AJH 1997;10:957–963

Magnetic Resonance Angiography Has a High Reliability in the Detection of Renal Artery Stenosis

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In this prospective study we examined the value of magnetic resonance angiography (MRA) in the imaging of the proximal renal arteries, with the main aim of detecting renal arterial stenosis, as compared with intraarterial digital subtraction angiography.

The study was done among a group of 38 hypertensive patients seen in the outpatient department of the department of medicine of our university hospital. In all patients a magnetic resonance angiography and an intraarterial subtraction angiography of the renal arteries was made, and the outcomes of the investigations were compared. Clinical and biochemical data of the patients also were analyzed in relation to the presence or absence of a stenosis.

In one patient, MRA resulted in technical failure because of unsuspected claustrophobia. Of the remaining 37 patients, 14 had renal artery stenosis. Of 12 patients in whom the stenoses were >50% of luminal surface on intraarterial digital subtraction angiography, eight were unilateral and four bilateral. All these stenoses were recognized by magnetic resonance angiography. There was also one false positive result by magnetic resonance. Thus, for the identification of stenoses >50%, magnetic resonance has a sensitivity of 100% and a specificity of 96%. Of the 12 accessory renal arteries seen on digital subtraction angiography, only three were identified by magnetic resonance angiography.

We conclude that magnetic resonance angiography has great accuracy in depicting the main renal arteries and detecting clinically significant renal artery stenosis; however, the identification of accessory renal arteries is suboptimal and should be improved. Am J Hypertens 1997;10:957–963 © 1997 American Journal of Hypertension, Ltd.

KEY WORDS: Hypertension, renal artery stenosis, magnetic resonance angiography, diagnostic tests.

Hypertension caused by lesions of the renal vasculature remains among the most common forms of secondary hypertension, particularly in the elderly population. In addition, renal insufficiency caused by renal vascular lesions is regularly encountered in clinical medicine. Therefore, identification of renal arterial pathology continues to present a major clinical issue, especially because there are several treatment options for these conditions. Successful treatment means either cure or improvement of high blood pressure or restoration of renal function. Depending on the pa-

Received July 15, 1996. Accepted February 24, 1997.

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0895-7061/97/$17.00
PII S0895-7061(97)00157-X

thology of the stenosis, either cure or improvement of high blood pressure, or restoration of renal function, is accomplished in 50% to 90% of patients in whom a renal artery stenosis (RAS) is relieved.[1] Especially among patients with atherosclerotic stenoses the percentage of patients that profit from treatment of the stenosis is around 50%, which does not seem high enough to warrant screening for RAS in the general hypertensive population.[1,2] However, among subgroups of patients such as those with treatment-resistant hypertension, it is worthwhile to look for RAS, both because the prevalence among such a group is relatively high and also because the treatment resistance of the hypertension renders these patients candidates for treatment of a possibly present stenosis.[1–3]

To date, the definitive diagnosis of RAS depends on its demonstration by arterial angiography. However, angiography involves arterial puncture and the use of contrast material, which, particularly in the case of renal insufficiency, has an option for further deterioration of renal function while it also poses the risk of anaphylactic reactions.

Other presently available procedures, for which the use of contrast media or arteriotomy is not necessary, lack accuracy in the recognition of RAS.[3–8] The most consistent results in this respect have been accomplished with captopril renography, but the overall sensitivity of this procedure[9] does not surpass 75% to 80%. Thus, about 25% of patients with RAS would go undiagnosed if the clinician based patient management on the results of renography. In the case of renal failure or a solitary kidney, the results of capropril renography are even worse.[9] Therefore, a noninvasive and more sensitive technique would be of great clinical value. Magnetic resonance angiography (MRA) has the ability to image blood vessels, including renal arteries, without the use of contrast, and is noninvasive.[10–13] MRA could therefore be a valuable tool in the diagnosis of RAS if its accuracy proved to be sufficiently high. In a previous study of the value of MRA in the diagnosis of RAS, in comparison with intraarterial digital subtraction angiography (DSA) we found, however, a rather low sensitivity of MRA in the recognition of RAS—too low, at least, to permit its use in clinical practice.[14]

Recent developments in MRA procedures and applications software may enable a greater sensitivity. Therefore we set up another prospective study to compare MRA with intraarterial DSA to investigate whether the increased sensitivity of recent MRA techniques is sufficient to detect clinically significant renal artery stenosis.

METHODS

Included in the study were hypertensive patients seen at their first visit to the outpatient department. If a DSA was deemed necessary by the physicians responsible for the patients' care, these patients were included in the study upon informed consent. The indication for a DSA was usually made on the grounds of a baseline untreated supine diastolic blood pressure >110 mm Hg or of the presence of treatment-resistant hypertension, defined as a supine diastolic blood pressure >90 mm Hg despite adequate two-regimen antihypertensive treatment. Apart from blood pressure, other clinical characteristics of the patients such as weight, age, height, and biochemical data were gathered. Endogenous creatinine clearance was calculated according to a previously described method in which age, gender, and weight are taken into account.[15]

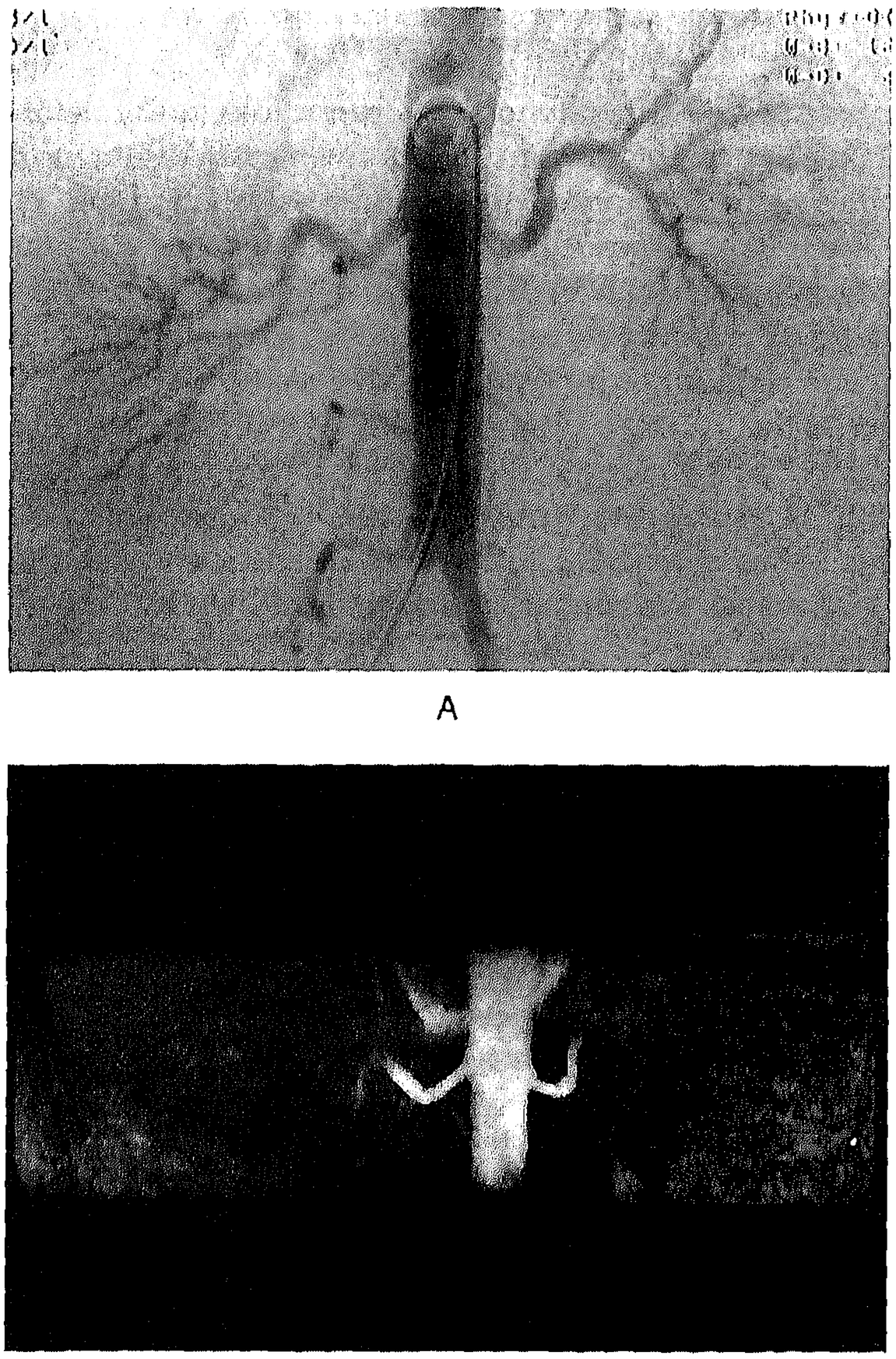
The DSA was done using the Seldinger technique with a 5F catheter. The catheter was positioned at the level of the renal arteries. DSA of the abdominal aorta in the 10° left anterior oblique view and 10° right anterior oblique view were routinely performed with 50 mL of 30% methylglucamine diatrizoate for each projection. These studies were obtained with 3 images/sec and a 1024 × 1024 matrix.

This procedure was done as an outpatient investigation early in the morning. Directly after the DSA was done the patients were admitted to the day care center of the outpatient department where they were observed in order to detect complications of the procedure. If no complications ensued, the patients were again dismissed after 5 h of supine rest. The MRA examination was usually done 1 week prior to the DSA.

MRA was done with a 1.5 T magnetic resonance imager (Siemens, Erlangen, Germany) using a body coil. The images were acquired during shallow respiration. To localize the renal arteries 5 scout images flash-2D (Repetition time/Echo time [TR/TE] 70/6 msec) were obtained in the coronal projection. This was followed by a third time-of-flight sequence (TONE) with scanning parameters of TR 29 msec, TE 7 msec, 20° flip angle, 192 × 256 matrix, 45 cm field of view, and two excitations.

Sections of 1.2 mm were obtained in the axial plane from the superior pole to the bifurcation of the aorta. Maximum-intensity projections of the source phase-contrast images were generated by scanner software after drawing regions of interest to include the visualized vessels in the axial imaging plane. The initial protocol foresaw in one three-dimensional image volume that resulted in an image that showed the main renal arteries and approximately 3 cm above and below the orifices of the main renal arteries.

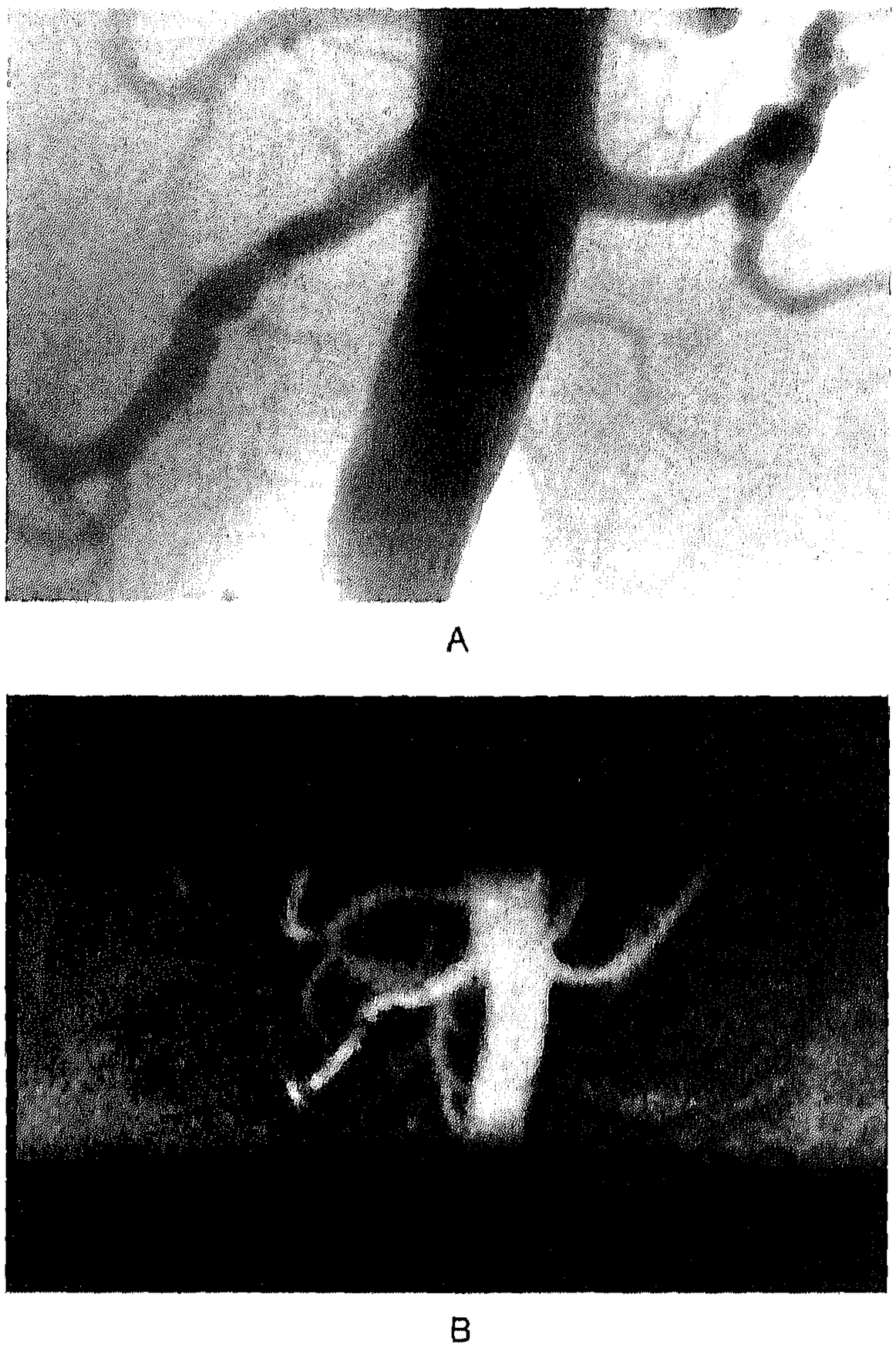
The usual precautions were taken not to include patients with standard contraindications to MRA, such as metal parts in their body, which could pose a threat in the high power magnetic fields. The angiograms and the MRA images were independently eval-



A

B

FIGURE 1. *Arterial digital subtraction angiography of two renal arteries without stenosis* (**A**) *and magnetic resonance angiography of the same arteries without signs of stenosis* (**B**).



A

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FIGURE 2. *Arterial digital subtraction angiography of two renal arteries showing an irregular wall with mild stenotic segments of the right artery in accordance with fibromuscular dysplasia* (**A**) *and magnetic resonance angiography of the same arteries showing an inhomogeneous signal in the right artery indicating mild stenotic segments suspect for fibromuscular dysplasia* (**B**). *No lesions are noticeable of the left artery.*

uated by experienced radiologists who were unaware of the clinical histories of the patients.

Each DSA was evaluated by two radiologists who had to reach consensus. Stenoses were graded in steps of 10%; thus, the vessel diameter was measured at the point of the stenosis and proximal and distal to the stenosis (and distal to a poststenotic dilatation). The percentage of the stenosis was computed according to the relationship between the vessel diameters at these points. Results were divided into normal or minimal stenosis (≤20%), mild (30% to 50%), severe (>50%), and occlusion. Assessment of renal arteries included evaluation of main arteries and determination of the number and abnormalities of accessory arteries.

The magnetic resonance (MR) angiograms were also evaluated by two radiologists. The renal arteries were graded as normal if the vessel signal was high and homogenous (Figure 1). Reduction of vessel diameter without complete loss of signal intensity was judged to be mild stenotic with a luminal obstruction of ≤50% (Figure 2). Signal intensity loss with or without distal recovery of flow signal intensity was graded as severe stenosis (≥60%) (Figure 3).[24] Thus, by MRA no distinction was made between severe stenosis and occlusion of the artery on the basis of whether there was signal recovery after initial signal intensity loss. In the overall analysis we distinguished only whether or not a significant stenosis was present, which was defined as a stenosis >50%.

RESULTS

A total of 38 patients were included in the study. The clinical characteristics of the patients are shown in

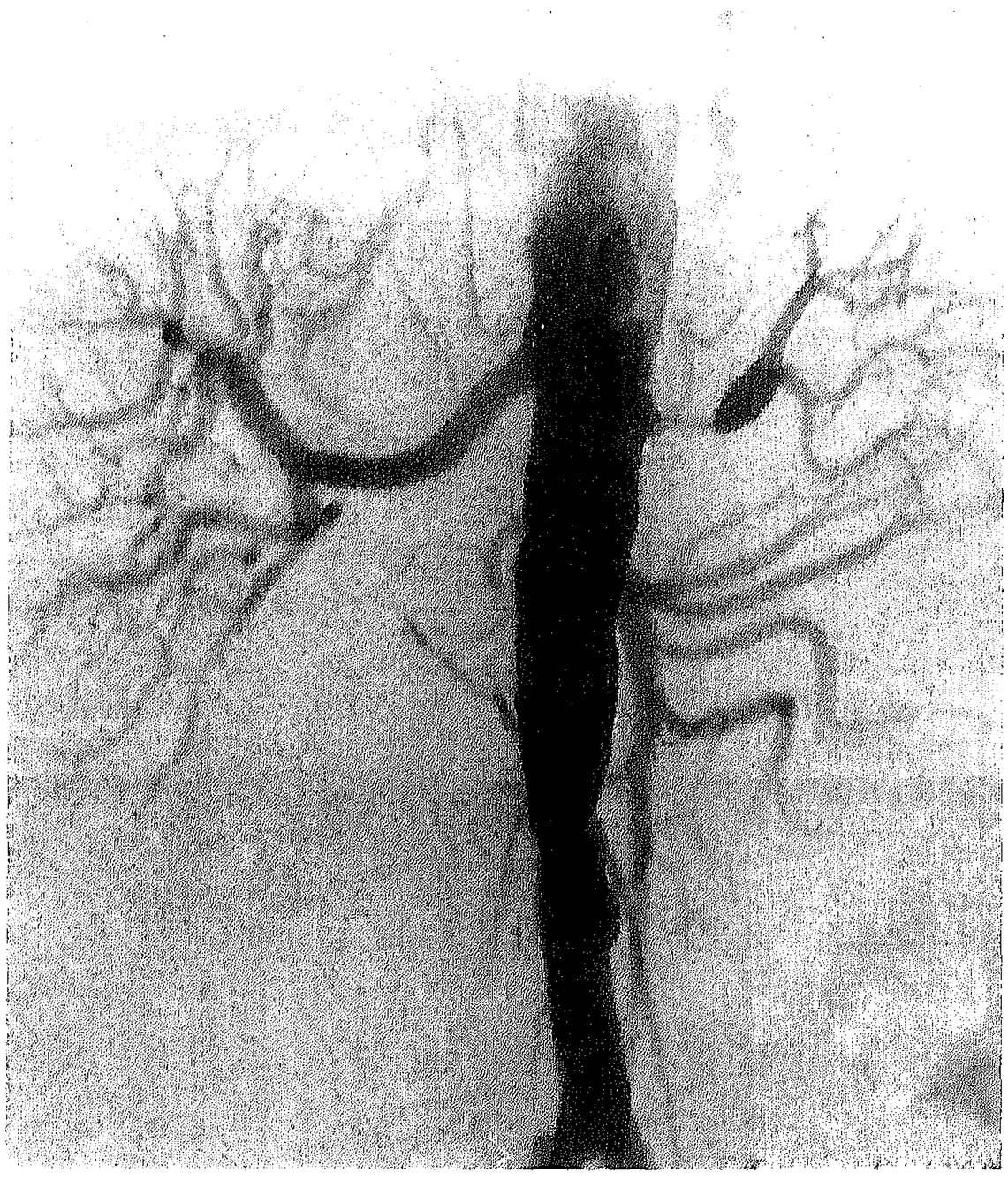

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FIGURE 3. *Arterial digital subtraction angiography of two renal arteries showing a severe stenosis of the left renal artery with post stenotic dilatation* (**A**). *Magnetic resonance angiography of the same vessels showing a normal signal intensity in the right renal artery and in the left renal artery complete signal loss with distal recovery of the signal* (**B**).

Table 1. In all patients an arterial digital subtraction angiography was done. In three patients the procedure was complicated by an inguinal hematoma that subsided uneventfully. In one patient the MRA investigation failed because of unforseen claustrophobia. Thus, the results of MRA and DSA of 37 patients were able to be compared. Of these 37 patients, 14 had RAS on DSA, four bilateral stenoses, and 10 unilateral stenoses. Five of the stenoses were radiologically determined to be of fibromuscular dysplastic origin, and nine were considered to be atherosclerotic (Table 2). One of the fibromuscular dysplastic stenoses was also identified as such by MRA (Figure 2). The characteristics of the subjects with a stenosis, as compared with those without, are noted in Table 1.

Of the 10 unilateral stenoses, two demonstrated a <30% narrowing of the arterial luminal surface on intraarterial arteriography. These stenoses were also identified by MRA, but one was assessed as being >50% and was therefore considered a false positive outcome.

The 12 stenoses >50% on DSA, four bilateral, and eight unilateral, were all also recognized by MRA (Tables 2 and 3). The bilateral stenoses were also identified as such by MRA (Tables 2 and 3). For the stenoses >50%, MRA had a sensitivity of 100% and a specificity of 96%. One patient had a small ostial aneurysm of the left renal artery, which could also be seen by MRA.

DSA identified 12 accessory renal arteries, of which only three were recognized by MRA. Five of the accessory renal arteries were localized within 3 cm above or below the main renal arteries; of these, three were seen on MRA. Seven accessory arteries were localized beyond 3 cm above or below the main renal arteries, and none of these was recognized by MRA.

Image Quality This MRA protocol, which included in the first 14 patients only one three-dimensional slab and later was extended with an additional slab to cover the whole distal abdominal aorta, resulted in 33 moderate-to-good studies and four poor studies. The poor quality was characterized by a poor signal from the vessels and many artifacts that seriously hampered the MIP images.

On MRA 67 main renal arteries were visible, seven main renal arteries were not seen because of a significant stenosis or an obstruction. The same vessels were all visible on DSA; there were no occlusions on DSA. Only 14 renal arteries were visualized at a length of >3 cm. All detected stenoses were located directly near the orifice of the main renal artery or within 3 cm of the aorta. The visualized part of the abdominal aorta was <4 cm caudally from the main renal arteries in 17 studies, in the patients involved, six accessory renal arteries were present of which five were missed by MRA. In the 20 studies that covered more than 4 cm of the distal abdominal aorta, six accessory renal arteries also were noted, of which four were missed by MRA.

TABLE 1. CLINICAL CHARACTERISTICS OF THE PATIENTS. A DIAGNOSIS OF ESSENTIAL HYPERTENSION (NO STENOSIS OR OTHER SECONDARY HYPERTENSION PRESENT) OR RENAL ARTERY STENOSIS (RAS) WAS BASED ON THE RESULTS OF THE DSA STUDY OF THE RENAL ARTERIES

	All Patients (n = 38)	EH (n = 24)	RAS (n = 14)
Sex (F/M)	19/19	12/12	8/6
Age (years)	52.2 (12.6)	50.9 (12.9)	54.5 (12.3)
Weight (kg)	76.8 (17.7)	79.8 (18.1)	71.1 (16.0)
Body mass index (kg/m^2)	26.9 (5.4)	27.6 (5.2)	25.7 (5.6)
Creatinine (μmol/L)	108 (56)	105 (59)	112.8 (50.5)
ECC (mL/min)	83.7 (38.4)	89.5 (37.8)	72.4 (38.6)
Systolic BP (mm Hg)	184 (28)	180 (30)	193 (22)
Diastolic BP (mm Hg)	105 (13)	104 (15)	108 (11)

Given are means and between brackets 1 SD. BP, blood pressure; ECC, endogenous creatinine clearance.[15] Between these groups there were no significant differences in the shown characteristics.

DISCUSSION

With the development of MRA, a noninvasive procedure to image the renal arteries has become available. In a previous study we found for MRA a sensitivity of 80% to detect RAS.[14] These results were reached by using time-of-flight sequences with the MR imaging. These sequences are slower and result in lesser contrast as compared with the techniques we used in the present study. With the application of these improved software techniques of MRA, the sensitivity we now found was 100% and the specificity 96%. These are very promising characteristics for the detection of a low-prevalence condition such as renal arterial stenosis among the general hypertensive population. Other studies gave comparable results with sensitivities ranging from 70% to 87%, although techniques and patients were not fully comparable with those in the present study.[16–21] Our study was done in the setting where a noninvasive, reliable examination procedure of the renal arteries is much needed: namely the outpatient clinic of the internal medicine department. Especially in patients with diminished renal function, the advantages of MRA can be fully exploited, because the use of potentially nephrotoxic contrastmaterial can be avoided. In our present study we were also able to make, in one patient, a distinction between atherosclerosis and fibromuscular dysplasia in the morphology of the stenosis (Figure 2). This is only possible if the stenosis is not >50% of luminal surface because, if the stenosis is >50%, there is signal intensity loss on MRA, by definition, and a distinction cannot be made. We have not made a special study of the ability of MRA to recognize the various types of morphology of renal artery stenosis, so firm conclusions cannot be

TABLE 2. CHARACTERISTICS OF THE STENOSES OF THE PATIENTS WITH A RENAL ARTERY STENOSIS

Patient No.	Age	DSA Pathology	DSA Grade	MRA
1	71	ATH	BL >50%	BL
2	54	FMD	UL right >50%	UL right
3	31	FMD	UL right >50%	UL right
4	64	FMD	UL right <50%	UL right
5	59	ATH	BL >50%	BL
6	61	ATH	BL >50%	BL
7	59	FMD	UL right >50%	UL right
8	56	ATH	UL right <50%	no stenosis
9	37	ATH	UL left >50%	UL left
10	59	ATH	UL left >50%	UL left
11	68	ATH	UL left >50%	UL left
12	47	ATH	UL left >50%	UL left
13	47	FMD	UL right >50%	UL right
14	70	ATH	BL >50%	BL

MRA, magnetic resonance angiography; DSA, digital subtraction angiography; BL, bilateral; UIL, unilateral; ATH, atherosclerotic; FMD, fibromuscular dysplasia. The grade and the pathology of the stenoses are determined on the images of the DSA.

TABLE 3. THE RESULTS OF MAGNETIC RESONANCE ANGIOGRAPHY (MRA) COMPARED WITH ARTERIAL DIGITAL SUBTRACTION ANGIOGRAPHY (DSA) IN 37 HYPERTENSIVE PATIENTS

	DSA	MRA
No stenosis	23	23
Stenosis <50%	2	1
Bilateral stenosis >50%	4	4
Unilateral stenosis >50%	8	9 (1 false positive)
Accessory renal arteries (number)	12	3

The resulting sensitivity of MRA in the detection of a renal arterial stenosis of greater than fifty percent is 100% and the specificity is 96%. The one false positive stenosis identified by MRA was a stenosis of less than 50% on DSA that was overestimated by MRA as greater than 50%.

drawn. However, the fact that it is possible to make a distinction between atherosclerotic and fibromuscular dysplastic lesions in some patients is promising, and invites further study in this respect.

The one repeatedly encountered, unfavorable aspect of the renal artery imaging by MRA is its inaccuracy in depicting supernumerary renal arteries with a reported maximum error rate[16–21] of 60%. This low sensitivity for accessory renal arteries and arterial branches makes MRA less reliable as a screening procedure in potential renal donors in whom it is important to have a complete picture of the renal arterial vessels before nephrectomy.[19,22] In hypertensive patients, as well, this is a shortcoming because a stenosis in an accessory artery is possible, although not very common. What might the reason for this low sensitivity for accessory renal arteries?

In our study, when the MR images and the DSA angiograms were directly compared, in four of nine initially false-negative MR images the accessory arteries could be identified. This illustrates that the accessory arteries are easily overlooked or are interpreted as lumbar arteries because, for most of these arteries, only a shallow image is present on MRA.

After the initial 14 patients in whom the protocol foresaw in only one slab, we changed the policy in order to visualize the whole distal abdominal aorta because we missed so many accessory renal arteries. This, however, did not result in a greater chance of detection of accessory renal arteries; more renal arteries were discovered in retrospect, so a learning curve and the difficult interpretation of MRA images are more likely the main reasons for the poor detection of supernumerary arteries. Better sequences of MRA, additional experience on the part of the radiologists, and thorough study of this aspect can probably also lead to better understanding of the depiction of the involved vessels and to an interpretation of the images that allows better recognition of renal accessory arteries in the future. These considerations render MRA not, as yet, completely reliable in the study of the renal vasculature. In the interpretation of the images, one has to be aware of this. Another confounding factor can be the presence of intraabdominal surgical clips because these can give rise to artifacts and even to false-positive findings of renal artery stenosis.[18,23]

An important point of consideration to the practical clinical value of MRA is that it gives no anatomical image of the lumen of the artery and, hence, a stenosis can not be quantified. It is also impossible to decide on the basis of the MRA what type of intervention (percutaneous transluminal angioplasty, stent placement, or surgical treatment of the stenosis) should be preferred. So, once a stenosis has been established by MRA, a DSA to determine the intervention strategy with regard to the stenosis is still required. However, a percutaneous transluminal angioplasty or stent placement can potentially be performed at the same setting.

The cost of the procedure, in our institution, is almost the same as that of DSA. Although the cost of the MRA itself is higher compared with DSA, the necessity of observation in the day care center, after the intraarterial investigation, makes the total cost of DSA as high as that of the MRA. Because of this cost, the still relatively great burden for the patient, and the low prevalence of renal artery stenosis among the general hypertensive population, MRA is not generally indicated (even given such high sensitivity) as a screening procedure. Preferably a high-prevalence group should be formed in which it is worthwhile to perform a screening procedure with such a high sensitivity. Among these patients, MRA can then be considered the method of choice to look for RAS, especially in selected groups of patients such as those with renal insufficiency. A population of hypertensives with a prevalence of renal artery stenosis >30% can be composed on the basis of blood pressure criteria such as a high baseline blood pressure or treatment-resistant hypertension.[6,8] In such a group, the probability of the prior presence of RAS is high enough to permit the application of such a screening procedure.

With regard to the main renal arteries, we conclude that the present MRA methodology has great accuracy in imaging the main renal arteries and detecting the presence of renal arterial stenosis. However, further improvement in the technique and related software, and further experience of radiologists, is necessary in order to reliably infer the presence or absence of accessory renal arteries.

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