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Comparison of contrast-enhanced magnetic resonance angiography and digital subtraction angiography in the evaluation of renal artery stenosis and detecting of accessory and polar arteries

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ABSTRACT

Objectives: Renal artery stenosis (RAS) is the most common cause of secondary hypertension. RAS may cause renal insufficiency, uncontrolled hypertension and is associated with increased cardiovascular morbidity and mortality. We aimed to evaluate the accuracy of contrast enhanced Flash 3D Renal Magnetic Resonance Angiography (MRA) in the depiction of the RAS also detecting of accessory and polar renal arteries with intraarterial digital subtraction angiography (DSA) still serving as the reference standard.

Methods: In this retrospective case-control study, we reviewed contrast enhanced Flash 3D Renal MRA and DSA of 71 patients who were suspected of having RAS and underwent DSA after MRA within 15 days. DSA was accepted as gold standart and the specificity, sensitivity and accuracy of MRA were determined.

Results: Overall sensitivity and specificity values of contrast enhanced Flash 3D Renal MRA in detecting stenosis were 96.1% and 76.3% respectively.

Conclusions: Contrast enhanced Flash 3D Renal MRA is a reliable noninvasive imaging modality in the diagnosis of RAS.

Keywords: Renal artery stenoses, magnetic resonance angiography, digital substraction angiography

Renal artery stenosis (RAS) is one of the important and treatable causes of hypertension and end-stage renal failure [1]. In 90% of the cases, the cause of stenosis is atherosclerosis. Other important causes are fibromuscular dysplasia and vasculitis such as Takayasu arteritis and polyarteritis nodosa. In 12-14% of dialysis patients and 1-5% of hypertensive patients, the underlying cause is atherosclerotic renal artery stenosis. It is found at increasing rates as in 15% of persistent hypertension, 20% of coronary heart disease, and 30-40% of peripheral artery disease cases [2-4].

Even if the high blood pressure is reduced with medication, not correcting the renal artery stenosis may cause a decrease in renal blood flow and ischemic damage [5, 6]. Therefore, it is important to detect renovascular hypertension before it causes renal dysfunction [7]. Treatment of renal artery stenosis by the percutaneous transluminal route or surgery facilitates the control of high blood pressure and preservation of kidney function [8-10].

The morphological imaging methods used in the diagnosis of RAS are Doppler ultrasonography, computed tomography (CT), magnetic resonance (MR) an-

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giography and conventional angiography.

Digital Subtraction Angiography (DSA) is considered the gold standard in the diagnosis of renal artery stenosis. The fact that it is an invasive method restricts its use for screening. In addition, diagnostic angiography is performed first in each patient planned to undergo endovascular treatment for renal artery stenosis. The advantages of DSA are the high resolution, its capacity to detect stenosis in the branches of the renal artery the hemodynamic significance of the stenosis by measuring the trans stenotic pressure difference [11].

Magnetic Resonance Angiography (MRA) is an imaging method that shows the vascular anatomy in detail and eliminates the risks of iodinated contrast and ionizing radiation. Contrast-mediated MRA is an effective method used in the diagnosis of renal artery stenosis with its advantages such as high resolution, ability to show the anatomy of the renal artery and the distal segmental branches, and its applicability in a short time (20-40 sec) [12, 13].

METHODS

Patients who had undergone renal MRA examination in the last five years were scanned in our archive. Out of 631 tests, those performed for preparation prior to renal transplantation, patients who had previously undergone endovascular treatment (patients with stents) and patients who had not undergone a DSA examination within 15 days of the MRA test, were excluded from the study. Among the remaining patients, the images of 75 patients who had undergone DSA within 15 days of the MRA examination were re-evaluated. Four patients whose images were not diagnostic were excluded from the study. The images of 71 patients who met the criteria were analyzed retrospectively.

A total of 71 (24 male 33%, 47 female 67%) patients between the ages of 18 and 84 (average 63.6) were included in the study. First, contrast enhanced renal MRA and then, bilateral selective renal DSA within 15 days were performed in all patients. The MRA and DSA images were evaluated by two separate radiologists.

MR Angiography Protocol

All patients underwent a contrast-enhanced Flash (fast low angle shot) 3D coronal T1 weighed MR sequence in a 1.5 Tesla MR (Magnetom Symphony; Siemens Medical Systems, Erlangen, Germany) unit with the breath-hold “Care bolus” technique. Peripheral vascular access was established from the level of the antecubital fossa, preferably in the right upper extremity, with a 22-gauge needle. Body bandage was used since the abdominal aorta and renal arteries would be scanned. The body bandage was placed on the patient with the upper end at the level of the nipple and the lower end at the level of the umbilicus.

Patients were placed in the magnet in the headfirst position. Scout images were obtained. Before administration of the intravenous contrast agent, patients were told to hold their breaths and non-contrast masked images were obtained. Then, an infusion of 0.02 mmol/kg contrast agent (Gadobenate Dimeglumin, Multihance; Bracco SpA, Milan, Italy) was started. Using the "Care Bolus" technique, the moment the contrast agent appeared on the screen, the sequence was begun, and images were obtained. Immediately after completion of contrast agent administration, 15 ml serum saline was pushed at a rate of 0.5 mL/seconds, allowing the entire contrast medium to pass into the body. The coronal Flash 3D T1 weighted sequence was then repeated 2 times with a short breath break. The examination parameters have been summarized in the table (Table 1).

Intraarterial DSA Protocol

Catheter angiography was performed using the digital subtraction technique (Multistar; Siemens, Erlangen, Germany). After covering of the patient in ac-

Table 1. Parameters of contrast-enhanced Flash 3D coronal T1 weighed renal MRA sequence

TR (time of repetetation)	3.64 msn
TE (time of echo)	1.36 msn
FOV (field of view)	420 mm
Slice thickness	2 mm
FA (flip angle)	25 degree
Resolution	40×512
Time	18 sec
NEX	1
SLAP	1

cordance with the sterilization rules and local anesthesia with lidocaine, a 5 French (Fr) vascular sheath was inserted into the main femoral artery from the right/left main femoral artery using the Seldinger method and aortography images were obtained after advancing the pigtail catheter into the distal abdominal aorta. Selective bilateral renal angiography images were obtained by selectively entering the main renal arteries with a shepherd hook catheter. Angiography images were obtained by selectively entering accessory and polar arteries with the shepherd hook catheter, which were observed in the evaluation of the aortography images. If a non-enhanced area were detected in the renal parenchyma during the selective injections from the main renal artery, the areas suspected in aortography were scanned with a shepherd hook catheter.

Evaluation of the Images

The MRA and DSA images were evaluated by two separate radiologists. MIP images and raw images were used in the evaluation of the MRA images. For the suspicious spots on MIP images, the raw images were evaluated in 3D to make decisions.

While examining the images, the main purpose was to determine the presence and the degree of renal artery stenosis. In addition, imaging of accessory and polar arteries and detection of pathological diseases in the renal artery such as FMD were also considered as other purposes of the study.

In our study, renal artery stenosis was divided into 4 set:

Grade 0: No renal artery stenosis, normal renal artery.

Grade 1: <50% stenosis

Grade 2: Stenosis of 50% and higher

Grade 3: Total occlusion of the renal artery

In our study, stenoses of 50% and higher were regarded as significant stenosis, because they are candidates for DSA and endovascular treatment. Similar rating tables are available in the literature. In his study, Fleischmann described the stenoses between 50-70% as significant and stenoses higher than 70% as severe stenosis.

Statistical Analysis

Analysis of the data was carried out using the SPSS 11.5 (Statistical Package for Social Sciences, SPSS Inc., Chicago, IL, USA) package program. The Spearman's Rho test was used to determine whether there was a significant difference between DSA and MRA staging in terms of diagnosis. To assess the diagnostic performance of MRA compared to DSA, the

Table 2. DSA results of 142 main renal arteries

DSA		Male n (%)	Female n (%)	Total n (%)
Grade of* stenosis				
Right Main Renal Arteries	0	3 (12.50)	17 (36.17)	20 (28.17)
	1	7 (29.17)	15 (31.91)	22 (30.99)
	2	12 (50.00)	13 (27.66)	25 (35.21)
	3	2 (8.33)	2 (4.26)	4 (5.63)
Left Main Renal Arteries	0	5 (20.83)	13 (27.66)	18 (25.35)
	1	11 (45.83)	13 (27.66)	24 (33.80)
	2	8 (33.33)	20 (42.55)	28 (39.44)
	3	0 (0)	1 (2.13)	1 (1.41)
Existensce of Accessory Artery	No	21 (87.50)	44 (93.62)	65 (91.55)
	Yes	3 (12.50)	3 (6.38)	6 (8.45)
Existensce of Polar Artery	No	22 (91.67)	41 (87.23)	63 (88.73)
	Yes	2 (8.33)	6 (12.77)	8 (11.27)

*Grade 0 = No stenosis, Grade 1 = <%50 stenosis, Grade 2 =>%50 stenosis, Grade 3 = Total occlusion. Grade of stenosis showed as number of patients and percentage in gender groups. In 71 patients existence of polar and accessory arteries showed as number of patients and percentage in gender groups.

sensitivity, specificity and the diagnostic accuracy rates were calculated. The significance of diagnostic concordance between DSA and MRA was calculated with the correlation coefficient. The results were considered statistically significant for p values of < 0.05.

RESULTS

In 71 patients, a total of 142 main renal arteries were examined, right and left separately. While 38 of the main renal arteries examined in DSA were normal (grade 0), 46 had less than 50% (grade 1), 53 of the major renal arteries had 50% or higher stenosis (grade 2), and 5 major renal arteries were totally occluded (grade 3). Six accessory arteries and eight polar arteries were detected (Table 2). Based on DSA, 58 patients had stenosis that caused significant hemodynamic changes (grades 2 and 3).

In the evaluation of the same patients with MRA, 33 of the major renal arteries examined were normal (grade 0), 39 had less than 50% (grade 1), 64 major renal arteries had 50% or higher stenosis (grade 2) and 6 major renal arteries were found to be totally occluded (grade 3). On MRA, 9 accessory arteries and 5 polar arteries were detected.

Based on MRA, a total of 70 patients had stenosis causing significant hemodynamic changes (grade 2 and 3). In the correlation with DSA, it was concluded that one major renal artery was incorrectly evaluated as total occlusion and 11 major renal arteries were incorrectly evaluated within grade 2 (> 50% stenosis) (Table 3).

In the comparison of diagnostic concordance of the DSA and MRA in all grades of stenosis (142 major renal arteries); the Spearman's Rho was calculated as 0.862 and $p < 0.01$. The diagnostic concordance of DSA and MRA was found to be significant and well correlated (Fig. 1). The sensitivity of MRA in the detection of all renal artery stenoses was calculated as 96.1% and specificity as 76.3%.

In the comparison of diagnostic concordance of the DSA and MRA in grade 2 and 3 stenoses (70 major renal arteries); Spearman's Rho was calculated as 0.885 and $p < 0.01$. It was shown that the diagnostic concordance of DSA and MRA was significant and well correlated (Fig. 2).

While the number of accessory arteries was 6 on DSA, 9 accessory arteries were observed on MRA. The polar artery number was found to be 8 on DSA. Five of these polar arteries were detected on MRA. The main renal artery showing early segmentation, double renal artery originating from a common root, thin polar artery or its origin being localized inferiorly

Table 3. MRA results of 142 main renal arteries.

MRA		Male n (%)	Female n (%)	Total n (%)
Grade of* stenosis				
Right Main Renal Arteries	0	3 (12.50)	13 (27.66)	16 (22.54)
	1	6 (25.00)	13 (27.66)	19 (26.76)
	2	12 (50.00)	19 (40.43)	31 (43.66)
	3	3 (12.50)	2 (4.26)	5 (7.04)
Left Main Renal Arteries	0	5 (20.83)	12 (25.53)	17 (23.94)
	1	9 (37.50)	11 (23.40)	20 (28.17)
	2	10 (41.67)	23 (48.94)	33 (46.48)
	3	0 (0)	1 (2.13)	1 (1.41)
Existense of Accessory Artery	No	19 (79.17)	43 (91.49)	62 (87.32)
	Yes	5 (20.83)	4 (8.51)	9 (12.68)
Existense of Polar Artery	No	22 (91.67)	44 (93.62)	66 (92.96)
	Yes	2 (8.33)	3 (6.38)	5 (7.04)

Grade of stenosis showed as number of patients and percentage in gender groups. In 71 patients existence of polar and accessory arteries showed as number of patients and percentage in gender groups.

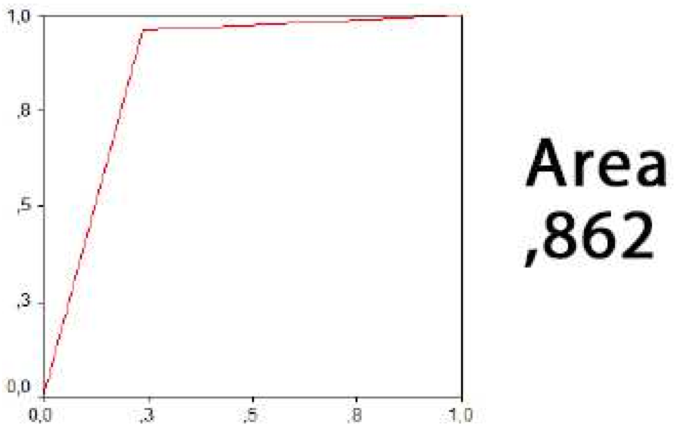

Fig. 1. **In the comparison of diagnostic concordance of the DSA and MRA in all grades of stenosis; the Spearman's Rho test was showed as ROC curve graphic and the area was calculated 0.862.**

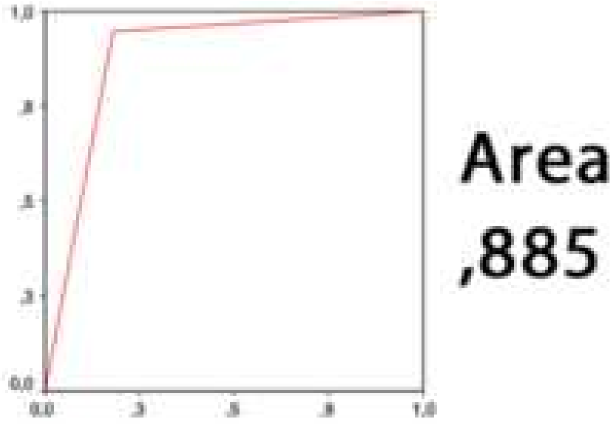

Fig. 2. **In the comparison of diagnostic concordance of the DSA and MRA in grade 2 and grade 3 stenosis; the Spearman's Rho test was showed as ROC curve graphic and the area was calculated 0.885.**

can be listed among the reasons of these discordances.

The Spearman's Rho test was used to examine the diagnostic performance of MRA compared to DSA in the detection of accessory arteries. The correlation coefficient 0.797 shows that a correlation is present between the two tests ($p < 0.01$).

Although the diagnostic performance of MRA decreases in the detection of polar arteries, a correlation is present between the two tests, albeit low (Spearman's Rho 0.598 and $p < 0.01$).

DISCUSSION

DSA is the gold standard method in the evaluation of renal arteries, but a non-invasive, reliable imaging method is needed due to complications caused by arterial catheterization [14].

In the detection of renal artery stenoses in our study, contrast-enhanced Flash 3D MR angiography demonstrated a good correlation with DSA with values of 96.1% and specificity of 76.3% and was deemed successful in terms of diagnostic concordance (Spearman's Rho 0.86) and no statistical difference was detected in terms of diagnostic success when compared to DSA ($p < 0.01$). The findings are consistent with the literature [12, 15, 16]. Recent concerns about the association between gadolinium-based contrast agents and nephrogenic systemic fibrosis has initiated the search for reliable non-enhanced renal MRA techniques [17]. Non-contrast-enhanced MRA techniques are successful in detecting the presence of renal artery stenosis, but in the evaluation of renal artery stenosis of 50% and higher in particular, it has a tendency to overestimate stenosis. Some studies have recommended to perform the first examination without contrast if renal artery stenosis is suspected, and to continue the tests with contrast enhanced MRA if needed after the images are evaluated [18]. In our study non-contrast enhanced MRA techniques not included because we have very small number of cases. Today, 3.0 T non-enhanced MRA techniques have been developed, but with these techniques, diagnostic problems such as overestimating stenosis and low sensitivity (80%) and specificity (63%) remain, but on the decrease [19].

Since the day they were first introduced, contrast mediated MRA techniques continue to be updated to achieve higher temporal and spatial resolution. Contrast-enhanced MRA is developing with techniques such as view sharing techniques (TRICKS, TWIST, DISCO, CAPR) that improve speed and parallel acquisition techniques (SENSE, REFS) [20]. These techniques have advantages such as better temporal resolution and dynamic information provision, but spatial resolution is similar to standard contrast MRA techniques [21]. It may be possible to obtain images with higher spatial and temporal resolution with new MR angiography techniques such as 3D through-time radial generalized auto calibrating partially parallel acquisition (GRAPPA). In the literature, there are Renal MR Angiography studies with the GRAPPA technique, but it is not possible to make objective interpretations, since comparative studies with conventional

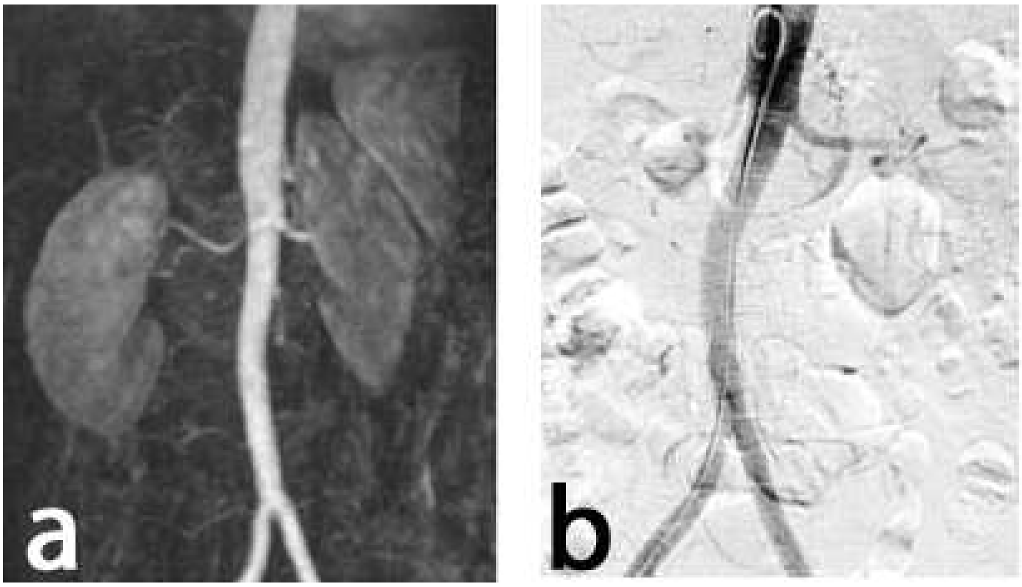

Fig. 3. **Contrast enhanced 3D Renal MRA coronal MIP image showed grade 2 stenoses of right main renal artery proximal part (a). Abdominal aortagraphy DSA image showed a severe angulation of the right main renal artery proximal part in the cranio-caudal direction close to the ventral surface of the abdominal aorta, and no evidence of stenosis (b).**

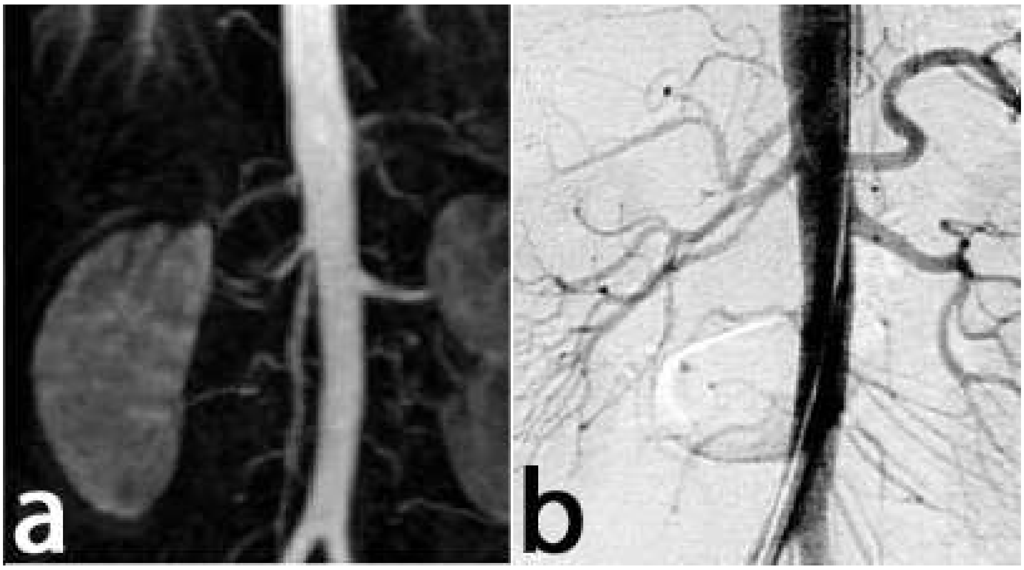

Fig. 4. **Contrast enhanced 3D Renal MRA coronal MIP image showed grade 2 stenoses of right main renal artery mid part (a). Abdominal aortagraphy DSA image showed renal artery had early segmentation and no evidence of stenosis (b).**

MR sequences or DSA have not been conducted yet [22].

Stenoses above 50% in the renal artery lead to hemodynamic changes. The diagnosis of Grade 2 and above stenoses with MRA is important, because they may need to be treated. In our study, 64 main renal arteries were classified as grade 2 on MR angiography. However, this number stopped at 53 on DSA. Despite not causing meaningful stenosis on DSA, 11 main real arteries were considered to be in the meaningful stenosis group on MRA. Similar to the literature, MR angiography overestimated the stenoses. In the retrospective comparative evaluation of these false positive cases, potential reasons other than the exaggerated appearance of the potential stenosis were identified in 3 cases. A severe cranio-caudal direction angulation in the main renal artery proximal part close to the ventral surface of the abdominal aorta was detected in 2 cases (Fig. 3). One case was diagnosed with grade 2 despite not having any stenosis on DSA in a renal artery that showed early segmentation (Fig. 4). One of the limitations of contrasted MRA is the inadequate evaluation

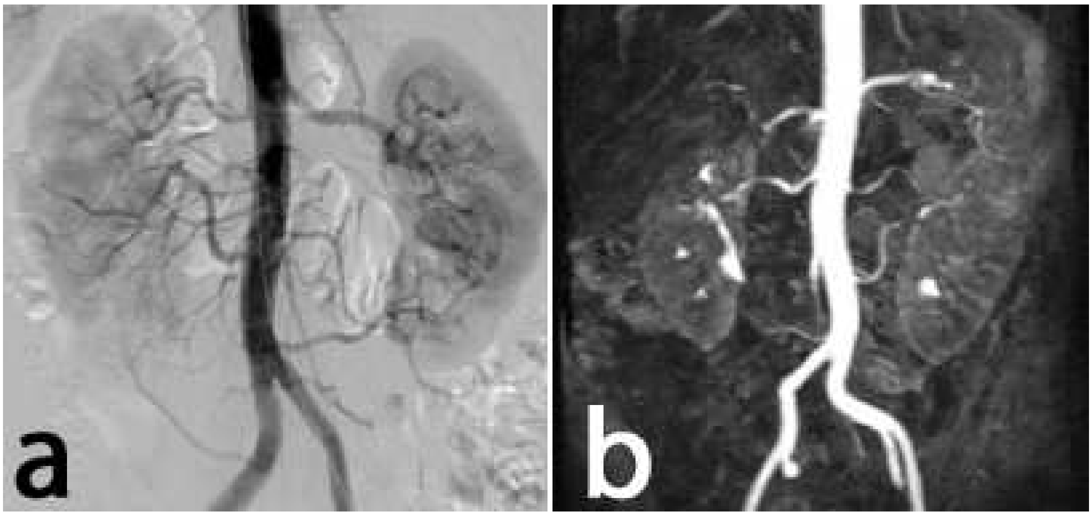

Fig. 5. **Abdominal aortagraphy DSA image showed a left polar renal artery arised from left main iliac artery and reached to the left kidney lower pole (a). No evidence of polar artery on contrast enhanced 3D Renal MRA coronal MIP image (b).**

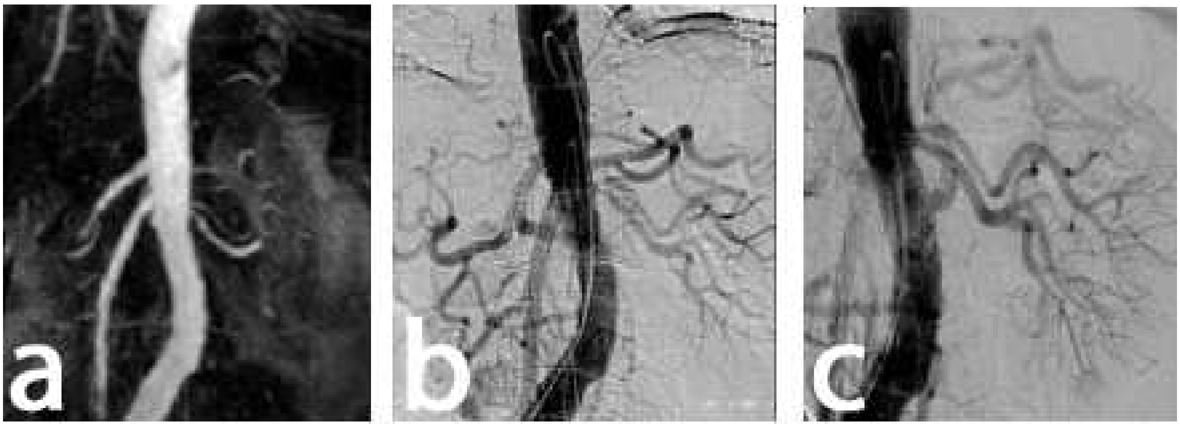

Fig. 6. **Contrast enhanced 3D Renal MRA coronal MIP image showed an accessory renal artery arised from aorta and found adjacent to the left main renal artery (a). Abdominal aortagraphy DSA image showed two main renal arteries arised from same origin and both of them had grade 2 stenosis (b). Abdominal aortagraphy DSA image showed two left main renal arteries treated with stent placement (c).**

of segmental branches. In addition, although stenosis is not common in the distal 1/3 section of the renal artery, the evaluation of stenoses in this section is problematic on MRA [19, 23].

In our study, 5 renal arteries were detected to be occluded on DSA. On MRA, 6 main renal arteries were regarded as grade 3. One main renal artery, which was observed as grade 2 on DSA but had stenosis higher than 90%, was incorrectly evaluated as stage 3 on MRA. Exaggerated signal loss at stenosis levels can prevent the accurate identification of the degree of stenosis. Although such signal losses on MRA are largely prevented by contrast enhancement, some signal loss occurs in areas with turbulent flow, such as severe stenosis or the orifice level. In particular, slight signal losses that appear as a localized lumen narrowing at the orifice, attention should be paid to the dephasing artifact that causes signal loss [24].

Accessory arteries enter the kidney from the hilum together with the main renal artery, and the polar arteries enter the kidney directly from the capsule outside the hilum. The correct detection of these arteries is very important in the pre-transplant evaluation of living kidney donors. In our study, polar and accessory arteries were detected in 8.4% and 11.2% of the cases, respectively. Retrospectively, cases without a polar artery on MRA were re-evaluated. The first reason for the inability to detect the polar arteries can be the origin of the polar artery originating from the distal abdominal aorta or the main iliac artery far from the renal artery origin or being very thin (Fig. 5).

In our study, the detection rate of accessory arteries was higher compared to polar arteries. The correlation coefficients were 0.797 and 0.598, respectively. While the number of accessory arteries was 6 on DSA, 9 accessory arteries were observed on MRA. When the images, which had been incorrectly evaluated as accessory arteries in MRA, were retrospectively re-evaluated, it was observed that the discordances were due to reasons such as the main renal artery showing early segmentation, and a double renal artery originating from a common root (Fig. 6).

Contrast-enhanced Flash 3D MRA is a reliable non-invasive imaging method with high specificity and sensitivity in the evaluation of renal artery stenosis. Although the diagnostic performance of MRA in the detection of accessory renal arteries and polar arteries decreases compared to the successful rates for stenosis detection, there is no statistically significant difference when compared to DSA.

CONCLUSION

We concluded in our study: severe angulations and early segmentations of renal arteries are weak points of MRA in the evaluation of renal artery stenosis. In our study we found weak points of MRA in the detection polar and accessory arteries: distal origin of the polar artery and early segmentation main renal artery.

Authors' Contribution

Study Conception: CB; Study Design: CB; Supervision: CB; Funding: UMY; Materials: CB, UMY; Data Collection and/or Processing: UMY; Statistical Analysis and/or Data Interpretation: UMY; Literature Review: UMY; Manuscript Preparation: UMY and Critical Review: UMY.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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