance ranges for criteria were set up as follows: 90–100%: "very high", 80–89%: "high", 70–79%: "moderate", 60–69%: "weak", 50–59%: "unsuccessful", <50%: "unavailable".

The sensitivity and specificity with exact 95% confidence intervals were calculated for DUSG, CE-MRA, and co-DUSG-CE-MRA.

For power analysis used the one-sided binomial test. The target significance level was 0.05.

A total sample size of 130 achieves 84% power to detect a change in sensitivity from 0.5 to 0.7 and 82% power to detect a change in specificity from 0.5 to 0.7. The actual significance level achieved by the sensitivity test was 0.0442 and 0.0466 was achieved by the specificity test. The prevalence of the disease was 0.65.

Results

Seventy-two patients (24 Male [M], 48 Female [F]) in group 1, and 58 patients (26 M, 32 F) in group 2 were included in the study.

Mean basic demographic and mean biochemical data of both groups are shown in Table 1. Mean serum creatinine and GFR levels before and after DUSG, CE-MRA, and co-DUSG-CE-MRA imaging did not change in either groups (p>0.05). However, after SRA imaging, there were significant increases in serum creatinine levels in both groups (p<0.05). Additionally, after SRA imaging, there were significant decreases in serum GFR levels in both groups (p<0.05).

SRA in patients with renal artery stenosis

A total of 144 main renal arteries were evaluated with SRA in group 1 patients (n=72). Forty renal arteries were detected to be stenotic and the remaining 104 did not have stenosis. The overall prevalence of significant stenosis (ie, those >50%) was found to be 27.7%.

In group 2 subjects (n=58), 116 renal arteries were also assessed and 34 main renal arteries were stenotic. The overall prevalence of significant stenosis (i.e., those >50%) was 29.3%. The number of vessels with and without stenosis evaluated with imaging methods in all patients is shown in Table 2.

Reliability of DUSG performance in patients with renal artery stenosis and comparison with SRA

Twenty-four subjects in group 1 were evaluated only with DUSG. DUSG showed a total of 48 main arteries and 26 of them were found to have stenosis in group 1. The overall prevalence of significant stenosis (ie, those >50%) was 54.1%. One vessel was found to be stenotic with SRA even though it was assessed as normal with DUSG and 4 vessels detected as stenotic with DUSG were found to be normal with SRA.

Sixteen subjects in group 2 were evaluated with only DUSG. DUSG showed a total of 32 main renal arteries in group 2 and 24 of them were evaluated as stenotic. The overall prevalence of significant stenosis (ie, those >50%) was found to be 75%. Four vessels assessed as normal with DUSG were found to

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Table 2. The number of vessels with and without stenosis evaluated with imaging technics in all patients.

Method	Stenosis <50% or normal	Stenosis 50–100%	The number of total vessels
DUSG	30	50	80
CE-MRA	14	78	92
CE-MRA+DUSG	16	72	88
SRA	186	74	260

DUSG – Doppler ultrasonography; CE-MRA – contrast-enhanced magnetic resonance angiography; SRA – selective renal arteriography.

Table 3. Diagnostic performance of DUSG compared with SRA both group 1 and group 2.

Parameters	Groups	
	Group 1 (<60 years) percent	Group 2 (>60 years) percent
Sensitivity	83.3%	69.2%
Specificity	81.8%	0.0%
False positive	16.6%	25.0%
False negative	18.1%	75.0%
Positive predictive value	83.3%	75.0%
Negative predictive value	81.8%	0.0%
Accuracy	82.6%	56.2%

DUSG – Doppler ultrasonography; SRA – selective renal arteriography.

Table 4. Diagnostic performance of CE-MRA compared with SRA.

Parameters	Groups	
	Group 1 (<60 years) percent	Group 2 (>60 years) percent
Sensitivity	92.31%	100.00%
Specificity	36.36%	73.33%
False positive	7.69%	0.00%
False negative	63.63%	33.33%
Positive predictive value	63.16%	90.00%
Negative predictive value	80.00%	100.00%
Accuracy	66.66%	90.47%

CE-MRA – contrast-enhanced magnetic resonance angiography; SRA – selective renal arteriography.

be stenotic with SRA. Doppler performance assessments are shown in Table 3.

In group 1, for all of the parameters except FP and FN, the values were found as above 70% and there was a statistically significant relationship between DUSG and SRA ($p<0.05$). In group 2, no significant relationship was detected between DUSG and SRA ($p=0.267$). As seen in Table 3, the sensitivity of DUSG in group 2 subjects was moderate (69.2%) despite very low specificity (0%). The same situation was also detected for PP and NP values and accuracy was found to be below 56.2%.

Reliability of CE-MRA performance in patients with renal artery stenosis and comparison with SRA

Twenty-four subjects in group 1 were assessed with only CE-MRA. CE-MRA showed a total of 48 main arteries and 38 of them were assessed as stenotic in group 1. The overall prevalence of significant stenosis (ie, those >50%) was 79.1%. Ten vessels detected to be stenotic with CE-MRA were assessed as non-stenotic with SRA.

On the other hand, 22 subjects in group 2 were assessed with only CE-MRA. CE-MRA showed a total of 44 main renal arteries and 40 of them were found to be stenotic in group 2. The overall prevalence of significant stenosis (ie, those >50%) was 90%. Two vessels found to be not stenotic with CE-MRA were assessed as stenotic with SRA, whereas 4 vessels detected to be stenotic with CE-MRA were evaluated as not stenotic with SRA. The luminal stenosis at the renal artery orifice level on the MR angiographic evaluation of an FP stenotic subject was thought to be due to respiratory artifact. FN stenosis was thought to be due to the misdetection of the stenosis at the orifice level of a thin artery in CE-MRA assessment.

CE-MRA performance evaluation is shown in Table 4. For all parameters except specificity, distinctive results changing from mild to good level were detected in group 1 subjects with CE-MRA. For group 2 patients, all parameters had distinctive results up to almost 90% to 100% with CE-MRA. A statistically significant relationship between CE-MRA and SRA was detected in group 2 subjects ($p<0.05$).

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Table 5. Diagnostic performance of co-DUSG-CE-MRA compared with SRA.

Parameters	Groups	
	Group 1 (<60 years) percent	Group 2 (>60 years) percent
Sensitivity	100.00%	100.00%
Specificity	50.00%	100.00%
False positive	0.00%	0.00%
False negative	50.00%	0.00%
Positive predictive value	77.78%	100.00%
Negative predictive value	100.00%	100.00%
Accuracy	81.81%	100.00%

co-DUSG-CE-MRA – combination of Doppler ultrasonography plus contrast-enhanced magnetic resonance angiography; SRA – selective renal arteriography.

Reliability of co-DUSG-CE-MRA performance in patients with renal artery stenosis and comparison with SRA

Twenty-four patients in group 1 were evaluated with co-DUSG-CE-MRA. Co-DUSG-CE-MRA showed a total of 48 main arteries and 40 of them were assessed as stenotic in group 1. The overall prevalence of significant stenosis (i.e., those >50%) was established to be 83.3%. In 4 arteries detected to be stenotic with co- DUSG-CE-MRA, evaluation with SRA did not reveal stenosis.

Twenty patients in group 2 were evaluated with co-DUSG-CE-MRA. Co-DUSG-CE-MRA showed a total of 40 main arteries and 32 were found to be stenotic in group 2. The overall prevalence of significant stenosis (i.e., those >50%) was detected as 80%. SRA did not reveal stenosis in 4 vessels evaluated as stenotic with co-DUSG-CE-MRA. In another 4 vessels not assessed as stenotic with co-DUSG-CE-MRA, stenosis was exhibited with SRA.

Co-DUSG-CE-MRA performance evaluation is shown in Table 5. For group 1 subjects except specificity and FN parameters, good distinctive results were obtained with co-DUSG-CE-MRA. Ideal results were gathered with co-DUSG-CE-MRA for group 2 subjects. In this group of patients there was not significant statistical difference between SRA and co-DUSG-CE-MRA.

Discussion

Early detection and treatment of RAS is important to prevent permanent damage. Although SRA is the gold standard method for diagnosis, it has potential risks due to invasiveness, iodinated contrast ingredient, and nephrotoxicity. Therefore, looking for alternative diagnostic tests continues [11]. DUSG and CE-MRA are accurate, noninvasive imaging methods for detection of significant RAS and can obviate the need for contrast arteriographic examination. Our study suggests that CE-MRA and DUSG are safe methods for use in diagnosis of RAS. Specificity, sensitivity, and NP and PP values of DUSG and CE-MRA were shown to be increased when both methods were combined. There is a very little data on this in the literature.

The sensitivity and specificity of DUSG in detecting RAS were found to be 97% and 49%, respectively, in a study by Algin et al. [14]. There are many studies documenting the sensitivity and specificity of DUSG in detecting RAS [15,16], but none of them were grouped according to patient age. In our study, the specificity of DUSG in detecting RAS was found to be quite high (81.3%) in patients under 60 years old but it was 0% for subjects above 60 years old.

Contrast-induced nephropathy is most commonly defined as a ≥0.5 mg/dl absolute increase in serum creatinine or a ≥25% relative increase compared to baseline serum creatinine [17]. There are numerous studies on contrast-induced nephropathy [18,19]. In a retrospective study of 5967 all-comer patients with normal renal function undergoing contrast media, Lindsay et al reported that 208 patients (3.5%) developed significant contrast-induced nephropathy [20]. Similarly, we found that significant contrast induced nephropathy developed after SRA imaging in our study.

Studies comparing CE-MRA with SRA are generally small, involving 20–50 patients [21,22], with the largest study including 103 patients [23]. These studies showed that CE-MRA is highly sensitive and specific for the diagnosis of renal artery stenosis. The sensitivity and specificity of CE-MRA in diagnosis RAS were detected to be 81% and 97%, respectively, in a study by Algin et al. [14]. In addition, the sensitivity and specificity of CE-MRA in several studies performed with distinct methods were found to range from 88–100% and 90–94%, respectively. However, in these studies it is unclear which age group of subjects had the most accurate sensitivity and specificity [24,25]. A total of 993 main renal arteries were visualized with CE-MRA by Tan et al. in a meta-analysis study reporting that using CE-MRA in detecting RAS, sensitivity and specificity were 97% and 93%, respectively. When CE-MRA was compared with SRA FP, FN results were 48% and 10%, respectively [25]. Thornton et al evaluated 62 consecutive patients with clinically suspected secondary hypertension. When SRA and CE-MRA in diagnosis of renal artery stenosis were compared, the sensitivity and specificity of CE-MRA in detecting RAS were founded as 88% and 98%, respectively; accuracy was 96% and PP values and NP values were 92% and 97%,

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respectively [26]. In our study, although specificity of CE-MRA was only 36.36% and sensitivity was 92.31%) for group 1, both specificity and sensitivity of CE-MRA in group 2 was high, at 100% and 73.33%, respectively.

Soulez et al have suggested that PP values in detecting RAS above 90% could be a sign of serious stenosis and NP values in detecting RAS above 85% could be a remarkable sign for ruling out severe stenosis [27]. In their study of 154 males and 139 females with a mean age of 61 where CE-MRA was compared with SRA, they found that the NP and PP values were 91.2% and 78.5%, respectively. A study by Rieumont et al did not indicate which age group of subjects had more accurate predictive values [28]. In our study, although PP and NP values in detecting RAS were 63.16% and 80%, respectively, with CE-MRA in patients under 60 years of age, it was 90% and 100%, respectively, for subjects above 60 years of age. Nevertheless, we found that PP and NP values increased when CE-MRA was combined with DUSG regardless of subject age.

Stenosis in intrarenal and segmental branches is rare, and is primarily seen in young, non-uremic subjects with hypertension or fibromuscular dysplasia. Nevertheless, stenosis at this level may be difficult to diagnose [29]. In our study, stenosis at this level was not observed with SRA in hypertensive subjects who had normal CE-MRA evaluation, but with FMD suspicion. In this regard our results suggest that SRA should be performed only under severe clinical RAS possibility in young patients with FMD suspicion, even if they have normal CE-MRA assessments [28].

Stenosis was not detected with SRA in 7 renal arteries evaluated as stenotic with CE-MRA in group 1 and group 2. Stenosis was not detected in 1 artery with SRA evaluated as stenotic with CE-MRA. We suspect this was due to unrecognized impaired compliance of the subjects. Although there were no respiratory problems in 2 FP subjects, stenosis was not detected with SRA. This can be explained by the signal loss due to the severe stenosis or turbulent flow at the orifice level, even though evaluation with contrast tends to hinder this signal loss [30].

Patients with renal disease are more likely to undergo *in vivo* accumulation because of obviously prolonged clearance of gadolinium agents [31]. Linear nonionic chelates such as gadodiamide and gadoversetamide would seem to be at higher risk for accumulation than the linear ionic chelates such as gadopentetate dimeglumine and gadobenate dimeglumine. There are many published case reports [32–34] of nephrogenic systemic fibrosis (NSF) associated with gadopentetate dimeglumine. Although creatinine levels were high in these case series, none of our patient had renal disease. Additionally, each of our cases received only gadopentetate dimeglumine. None of gadolinium agents other than gadopentetate dimeglumine were administered to our patients. However, we found no cases of NSF after the administration of gadopentetate dimeglumine.

One of the major limitations of our study was the number of subjects. Even though it met the power analysis, we believe that further studies with larger numbers of patients will provide better results.

Conclusions

Our study results confirm that DUSG is an alternative to SRA for detecting RAS in subjects less than 60 years of age. Nonetheless, CE-MRA is also an alternative to SRA for detecting RAS in subjects over age 60. DUSG and CE-MRA are alternative methods to SRA for detecting RAS. The co-DUSG-CE-MRA in patients over age 60 years of age provides the highest specificity, sensitivity, and PP and NP values.

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