Diagnosis of renal arterial stenosis and quantification of the degree of stenosis: multidetector computed tomography angiography versus digital subtraction angiography

Renal arter stenoz tanısı ve stenoz derecesinin belirlenmesinde çokkesitli bilgisayarlı tomografik anjiyografi ve dijital subtraksiyon anjiyografi

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Background: We determined the diagnostic value of multidetector computed tomography angiography (MDCTA) for detection and gradation of renal arterial stenosis (RAS).

Methods: Seventy-eight patients (53 males, 25 females; mean age 60.8±14.9 years; range 18 to 86 years) who suffered from hypertension and were found to have RAS on MDCTA or who were found suitable for endovascular treatment of an abdominal aortic aneurysm during the evaluation with MDCTA underwent digital subtraction angiographic (DSA) examinations. The MDCTA findings were compared with the DSA findings. Statistical analysis of data was performed to detect renal arterial stenosis and the degree of stenosis based on diameter measurement. The study was carried out prospectively and approved by the hospital institutional review board. Informed consent was obtained from all patients.

Results: Seventy-nine of 156 renal arteries were found to have stenosis and six were found to have occlusion while 71 were normal on MDCTA. Seventy of 156 renal arteries were found to have stenosis and six to have occlusion while 80 were normal on DSA. Overall sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy rate were found to be 97.4%, 86.3%, 87.1%, 97.2% and 91.7%, respectively. For determination of the degree of stenosis, the sensitivity was in the range of 74.1-100%, the specificity was in the range of 93.7-100%, the PPV was in the range of 55-100%, the NPV was in the range of 94.5-100%, and the accuracy rate was in the range of 90.4-100%.

Conclusion: Multidetector computed tomography angiography can be accepted as a noninvasive and reliable modality for the evaluation of RAS with high sensitivity, specificity, and diagnostic accuracy rates.

Key words: Angiography; digital subtraction angiography; multidedector computed tomography; renal arterial stenosis.

Amaç: Renal arteriyel stenozun (RAS) tespiti ve derecelendirmesinde çok kesitli bilgisayarlı tomografik anjiyografinin (ÇKBTA) tanısal değeri belirlendi.

Çalışma planı: Hipertansiyonu olan ve ÇKBTA'da RAS saptanan veya ÇKBTA'da abdominal aort anevrizması nedeni ile abdominal aort anevrizmasının endovasküler tedavisi uygun bulunan 78 hastaya (53 erkek, 25 kadın; ort. yaş 60.8±14.9 yıl; dağılım 18-86 yıl) dijital subtraksiyon anjiyografisi (DSA) incelemeleri yapıldı. Çok kesitli bilgisayarlı tomografik anjiyografi bulguları DSA bulguları ile karşılaştırıldı. İstatistiksel değerlendirmeler renal arter stenozunun saptanması ve renal arter stenoz derecesinin çapa göre değerlendirilmesi için yapıldı. Çalışma prospektif olarak gerçekleştirildi, hastane kurumsal inceleme kurulu tarafından onaylandı. Tüm hastalardan bilgilendirilmiş onam formları alındı.

Bulgular: Yüz elli altı renal arterin 79'unda stenoz, altısında oklüzyon saptanır iken 71'i ÇKBTA'da normal idi. Dijital subtraksiyon anjiyografide 156 renal arterden 70'inde stenoz, altısında oklüzyon saptanır iken 80'i normal idi. Genel duyarlılık, özgüllük, pozitif kestirim değeri (PKD), negatif kestirim değeri (NKD) ve doğruluk oranı sırasıyla %97.4, %86.3, %87.1, %97.2 ve %91.7 olarak hesaplandı. Stenoz derecesinin saptanmasında duyarlılık %74.1-100 aralığında, özgüllük %93.7-100 aralığında, PKD %55-100 aralığında, NKD %94.5-100 ve doğruluk oranı %90.4-100 aralığındaydı.

Sonuç: Çokkesitli bilgisayarlı tomografik anjiyografi RAS değerlendirmesinde yüksek duyarlılık, özgüllük ve tanısal doğruluk oranlarına sahip noninvazif ve güvenilir bir yöntem olarak kabul edilebilir.

Anahtar sözcükler: Anjiyografi; dijital subtraksiyon anjiyografi; çokkesitli bilgisayarlı tomografi; renal arter stenozu.

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Renal artery stenosis (RAS) is one of the the underlying cause of renovascular hypertension (RVH).[1] Renal artery stenosis is one of the most frequent causes of progressive ischemic nephropathy and secondary hypertension with an estimated prevalence of 3-5% in the general population of hypertensive patients.[2-4] Despite this low proportion, the detection of RAS is important because it is a potentially curable cause of hypertension. Renovascular hypertension is mostly caused by either atherosclerotic RAS or fibromuscular dysplasia (FMD).[5] Atherosclerosis accounts for 70-90% of cases of RAS, and FMD is responsible for 10-30% of cases of RAS.[5-11] Renovascular hypertension becomes symptomatic when the stenosis of the renal artery exceeds 60%. This should be investigated in the following instances: in patients younger than 30 or older than 50 years of age with newly-developed hypertension; in patients older than 60 years of age with previously well-controlled hypertension that is now uncontrolled; in patients with the need for more than three antihypertensive drugs for controlling blood pressure; in patients with the presence of a murmur in the abdomen: and in patients with asymmetric kidney sizes that have been detected at ultrasonographic examination. The differentiation between RVH, in which the frequency varies between 0.5-5%, and primary hypertension is of high importance as treatment is possible with interventional radiological or surgical procedures. The sensitivity and specificity of clinical surveys for the determination of the disease is low. Digital subtraction angiography (DSA) is regarded as the gold standard modality to diagnose RAS. However, the invasive nature of DSA and the difficulty in assessing the pathophysiological significance of stenotic lesions with DSA have encouraged the search for more widely available, non-invasive or minimally invasive diagnostic tests, such as contrast-enhanced magnetic resonance angiography, multidetector computed tomography angiography (MDCTA), and color Doppler ultrasonography.[5,12-15]

The purpose of this study was to determine the accuracy of MDCTA as a non-invasive modality for detection and graduation of RAS by comparing it with DSA as a gold standard modality.

PATIENTS AND METHODS

The prospective study was approved by the hospital institutional review board, and informed consent was obtained from all patients.

Patient selection

Seventy-eight patients (53 males, 25 females; mean age 60.8±14.9 years; range 18 to 86 years) who were either referred for renal artery MDCTA for evaluation of RVH or for abdominal aorta MDCTA for evaluation of endovascular treatment suitability for an abdominal aortic aneurysm were included in the study. Exclusion criteria for participation in the study were a history of renal insufficiency and adverse reactions to iodinated contrast agents. During the study period, no patient was excluded from the study.

All patients first underwent a MDCTA examination followed by a DSA examination. The time interval between the two examination was at least one week but not more than 25 days. Multidetector computed tomography angiography and DSA findings were independently evaluated for main renal artery stenosis by two different radiologists, each with more than four years of experience. The results were compared and a statistical analysis of data was performed to detect the main renal arterial lesions and the degree of stenosis separately. Accessory renal arteries were excluded.

Multidetector computed tomography angiography procedure

Multidetector computed tomography angiography evaluation was carried out with a 16-detector CT system (Somatom Sensation 16, Siemens, Germany). After obtaining an initial scout image (120 kV, 50 mAs), the scanning range was planned to cover the aortoiliac vascular system from the proximal abdominal aorta to the level of the inguinal ligaments. For optimal intraluminal contrast enhancement, the delay time between the start of contrast material administration and the start of scanning was obtained for each patient individually by using a bolus tracking technique (CARE-Bolus, Siemens). For this purpose, a single non-enhanced low-dose scan at the level of the proximal abdominal aorta was obtained first. Based on this axial image, a region of interest with an area of 5-15 mm^2 was set in the lumen of the proximal abdominal aorta. This region of interest served as a reference for the dynamic measurements of contrast enhancement. Subsequently, a nonionic iodinated contrast medium (370 mgI/100 ml iopromidum or 350-370 mgI/100 ml iohexol) was administered with an injection rate of 4-5 ml/sec via a 18-20 gauge needle that was placed into a superficial vein located in the antecubital fossa. The volume of contrast medium (mean, 95 ml; range, 70-120 ml) was adjusted to 1.5-2 mgI/kg. The contrast medium was administered with an automated injector (Ulrich 200, Ulrich Medical, Germany). The contrast material bolus was followed by 25 ml of saline administered at the same flow rate. At 10 seconds after the start of contrast material

administration, repetitive low-dose monitoring scans (120 kV, 20 mAs, 0.5-second scanning time, one-second interscan delay) were obtained. After reaching the preset contrast enhancement level of 100 HU, the scan initiated automatically four seconds later. During these four seconds, a signal was given for the patient to hold their breath. Data acquisition was performed craniocaudally with a protocol 16x0.75 mm detector line configuration, 3 cm section thickness, 13.5 mm/s feed rotation, 420 msec rotation time. The X-ray tube voltage setting was 120 kV, and the current varied between 140 mAs and 200 mAs, depending on the size of the patient and the heat limitations of the tube. All scanning was performed with the patients holding their breath. (mean, 13 seconds; range, 10-17 seconds). Multidetector computed tomography angiography was performed on all patients without any complications, and none of the studies were repeated because of technical problems. The intravenous catheter was inserted while the patient was in the CT suite. The examination time, defined as the time from patient entry into the CT suite until the source data was available for three-dimensional reconstruction, was recorded for each patient.

Image post-processing

The axial source images were reconstructed retrospectively with a 1 mm slice thickness and a 0.7 mm interval. This was then post-processed on a workstation (Navigator, Siemens Medical Systems, Germany) to obtain multiplanar reformation (MPR) images and maximum intensity projection (MIP) images. Curved planar reformat (CPR) images were generated in axial and coronal planes. Curved planar reformat images were obtained by manually paralleling the center of the renal artery.

The degree of stenosis was determined by a combined evaluation of axial images with coronal MIP along with axial and coronal CPR images. Image post-processing was performed by a technician with three years of experience in angiographic image post-processing in MDCTA. If there was any hesitation, the post-processing was repeated and re-evaluated by one of the radiologists. The degree of stenosis was determined by the ratio of the diameter of the most stenotic segment of the renal artery in compared to the diameter of the normal part of the renal artery just distal part of the stenotic segment. If post-stenotic dilatation was present, the normal part was accepted after that segment.

Digital subtraction angiography procedure

Angiographic examination were performed with a DSA equipped system (Axiom Artis FC, Siemens, Germany) with either a femoral or high brachial (axillary) approach. Renal arteries were evaluated by an abdominal aortogram followed by selective catheterization in patients referred for evaluation of renal artery stenosis. They were then evaluated with abdominal aortograms with a 14 cm or 20 cm field of view at various projections in patients referred for evaluation of abdominal aortic aneurysm for endovascular therapy. In the first group, a non-calibrated pigtail catheter (Boston Scientific, USA) was used while a calibrated pigtail catheter (Pbn, Netherlands) was used in the second group. The pigtail catheter tip was positioned between the 12^{th} thoracic and first lumbar vertebrae, and 18-25 ml of a nonionic iodinated contrast material (370 mgI/100 ml of iopromidum) was injected. Then each renal artery was catheterized selectively with either a cobra catheter (Boston Scientific, USA) or a Simmons 1 catheter (Boston Scientific, USA), and 8-15 ml of nonionic contrast material was administered in each run for the first group. In the second group, the catheter tip was subsequently positioned above the aortic bifurcation for DSA of the pelvic arteries, and 20 ml of contrast material was injected in each run. In all patients, additional oblique projections were obtained for evaluation of the aortoiliac arteries. In particular, the arterial segments of both renal arteries were examined by using additional 15°-25° left and right anterior oblique projections. Lateral projections were performed in the second group of patients and performed only if necessary in the first group of patients. No prior conscious sedation was performed in any patient. Digital subtraction angiography was performed in all patients without any complications. All patients who had more than 70% stenosis on MDCTA images were premedicated (starting four days before the procedure with clopidogrel 75 mg/day, aspirin 100 mg/day) before the DSA examination. If renal arterial stenosis was confirmed at DSA, stent implantation or percutaneous transluminal angioplasty was performed during the same session. The calculation of the degree of stenosis was performed on the projection where the renal arterial stenosis and pre-stenotic and post- stenotic renal arterial segments were best visualized full of contrast. The degree of stenosis was determined via an automated calculation program on the angiographic equipment or manually calculated by dividing the diameter of the most stenotic segment by the diameter of the normal part of the renal artery just distal part of the stenotic segment. If post-stenotic dilatation was present, the normal part was accepted after that segment. Manual calculation was performed if renal arterial tracing was not optimal in the automated calculation.

Table 1. Demographic data of the patients for MDCTA angiography and DSA

			MDCTA		DSA	
No	Sex	Age	Right	Left	Right	Left
1	M	80	N	N	N	N
2	M	18	N	N	N	N
3	F	18	N	N	N	N
4	M	41	N	N	N	N
5	F	64	N	N	N	N
6	F	39	N	Ml	N	N
7	F	74	N	Md	N	Ml
8	M	68	N	Md	N	Md
9	M	45	N	S	N	S
10	M	60	N	N	N	N
11	F	33	Md	N	Md	N
12	M	61	Md	S	S	N
13	F	56	Md	N	Md	N
14	F	78	S	Ml	S	Ml
15	M	70	S	O	S	O
16	M	86	S	S	S	S
17	F	50	S	S	S	S
18	M	72	S	N	S	N
19	F	44	S	N	Md	N
20	M	75	S	Ml	S	Ml
21	M	55	O	O	O	O
22	M	55	N	S	N	S
23	M	55	N	Ml	N	Ml
24	M	48	Ml	N	Ml	N
25	M	80	N	N	N	N
26	M	45	S	Md	S	Md
27	F	62	Md	O	Md	O
28	F	60	Ml	Md	Ml	Md
29	M	54	N	N	N	N
30	F	67	S	Ml	S	Ml
31	F	75	Ml	S	Ml	S
32	M	53	S	N	S	N
33	F	75	S	N	S	N
34	F	24	S	N	S	Md
35	M	53	S	Md	S	N
36	M	55	Md	Md	Ml	Ml
37	F	76	S	S	S	S
38	M	64	Md	Md	N	Md
39	M	67	N	Md	N	Md
40	M	65	Ml	O	Ml	O
41	F	56	N	N	N	N
42	F	67	S	S	S	S
43	M	60	N	Md	N	Md
44	M	77	Ml	Ml	Ml	Ml
45	M	73	Ml	Ml	Ml	Ml
46	M	68	Ml	Ml	Ml	Ml
47	M	67	N	N	N	N
48	M	61	Md	S	Ml	S
49	M	70	S	S	S	S
50	M	48	N	N	N	N
51	M	83	Ml	N	Ml	N
52	F	67	N	N	N	N

Table 1 continued

			MDCTA		DSA	
No	Sex	Age	Right	Left	Right	Left
53	M	74	Ml	Ml	Ml	Ml
54	F	47	N	N	N	N
55	M	77	S	S	S	S
56	F	55	N	N	N	N
57	M	71	S	Md	S	Ml
58	M	75	Ml	Ml	Ml	Ml
59	M	63	Ml	N	N	N
60	M	61	N	N	N	N
61	M	61	Ml	N	N	N
62	M	76	S	Ml	S	N
63	M	80	N	Md	N	Md
64	F	28	N	N	N	N
65	M	75	S	Md	S	Md
66	M	60	N	N	N	N
67	M	56	N	Ml	N	N
68	M	80	N	Ml	N	N
69	M	53	N	Ml	N	Ml
70	M	74	N	Md	N	Ml
71	M	40	N	N	N	N
72	M	57	N	N	N	N
73	M	38	N	N	N	N
74	M	60	Ml	N	N	N
75	F	67	N	Ml	N	N
76	M	75	O	N	O	N
77	F	58	N	N	Ml	N
78	M	65	N	N	N	N

MDCTA: Multidetector computed tomography angiography; DSA: Digital subtraction angiography; N: Normal; Ml: Mild; Md: Moderate; S: Severe; O: Occluded.

Statistical analysis

Renal artery lesions were grouped as normal (<10%), mild (11-49%), moderate (50-70%), severe (70%<), and occluded. Both MDCTA and DSA findings were compared for detection of renal arterial lesions (stenosis and occlusion) and for determining the degree of stenosis. Digital subtraction angiography was accepted as the gold standard modality and sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy rate (AR) were calculated.

RESULTS

Fifty-one (65.4%) patients were referred for RVH evaluation, and 27 (34.6%) patients were referred for abdominal aortic aneurysm evaluation. Demographic data of the patients is given in table 1.

Table 2. Comparison of the MDCTA findings with DSA findings

	DSA		
	RAL (+)	RAL (–)	*Total*
MDCTA			
RAL (+)	74	11	85
RAL (–)	2	69	71
Total	76	80	156

RAL: Renal arterial lesion including stenosis and occlusions; MDCTA: Multidetector computed tomography angiography; DSA: Digital subtraction angiography.

In 78 patients a total of 156 renal arteries (78 left, 78 right) were evaluated with both MDCTA and DSA. Multidetector computed tomography angiography showed 85 renal arterial lesions, and DSA showed 76 (Table 2). Multidetector computed tomography angiography revealed 71 (45.5%) normal, 79 (50.7%) stenotic, and six (3.8%) occluded arteries. Digital subtraction angiography revealed 80 (51.3%) normal, 70 (44.9%) stenotic, and six (3.8%) occluded arteries. Sixty-nine arteries were normal; 20 were mildly stenotic, 11 were moderately stenotic, 29 were severely stenotic, and six were occluded on both modalities (Figure 1-3). Eleven arteries that had mild (n=8), moderate (n=2), and severe (n=1) stenosis on MDCTA were found to be normal in DSA (Figure 1, 4). Two arteries were normal in MDCTA while one was mildly stenotic, and one was moderately stenotic in DSA. Six arteries were moderately stenotic at MDCTA while all were mildly stenotic in DSA. One artery was severely stenotic in MDCTA while it was moderately stenotic in DSA (Table 3).

These findings revealed 97.4% sensitivity, 86.3% specificity, 87.1% PPV, 97.2% NPV, and 91.7% AR for

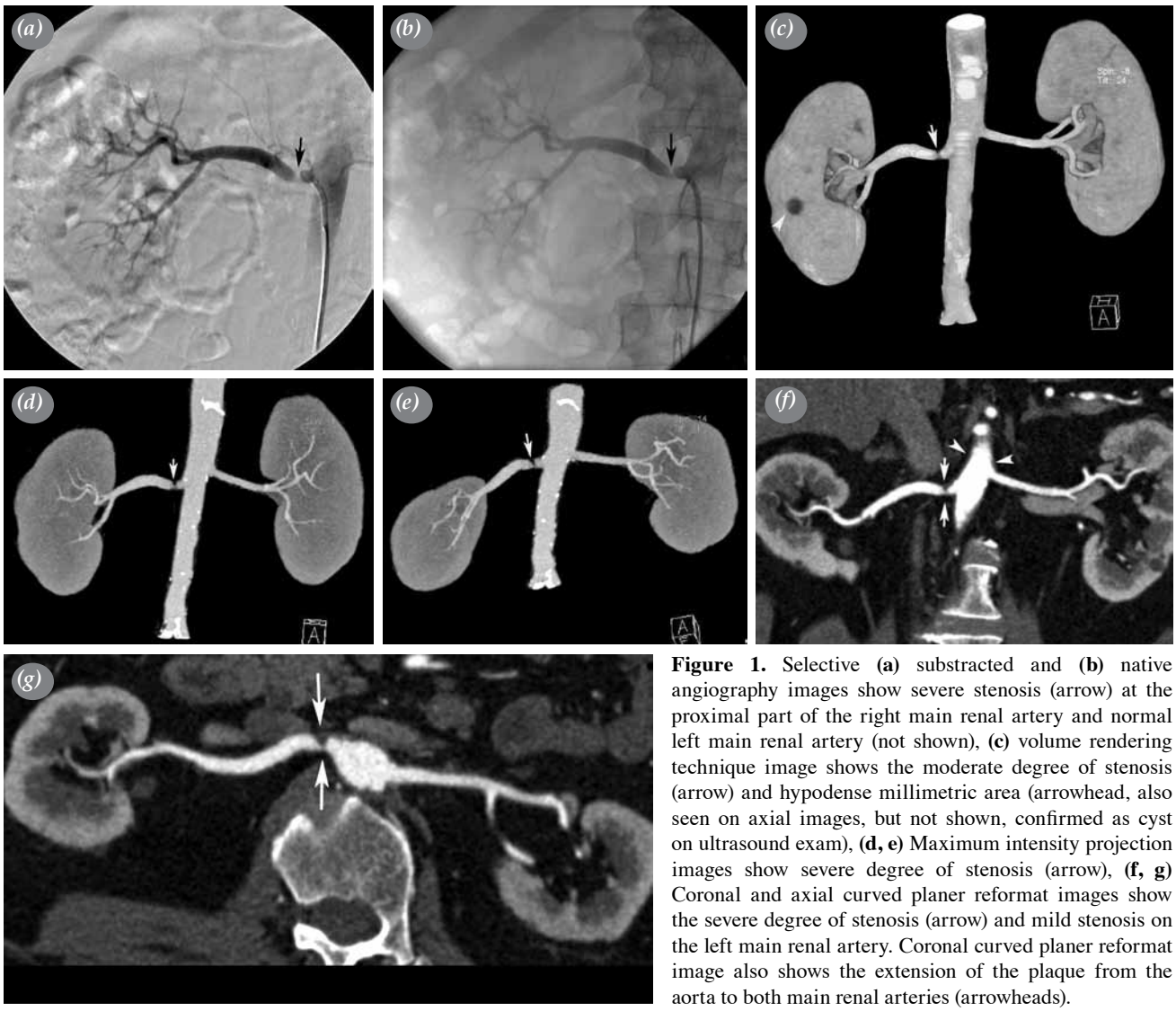

Figure 1. Selective **(a)** substracted and **(b)** native angiography images show severe stenosis (arrow) at the proximal part of the right main renal artery and normal left main renal artery (not shown), **(c)** volume rendering technique image shows the moderate degree of stenosis (arrow) and hypodense millimetric area (arrowhead, also seen on axial images, but not shown, confirmed as cyst on ultrasound exam), **(d, e)** Maximum intensity projection images show severe degree of stenosis (arrow), **(f, g)** Coronal and axial curved planer reformat images show the severe degree of stenosis (arrow) and mild stenosis on the left main renal artery. Coronal curved planer reformat image also shows the extension of the plaque from the aorta to both main renal arteries (arrowheads).

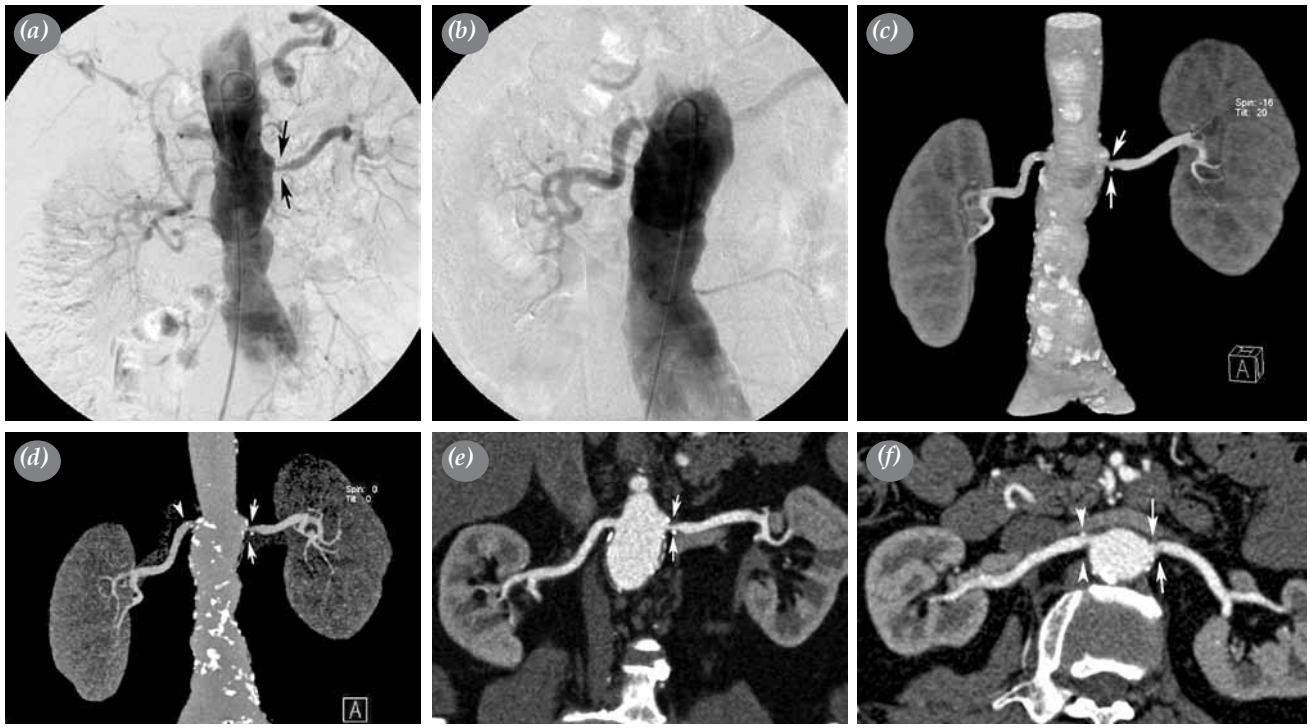

Figure 2. Abdominal aortogram **(a, b)** shows severe osteal stenosis (arrows) at the left main renal artery and mild osteal stenosis on the right, **(c)** volume rendering technique image shows the severe degree of stenosis (arrows), but normal right renal artery, **(d)** Maximum intensity projection image shows the severe degree of stenosis (arrows) and renal artery wall calcification on the right (arrowhead), **(e, f)** Coronal and axial curved planer reformat images show the severe degree of stenosis (arrow) on the left and show mild osteal stenosis (arrowheads) on the right.

the MDCTA in detecting renal arterial lesions, including stenosis and occlusions. For determining the degree of stenosis, the sensitivity, specificity, PPV, NPV, and AR values were found to be in the range of 74.1-100%, 93.7-100%, 55-100%, 94.5-100%, 90.4-100%, respectively (Table 4).

DISCUSSION

The early diagnosis and treatment of renovascular hypertension, a relatively rare cause of hypertension, has significantly reduced the development of cardiovascular diseases, renal failure, and cerebrovascular events in critical patients. Since DSA is still accepted as the gold standard method, screening of hypertensive patients with an invasive method would not be appropriate. However, considering the presence of a treatable serious complication, the determination or elimination of stenosis is very important.[16]

The MDCTA has become one of the most preferred, non-invasive methods for evaluating many arterial systems in the body. Rapid developments in CT technology, like MDCT usage, is eliminating the need for the conventional spiral CT to evaluate arterial systems. With MDCT, a larger volume can be scanned in less time with higher spatial resolution using less contrast agents. This may facilitate multiplanar reconstructed and reformatted images.[14,17]

Evaluation of axial images with reformatted images, such as MIP, volume rendering technique (VRT) and CRP, facilitates clearer evaluation and helps to determine details not previously seen.[14,18] However, arteries evaluated with only VRT or MIP images can lead to exaggerated results with inner lumen stenosis and calcifications.[18] Only using the axial images to evaluate tortuous vessels may lead to false positive results.[19] Johnson et al.[20] compared the MIP and VRT protocols with DSA for renal arterial stenosis of over 50% in 25 patients and reported the sensitivity and specificity as 94% and 87% versus 89% and 99%, respectively. They also reported that combining both protocols increases the sensitivity and specificity. Rubin et al.[21] also reported the sensitivity and specificity for MIP protocol in determining the renal arterial stenosis of over 70% in 31 patients as 92% and 83%, respectively. Although Saba et al.[22] suggested that the best performance for the study of the renal arteries was given by MIP and VRT, they did not correlate the results with DSA.

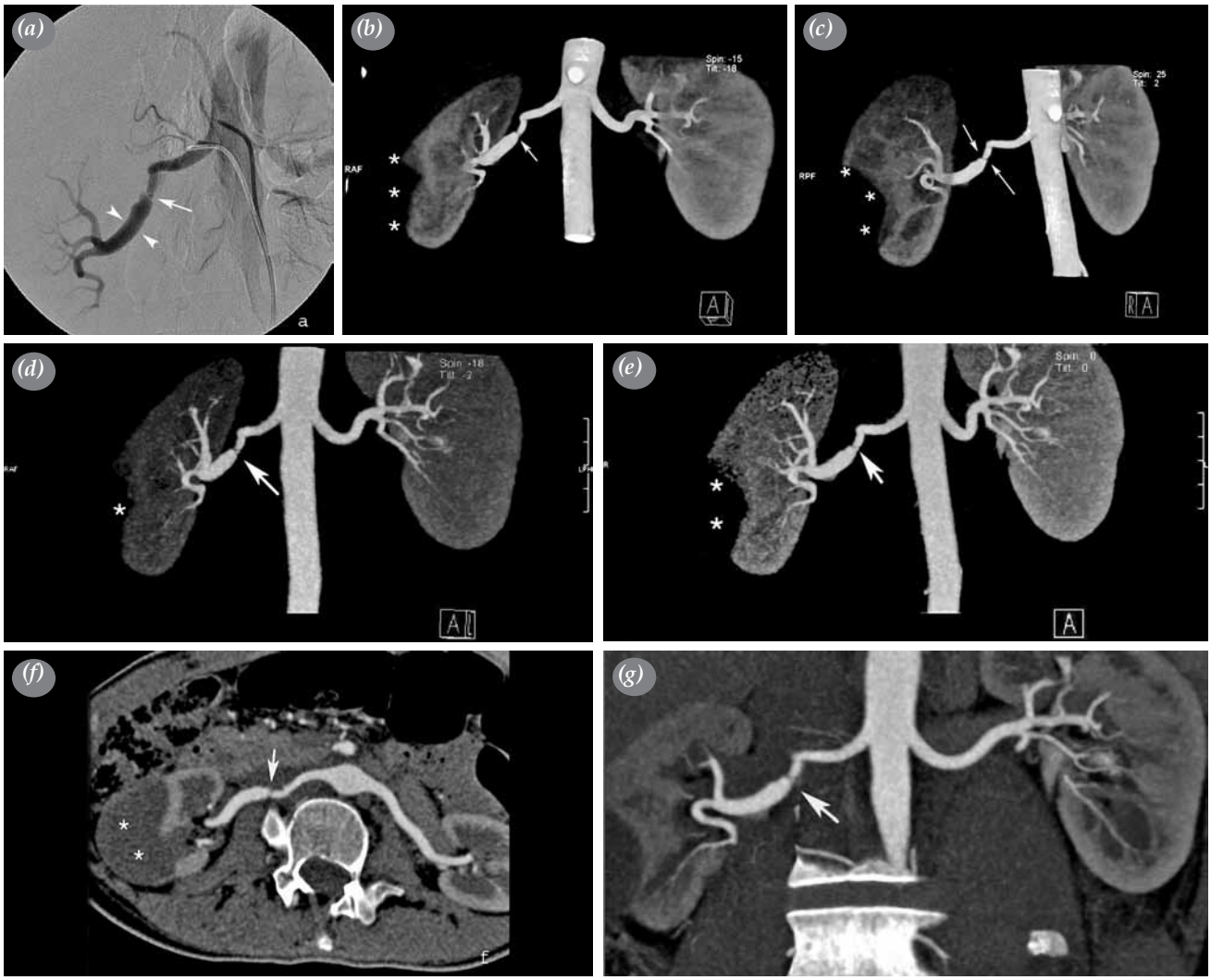

Figure 3. (a) Selective right renal angiogram shows severe stenosis (arrow) in the mid portion of the right main renal artery and post-stenotic dilatation (arrowheads), **(b, c)** volume rendering technique images show the severe degree of stenosis (arrow), post-stenotic dilatation, and normal left main renal artery, **(d, e)** Maximum intensity projection images show the severe degree of stenosis (arrow), post-stenotic dilatation, and normal left main renal artery, **(f, g)** Coronal and axial curved planer reformat images show the severe degree of stenosis (arrow), post-stenotic dilatation, and normal left main renal artery, On all reformatted computed tomography images, there is a cortical defect at the right kidney that may be the result of a sequel (asterix).

Prokop[23] suggested a bolus triggering technique for optimal imaging of the renal arteries and for the evaluation of axial images with MIP and VRT reformatted images. He reported sensitivity, specificity, and NPV as 90%, 98% and 95%, respectively. Hahn et al.[24] evaluated 63 renal arteries with MDCTA and DSA, and they reported sensitivity, specificity, PPV, and NPV as 90%, 98%, 90% and 98%, respectively. Fraioli et al.[25] compared the diagnostic value of MDCT with DSA for the detection and quantification of both main and accessory renal artery stenosis in patients with secondary hypertension, and they reported 100% sensitivity, 97.3% specificity, 97.8% AR, 98.2% PPV, and 97.8% NPV for 50%-100% luminal narrowing. They concluded that MDCTA is very accurate and robust, even for the assessment of renal artery stenosis and that it has the potential to become a viable substitute, in most cases, for diagnostic, catheter-based DSA.

There are many reports in the literature that confirm the sensitivity and specificity of the MDCTA / CTA being as high as 97-100% compared to DSA.[9,20,26-31] Vasbinder et al.[26] in one of the largest reported series, studied the accuracy of the MDCTA and MRA by comparing the findings with DSA for the diagnosis of renal artery stenosis in 356 patients. They reported

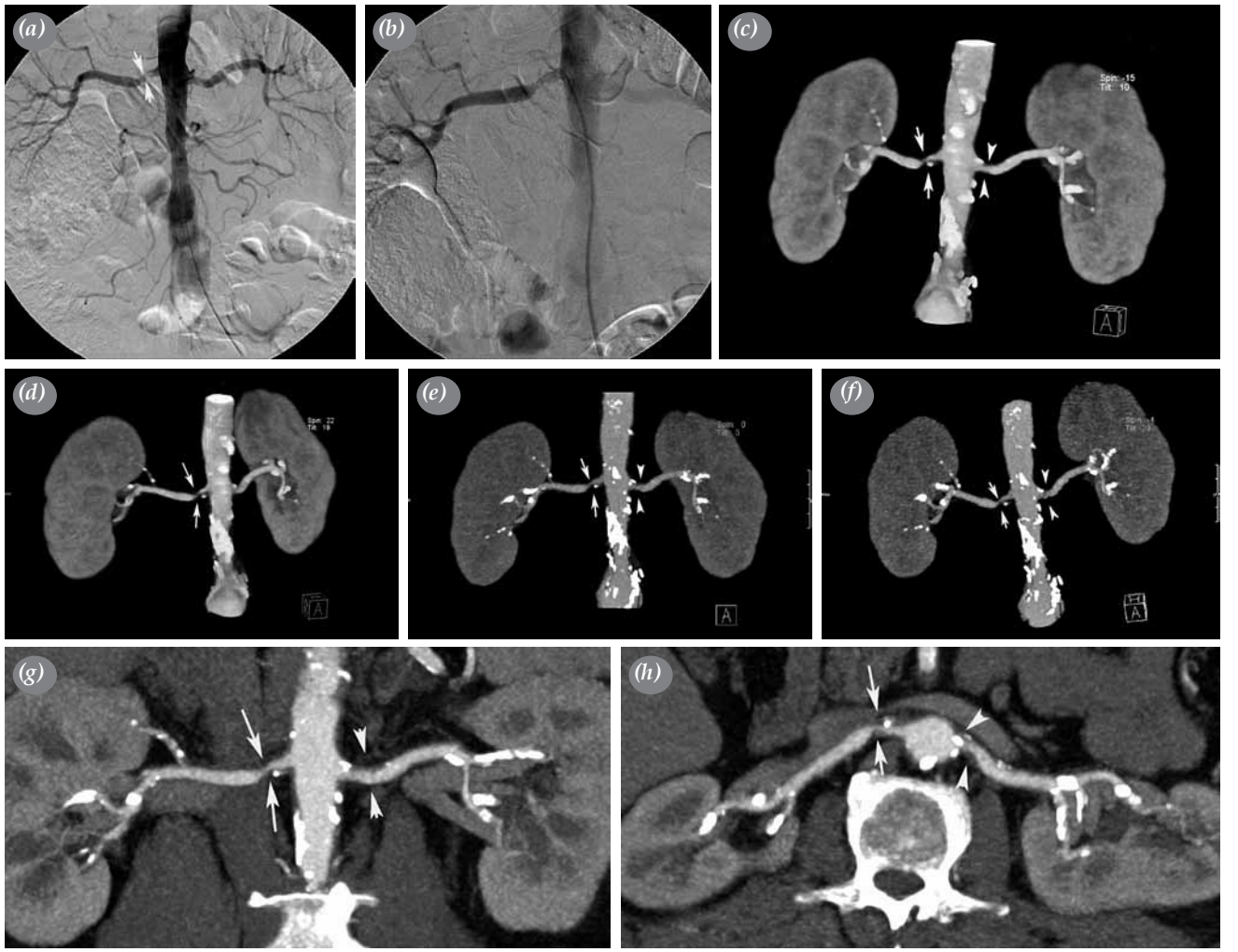

Figure 4. Abdominal aortogram **(a)** shows moderate-severe stenosis at the proximal part of the right main renal artery and normal left main renal artery, **(b)** selective right main renal artery angiogram shows severe stenosis (arrow), **(c, d)** volume rendering technique image shows the severe degree of stenosis (arrow) and mild osteal stenosis at the left main renal artery (arrowhead), **(e, f)** Maximum intensity projection images show the severe degree of stenosis on the right and moderate degree of stenosis on the left, **(g, h)** Coronal and axial curved planer reformat images show the severe degree of stenosis (arrow) on the right and moderate stenosis on the left.

20% of the patients had 50% or more stenotic segments in all three methods and reported the sensitivity and specificity for MDCTA is 64% and 92% while for MRA it is 62% and 84% respectively. They pointed out that technical insufficiencies, lack of experience in grading the stenosis, and poor patient selection might be reasons for the low sensitivity results.

In our study, we used a bolus triggering technique, and all renal arterial branches were clearly visualized and evaluated. We compared MDCTA findings with DSA findings in the evaluation of RAS and the determination the degree of stenosis. For detection of renal arterial lesions, the overall sensitivity was 97.4%, specificity was 86.3%, PPV was 87.1%, NPV was 97.2%, and AR was 91.7%. In three patients, renal arteries were moderately and severely stenotic in MDCTA while normal in DSA (Figure 3). In two patients, false positive results were attributed to obesity in one patient and tortuosity of the vessel in the other. We believe that in the case of obesity, modifying the examination parameters (kV and mA) may prevent such false positive results. In the latter case, the reason may be a lack of experience. We established that CPR images are more helpful than VRT images in determining stenosis, especially in tortuous anatomy, if processed both in axial and in coronal planes. Also, evaluating axial images with CPR and MIP images facilitates the diagnosis of stenosis and determines the degree of stenosis more accurately than evaluation with axial images or MIP images alone. Nevertheless, it should be kept in mind that experience in image

Table 3. Correlation of the degree of stenosis between the multidetector computed tomography angiography and digital subtraction angiography findings

	Digital subtraction angiography					
	Normal	Mild	Moderate	Severe	Occluded	*Total*
MDCTA						
Normal	69	1	1	0	0	71
Mild	8	20	0	0	0	28
Moderate	2	6	11	1	0	20
Severe	1	0	1	29	0	31
Occluded	0	0	0	0	6	6
Total	80	27	13	30	6	156

MDCTA: Multidetector computed tomography angiography.

Table 4. Statistical parameters in the degree of stenois

	%				
	Mild	Moderate	Severe	Occluded	Overall
Sensitivity	74.1	84.6	96.6	100	97.4
Specificity	93.8	93.7	98.4	100	86.3
Positive predictive value	71.4	55.0	93.5	100	87.1
Negative predictive value	94.5	98.5	99.2	100	97.2
Accuracy rate	90.4	92.9	98.1	100	91.7

Table 5. Distribution of the lesions after unifying the normal, mild and moderate degree of stenosis groups in multidetector computed tomography angiography and digital subtraction angiography

	Digital subtraction angiography			
	Normal, mild, moderate	Severe	Occluded	*Total*
MDCTA				
Normal, mild, moderate	118	1	0	119
Severe	2	29	0	31
Occluded	0	0	6	6
Total	120	30	6	156

MDCTA: Multidetector computed tomography angiography.

post-processing is very important, especially in CPR images; the degree of stenosis may be upgraded or downgraded if image post-processing is done only in one plane.

There were also differences between MDCTA and DSA modalities in determining the degree of stenosis in the renal arteries (Table 3). For grading the stenosis with MDCTA, sensitivity was found to be in the range of 74.1-100%, specificity in the range of 93.7-100%, PPV in the range of 55-100%, NPV in the range of 94.5-100%, and AR values in the range of 90.4-100% (Table 4).

If the stenosis classification is rearranged according to the therapeutic approach criteria (medical therapy for ≤70% stenosis and surgical or interventional therapy for >70% stenosis), normal, mild, and moderate groups would be considered as one group (Table 5). After reclassification of the groups, sensitivity, specificity, PPV, NPV, and AR were found to be 98.3%, 97.2%, 99.2%, 94.5%, and 98.1%, respectively. These results show that sensitivity, specificity, PPV, NPV, and AR increased as the degree of stenosis increased. Reevaluation of the groups following reclassification according to the therapeutic approach criteria showed that the degree of stenosis was upgraded in three renal arteries and downgraded in one renal artery in MDCTA. Patients with upgraded results may undergo an angiographic procedure that will clearly delineate the degree of stenosis and may lead to a reliance on medical therapy instead of interventional therapy. The downgraded result may lead to a preference for medical therapy instead of interventional or surgical therapy which may increase the degree of ischemic

nephropathy. It is obvious that misgraded results will cause a delay in the appropriate therapy to be scheduled, and we believe it may not only be related to technical reasons, but also to the experience of the reporters.

As a result, we think MDCTA may be preferred as a noninvasive modality during the investigation or evaluation of RVH, RAS and also for the therapeutic planning of RAS. In addition, it will become an alternative to the DSA with high sensitivity, specificity, and accuracy as MDCT technology and image post-processing software continue to develop.

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