Moving-Table MR Angiography of the Peripheral Runoff Vessels: Comparison of Body Coil and Dedicated Phased Array Coil Systems

A. Huber[1]
J. Scheidler[1]
B. Wintersperger[1]
A. Baur[1]
M. Schmidt[2]
M. Requardt[2]
N. Holzknecht[1]
T. Helmberger[1]
A. Billing[3]
M. Reiser[1]

OBJECTIVE. The aim of our study was to compare the signal-to-noise ratio and the diagnostic accuracy of moving-table MR angiography of the peripheral arteries with body coil and dedicated phased array coil systems.

SUBJECTS AND METHODS. Forty patients were examined with digital subtraction angiography and moving-table MR angiography with a 1.5-T MR imaging system either with a body coil (*n* = 20) or with a dedicated phased array coil (*n* = 20). The timing of contrast material was performed with real-time MR fluoroscopy.

RESULTS. For the iliac artery, upper leg, and lower leg, the mean values for signal-to-noise ratios were 56, 51, and 17, respectively, for the body coil, and 54, 74, and 64, respectively, for the dedicated phased array coil. For the body coil, sensitivity and specificity in identifying stenosis greater than 50% and occlusions were 100% and 96%, respectively, for the iliac arteries, and 100% and 96%, respectively, for the upper leg. For the dedicated phased array coil, sensitivity and specificity for stenosis greater than 50% and occlusions were 100% and 96%, respectively, for the iliac arteries, and 100% and 98%, respectively, for the upper leg. Sensitivity and specificity were inferior for the body coil (88% and 85%) compared with the dedicated phased array coil (100% and 96%) in the lower leg. A significant difference of the mean values of contrast-to-noise ratio was found before and after subtraction for the dedicated phased array coil and body-coil techniques (Student's *t* test, $p < 0.01$).

CONCLUSION. In comparison with the body coil, the dedicated peripheral phased array surface coil system improves signal-to-noise ratio for the upper and lower leg and diagnostic accuracy in the lower leg.

The gold standard for the imaging and assessment of the peripheral arterial system is digital subtraction angiography (DSA). DSA requires an arterial puncture and application of iodinated contrast media, which has the risk of nephrotoxicity and allergic reactions [1, 2], and involves exposure to ionizing radiation. Waugh and Sacharias [3] found an overall prevalence of systemic complications of 1.8% after collecting data from 2475 patients. Therefore, a noninvasive method that could replace invasive diagnostic angiography is desirable, especially in patients who have renal failure and who are at risk for allergic reactions to iodinated contrast media.

Gadolinium-enhanced three-dimensional (3D) gradient-echo MR angiography is a useful and accurate technique in imaging of the aorta and the iliac arteries [4, 5]. However, the field of view is restricted to a maximum of 40–50 cm. Two different techniques are used to image the peripheral vascular tree, in which a large field of view must be covered. First, the step-by-step technique with separate injections requires multiple repositioning of the patient, and second, the moving-table technique allows imaging of a large field of view during the application of one gadolinium bolus. The step-by-step technique can be performed with a body coil [6] or with a phased array coil [7–9]. The use of the phased array coil is especially advantageous in the lower leg.

With table movement, the entire aorta and iliac arteries [10, 11] or the peripheral vascular tree [12] can be examined. Ho et al. [12] used moving-bed infusion-tracking MR angiography to visualize the peripheral vascular tree with a single high-dose gadolinium bolus. A problem with moving-table MR angiography is the use of a body coil for two or three regions, which causes a low signal-to-noise ratio that may lead to a low diagnostic

Received August 5, 2002; accepted after revision October 11, 2002.

[1]Department of Clinical Radiology, Klinikum der LMU, Großhadern, Marchioninistr. 15, 81377 München, Germany. Address correspondence to A. Huber.

[2]Siemens AG, Medizintechnik, Henkestr. 127, 91052 Erlangen, Germany.

[3]Department of Surgery, Klinikum der LMU, Großhadern, 81377 München, Germany.

AJR 2003;180:1365–1373

0361–803X/03/1805–1365

accuracy in the lower leg arteries, where the vessels have a small diameter. Recently, dedicated phased array coil systems have become available for the peripheral arteries, which allow one to combine moving-table MR angiography with a surface coil technique. However, only limited experience with the dedicated peripheral vascular coils has been documented in the current literature [13–18]. Ruehm et al. [13, 14] used a lower extremity coil to image the peripheral arteries at two levels and to examine the lower extremity veins. Janka et al. [16] compared a step-by-step technique with separate contrast material injections and the phased array coil technique with a moving-table technique without the phased array coil technique

The aim of this study was to compare moving-table MR angiography at three levels with the body coil and dedicated peripheral coil systems. Both the signal-to-noise ratios and the diagnostic accuracy of the two techniques are compared in this study.

Subjects and Methods

Subjects

Forty consecutive patients with peripheral arterial occlusive disease, who ranged in age from 43 to 78 years (mean, 61 years), were included in our study. The indications for DSA were intermittent claudication (Fontaine grade IIb [19], $n = 31$) and rest pain (Fontaine grade III, $n = 9$). All patients underwent DSA within 7 days before or after moving-table MR angiography was performed. Twenty patients underwent moving-table MR angiography with a body coil technique, and another 20 patients underwent moving-table MR angiography with a dedicated phased array coil system. Written informed consent was obtained from all patients.

Conventional Angiography

In all patients, conventional angiography was performed using an angiographic unit (Integris 3000; Philips Medical Systems, Da Best, The Netherlands) with a programmable moving table and a digital subtraction technique (matrix, 1024 × 1024; field of view, 380 cm). A power injector was used for the administration of iodinated contrast material ([iopamidol] Solutrast 300; Bracco Byk Gulden, Konstanz, Germany). The flow rate was 15 mL/sec, and a dose of 125–200 mL was applied per patient. All angiographic procedures were supervised by experienced vascular radiologists. Conventional angiography was performed by puncturing the common femoral artery and placing the tip of a 4-French pigtail catheter in the distal aorta above the bifurcation. Both legs were examined in all patients using a nonselective injection in the distal aorta. The posteroanterior images were obtained at all levels by DSA. Oblique images were obtained in the pelvic region in all patients and, when necessary, in the proximal upper leg (seven patients). The results were documented on hard-copy images.

The results were assessed by two vascular radiologists, who were unaware of the results of MR angiography, in a consensus interpretation. The degree of stenosis was categorized using a 6-point scale (0, no stenosis; 1, stenosis with a narrowing in diameter of of 1–25%; 2, stenosis of 26–50%; 3, stenosis of 51–75%; 4, stenosis of 75–99%; and 5, complete occlusion).

MR Angiography

Contrast-enhanced 3D MR angiography was performed at three levels: first, in the iliac region and the proximal upper leg; second, in the middle and distal part of the upper leg and the knee region; and third, in the lower leg to the proximal foot.

Twenty patients were examined with the body coil, and 20 patients were examined with the dedicated peripheral surface coil (Fig. 1). The phased array body coil was used to image the pelvic region, and the dedicated peripheral surface coil was used to examine the upper and lower leg. The design of the dedicated phased array coil includes eight coil elements and four wings that can be wrapped around the patient's legs.

For the IV administration of contrast material, we injected gadopentetate dimeglumine (Magnevist; Schering, Berlin, Germany) via an 18-gauge needle into an antecubital vein using an MR-compatible injector (Liebel-Flarsheim, Sieg, Germany) with a three-phase application. First, 5 mL of contrast material was injected with a flow rate of 1 mL/sec, followed by 25 mL of gadolinium with a flow rate of 0.5 mL/sec, and, finally, 40 mL of saline with a flow rate of 0.5 mL/sec. The aim of the three-phase injection protocol was to achieve a high concentration in the arteries at the beginning of the scanning and to hold a high concentration with a slower injection rate without pushing the contrast material too quickly to the lower legs, where the deep veins could be enhanced too early.

For the timing of contrast material, we used a care bolus technique. This technique allows a real-time visualization of the abdominal aorta during repetitive measurements at the same coronal position with a T1-weighted two-dimensional gradient-echo sequence. MR angiography was started with a mouse-click by the operator when the arrival of the gadolinium-bolus was detected in the real-time fluoroscopy window.

The MR examinations were performed with a 1.5-T MR imaging unit (Magnetom Symphony; Siemens Medical Systems, Erlangen, Germany). After obtaining a multiplanar scout image including six slices with a fast imaging with steady-state free precession sequence, we positioned the 3D MR angiography slab as required by the anatomy of the vessel at each level.

For the pelvic region, the following parameters were used: coronal 3D slab with a field of view, 450 × 340 mm; thickness, 96 mm; matrix, 512 × 192; and number of slices, 64. Thus, the voxel size was $1.8 \times 0.9 \times 1.5$ mm^3 for the pelvic region. The acquisition time for the pelvic region was 23 sec, and the time to center of the k-space was 7.3 sec from the beginning of the acquisition.

For the upper leg, the following parameters were used: field of view, 450 × 300 mm; thickness, 75 mm; matrix, 512 × 192; and number of slices, 52. Thus, the voxel size was $1.6 \times 0.9 \times 1.4$ mm^3. The acquisition time was 22 sec, and the time to center of the k-space was 6.9 sec from the beginning of the acquisition. For both the pelvic region and the upper leg, the TR was 3.78, the TE was 1.37, and the bandwidth was 390 Hz/pixel.

For the lower leg, the following parameters were used: field of view, 450 × 300 mm; thickness, 65 mm; matrix, 512 × 192; and number of slices, 56. Thus, the voxel size was $1.3 \times 0.9 \times 1.2$ mm^3. The acquisition time was 26 sec, and the time to center of the k-space was 0.5 sec from the beginning of the acquisition. The reordering of k-space helps to avoid venous enhancement in the lower leg. For the lower leg, the TR was 4.45, the TE was 1.46, and the bandwidth was 390 Hz/pixel.

The 3D slab for the pelvic region had the largest thickness to cover the iliac arteries dorsally with their branching to the internal iliac arteries, and anteriorly, in the inguinal region, to the common femoral artery and the proximal parts of the superficial femoral artery. The slab for the upper leg was thinner and slightly angulated to cover the superficial

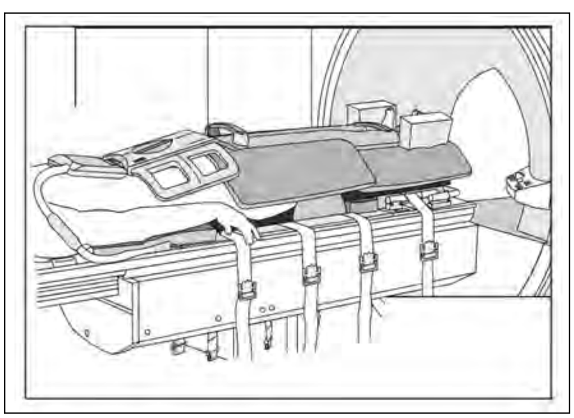


Fig. 1.—Drawing shows dedicated surface coil with flexible wings for upper and lower leg combined with body phased array coil for pelvic region.

femoral artery anteriorly and the popliteal artery posteriorly. The slab for the lower leg was strictly coronal. The three levels were imaged without contrast material before the same scanning was repeated after the application of contrast material. When the second scanning was started with a rerun function, no adjustment or sequence loading was necessary, despite the ability to plan the 3D slab individually and to choose the coil segments individually for each station. To achieve a sufficient contrast-to-noise ratio in spite of the use of only 30 mL of gadolinium, we used a subtraction technique before maximum-intensity-projection (MIP) reconstructions were calculated. The first data set was subtracted from the second data set at each level. Twenty MIP reconstructions over a 90° sector (–45° to 45°; 0° is the anteroposterior image) around the body axis were calculated for each subtracted data set.

Evaluation of MR Angiography

For both patient groups, the signal-to-noise ratio (signal intensity / SD_{noise}) and the contrast-to-noise ratio ([signal $intensity_1$ – signal $intensity_2$] / SD_{noise}) were determined for the pelvic region and for the upper and lower leg. The contrast-to-noise ratios were determined for the contrast-enhanced gadolinium data sets obtained with the body coil and the dedicated phased array coil systems. The contrast-to-noise ratios were determined for the unenhanced and contrast-enhanced data sets for both coil systems to determine whether a subtraction technique was necessary. The mean values were compared using the Student's *t* test.

Two radiologists, who were experienced in MR imaging and who were unaware of the DSA results, interactively evaluated both the MIP reconstructions and the single slices on a workstation, first independently and then in a consensus interpretation. The degree of stenoses and occlusions was determined as described for conventional angiography. Cohen's kappa value was calculated to determine the interobserver agreement. The following arterial vessel segments were included for the comparison of DSA and MR angiography results: the distal aorta; the common and external iliac arteries; the common, superficial, and deep femoral arteries; the popliteal arteries; the anterior and posterior tibial arteries; and the peroneal artery. To evaluate the diagnostic accuracy of MR angiography, we calculated sensitivity and specificity for all vessel segments.

Results

DSA

In the group of patients who were examined with MR angiography using the body coil, DSA identified 13 hemodynamically significant stenoses (with a narrowing of > 50% of vessel diameter) in the iliac arteries, 19 in the upper leg arteries, and 15 in the lower leg arteries. In addition, 10, 19, and 53 occlusions were detected on DSA, respectively. In the group of patients who were examined with MR angiography using the dedicated phased array coil, DSA identified 15 hemodynamically significant stenoses (with a narrowing of > 50% of vessel diameter) in the iliac arteries, 18 in the upper leg arteries, and 12 in the lower leg arteries. In addition, six, 21, and 56 occlusions were detected on DSA. These results were obtained from a consensus interpretation by two experienced vascular radiologists.

Contrast-Enhanced MR Angiography

Real-time MR fluoroscopy was sufficient for the timing of contrast material in 40 of 40 patients. The three-phase injection protocol allowed us to avoid deep venous enhancement in most patients. Enhancement of the superficial lower leg veins was observed in 11 of 20 patients with the body coil and in 12 of 20 patients with the dedicated phased array coil. The rotation of MIP reconstructions allows a clear view of the arteries in spite of enhancement of superficial veins in some patients in the lower

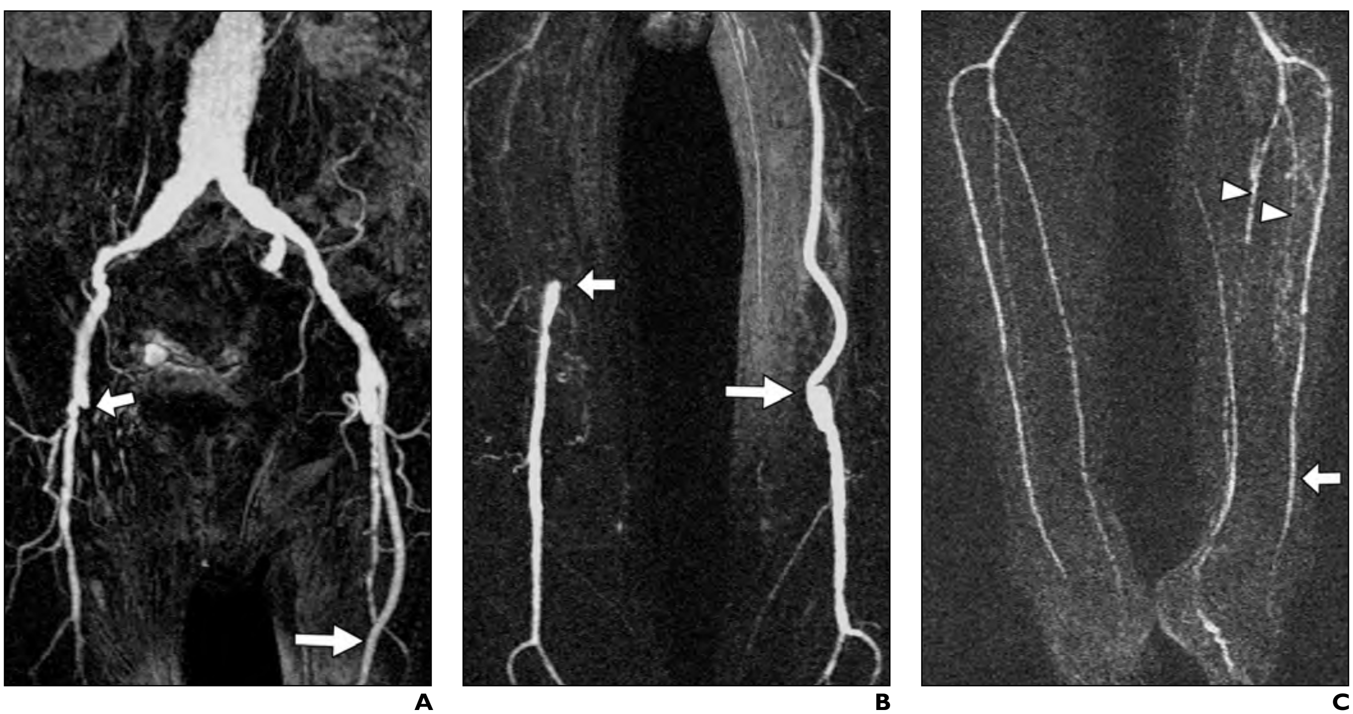


Fig. 2.—Maximum-intensity-projection reconstructions of subtracted data sets with moving-table MR angiography using body coil technique in 64-year-old man with peripheral arterial occlusive disease.
A, MR angiogram of pelvic region reveals occlusion of right (*small arrow*) and left superficial femoral arteries. MR angiogram shows patent bypass graft (*large arrow*) in left upper leg.
B, MR angiogram of upper leg reveals reconstitution of right superficial femoral artery (*small arrow*) and distal anastomosis of bypass graft (*large arrow*).
C, MR angiogram of lower leg reveals three patent arteries in right lower leg. Three patent arteries are visualized in left proximal lower leg (*arrowheads*), and anterior tibial artery (*arrow*) is also visualized in distal left lower leg. Image quality is decreased by low signal-to-noise ratio.

leg. Deep venous enhancement was observed in two of 20 patients with the body coil and in one of 20 patients with the dedicated phased array coil. In these three patients, the single slices of the subtracted data sets were analyzed to compare the results with DSA. The mean room time for moving-table MR angiography with the dedicated phased array coil was 23 min and with the body coil, 21 min. There was no significant difference in both groups (Student's *t* test, $p = 0.05$).

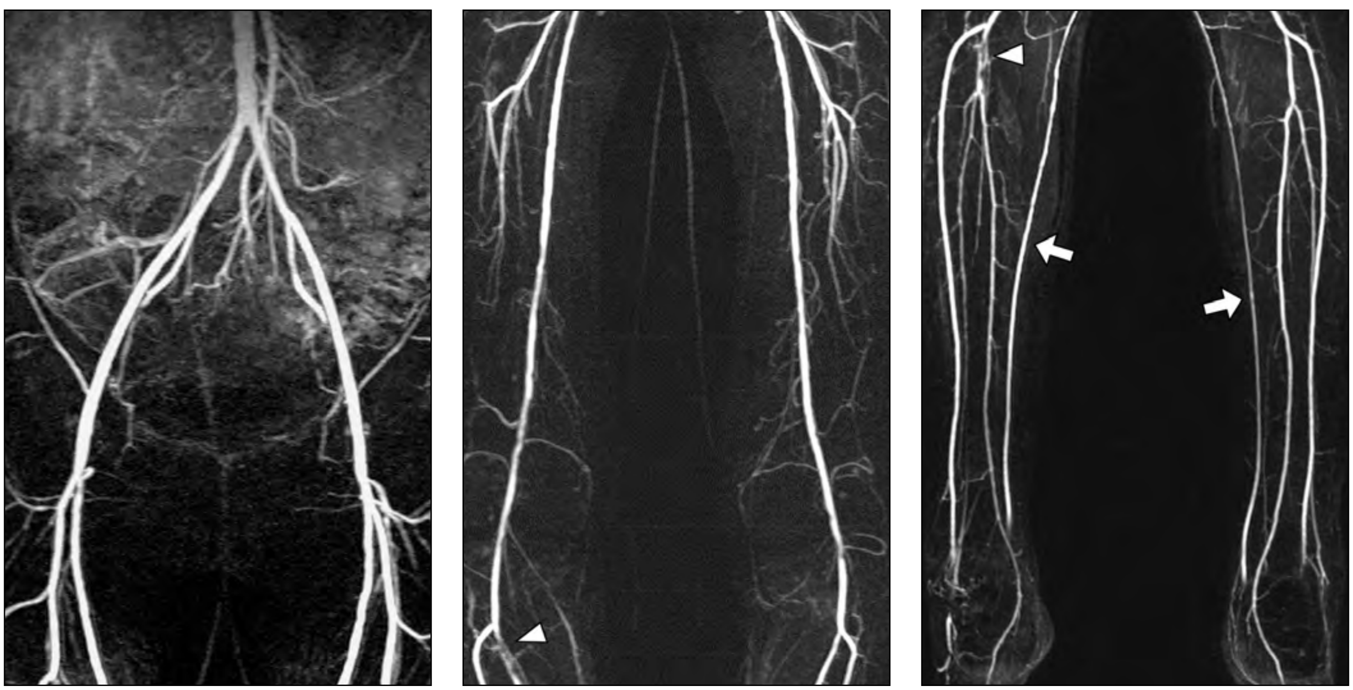
The mean values of signal-to-noise ratio for the patient group examined with MR angiography using the dedicated phased array coil and the group examined with MR angiography using the body coil were 56, 51, and 17, respectively, and 54, 74, and 64, respectively, for the iliac, upper leg, and lower leg arteries. A significant difference (Student's *t* test) was found for the upper ($p < 0.05$) and lower ($p < 0.01$) leg but not for the pelvic region ($p > 0.05$). The MIP reconstructions of a 64-year-old patient examined with MR angiography using the body coil are shown in Figure 2. The MIP reconstructions of a 52-year-old patient who was examined with MR angiography using the dedicated phased array coil are shown in Figure 3. MIP reconstructions on MR angiography (with the dedicated phased array coil technique) and the DSA study of a 69-year-old patient are shown in Figure 4.

For both coil systems, the contrast-to-noise ratios of the pelvic region and the upper and lower leg can be improved with the subtraction of the unenhanced data sets (Fig. 5). MIP projections before and after subtraction obtained from the MR angiography data sets with the dedicated phased array coil technique (Fig. 6) show that subtraction is a useful technique to improve image quality, especially in the upper and lower leg. A significant difference of the mean values (for contrast-to-noise ratio) was found before and after subtraction for the dedicated phased array coil and body coil systems (Student's *t* test, $p < 0.01$).

Comparison of MR Angiography and DSA

MR angiography was highly sensitive and specific for the detection of hemodynamically significant stenoses and occlusions in the arterial vessel segments for both observers (Tables 1 and 2). A high sensitivity and specificity in identifying stenosis greater than 50% and occlusions were found for the iliac (100% and 96%) and upper leg (100% and 96%) arteries for the body coil and for the dedicated phased array coil (iliac arteries, 100% and 96%; upper leg arteries, 100% and 98%). However, a lower sensitivity and specificity were found in the lower leg with the body coil (88% and 85%) compared with the dedicated phased array coil (100% and 97%).

The consensus interpretation showed no understaging of any stenosis or occlusion. However, with the dedicated phased array coil, two upper leg stenoses and five lower leg stenoses were overstaged, with a difference of less than 25% of luminal diameter. With the body coil, three upper leg and seven lower leg stenoses



A B C

Fig. 3.—Maximum-intensity-projection reconstructions of subtracted data sets with moving-table MR angiography using phased array surface coil technique in 52-year-old woman with peripheral arterial occlusive disease.
A, MR angiogram of iliac arteries shows no hemodynamically significant stenosis or occlusion of iliac arteries and proximal arteries of upper legs.
B, MR angiogram of upper leg shows higher signal-to-noise ratio than MR angiogram of upper leg examined with body coil technique. Right tibiofibular trunk shows hemodynamically significant stenosis (*arrowhead*).
C, MR angiogram of lower leg reveals higher signal-to-noise ratio than MR angiogram of lower leg examined with body coil technique. Right tibiofibular trunk shows hemodynamically significant stenosis (*arrowhead*). Superficial lower leg veins already show contrast enhancement (*arrows*); however, deep lower leg veins show no contrast enhancement.

were overstaged, with a difference of less than 25% of luminal diameter.

Discussion

Contrast-Enhanced MR Angiography

Previous studies have shown that contrast-enhanced MR angiography of the peripheral vascular tree can be performed with a moving-bed infusion tracking or a dynamic manual table translation during a single bolus injection [10–12]. These techniques can solve the problem of a limited field of view of 40–50 cm on MR angiography. However, the moving-table technique has some shortcomings.

With a moving-bed technique, the body coil must be used for two or three regions if no dedicated coil system is available. However, for the lower leg with small vessel diameters, a phased array body coil is advantageous to achieve a higher signal-to-noise ratio with a single dose of contrast material. An alternative method is the use of a dedicated coil [13, 15], but that system is not available for all standard MR imaging systems. Moreover, not all MR imaging systems allow individual positioning of the 3D slab for each region with a moving-bed examination. Thus, wraparound artifacts may hamper the diagnostic accuracy in the pelvic region if a narrow field of view is used. If a large field of view is used, the spatial resolution in the upper and lower leg is reduced, or the acquisition time is prolonged [20]. When

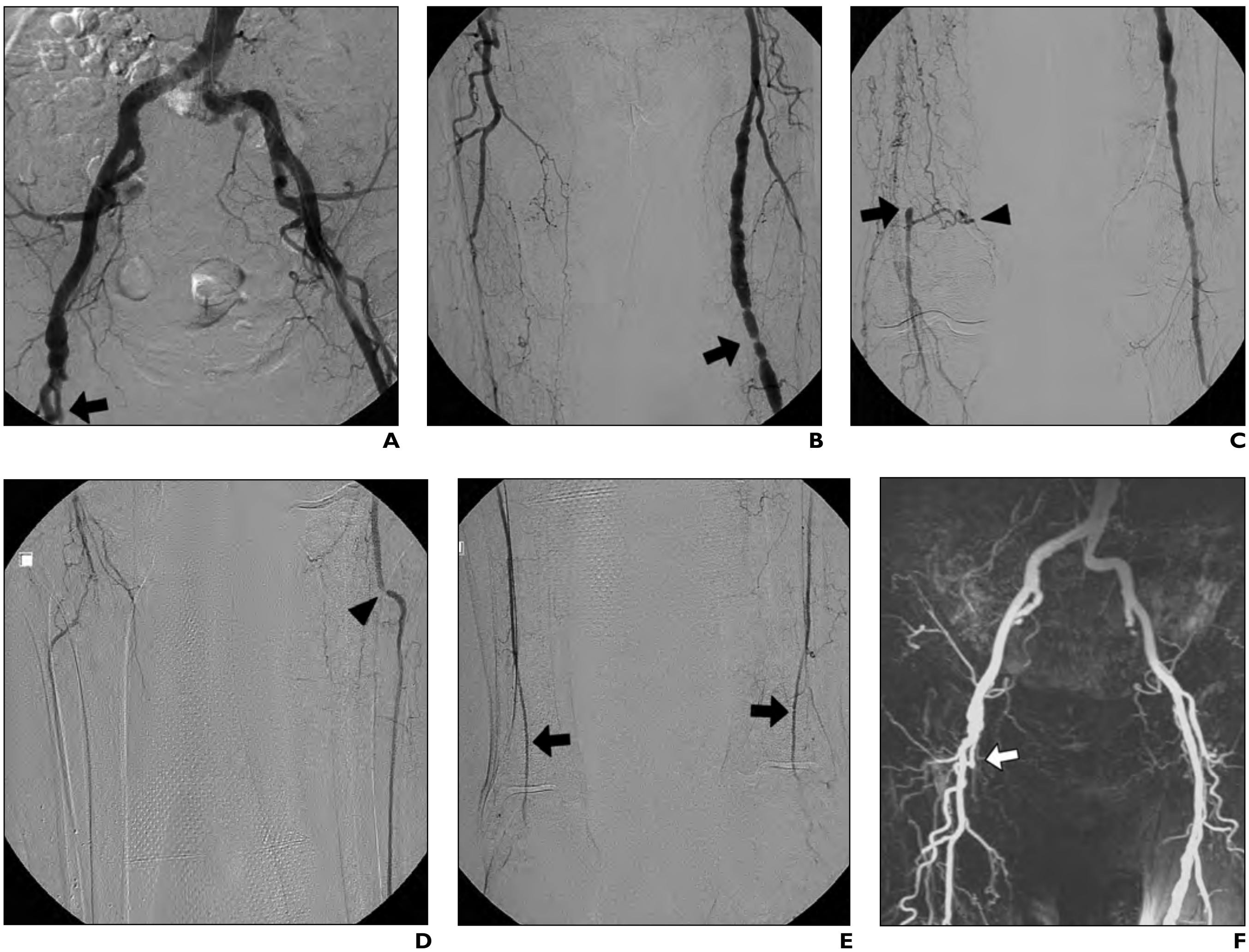
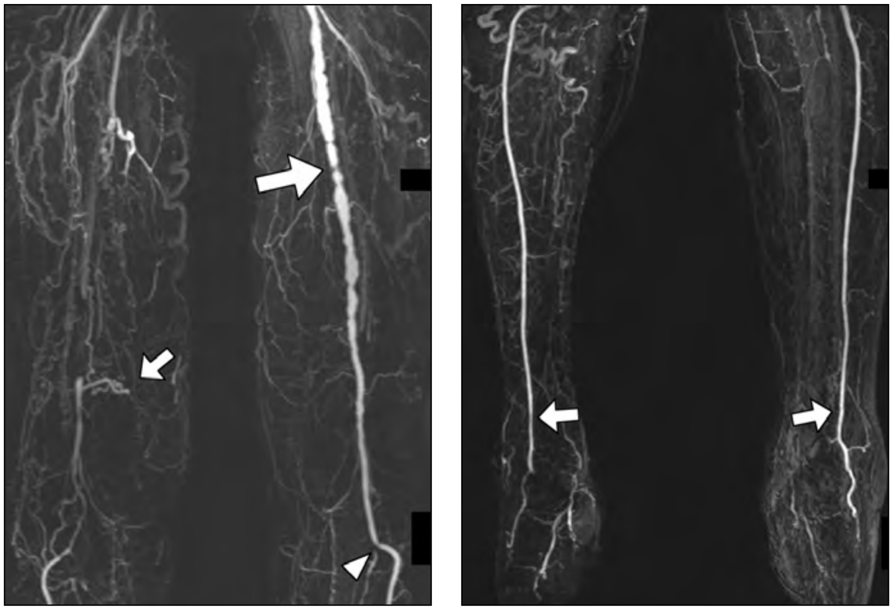


Fig. 4.—Comparison of moving-table MR angiography with phased array surface coil technique and digital subtraction angiography (DSA) in 69-year-old man with peripheral arterial occlusive disease.
A, DSA of pelvic region reveals kinking of left iliac arteries and occlusion (*arrow*) of right superficial femoral artery.
B, DSA of proximal upper legs reveals occlusion of right upper leg artery and three stenoses (*arrow*) of left superficial femoral artery.
C, DSA of distal upper legs reveals reconstitution of right popliteal artery (*arrow*) by small collateral vessels (*arrowhead*).
D, DSA of proximal lower leg reveals only one patent artery on each side of anterior tibial artery. Left anterior tibial artery shows stenosis at its origin, which may be confused with cortical bone artifact (*arrowhead*).
E, DSA of distal lower legs reveals patent anterior tibial arteries down to ankle joint (*arrows*).
F, MR angiogram of pelvic region reveals kinking of left iliac arteries and occlusion (*arrow*) of right superficial femoral artery.
(Fig. 4 continues on next page)



G H

Fig. 4. (continued)—Comparison of moving-table MR angiography with phased array surface coil technique and digital subtraction angiography in 69-year-old man with peripheral arterial occlusive disease.
G, MR angiogram of upper leg reveals occlusion of right superficial femoral artery and three stenoses of left superficial femoral artery (*large arrow*), reconstitution of right popliteal artery by small collateral vessels (*small arrow*), and stenosis (*arrowhead*) at origin of left anterior tibial artery.
H, MR angiogram of lower legs reveals patent anterior tibial arteries down to ankle joint (*arrows*).

the acquisition time is prolonged, the deep veins can be enhanced during the acquisition of the lower leg arteries; and when the spatial resolution is reduced, the tendency to overestimate the degree of stenosis increases. Thus, both a strong gradient system and a flexible software that allow individual positioning of the 3D slab are necessary to achieve a short acquisition time per volume with high spatial resolution. Our study clearly shows that for sufficient MR angiography results of the lower leg arteries, a surface coil system should be used because it improves the signal-to-noise ratio, the contrast-to-noise ratio, and the diagnostic accuracy. A subtraction technique is helpful to increase the contrast-to-noise ratio, both for the body coil and for the dedicated phased array coil (Figs. 5 and 6).

Different methods can achieve correct timing after IV injection of contrast material. First, a separate test-bolus injection with a small amount of contrast material can be performed. Second, a dynamic measurement with the 3D MR angiography slab can be performed without a previously planned bolus timing. The method we used is real-time MR fluoroscopy [17] with a repetitive two-dimensional fast low-angle-shot measurement at the level of the distal aorta. When the operator detects the arrival of contrast material, he or she can start the measurement on MR angiography with a mouse-click. This method improves the work flow because no previous evaluation of a test-bolus measurement is necessary. We used a two-phase injection of gadolinium followed by a saline bolus. The reason for the two-phase gadolinium injection is that we wanted to achieve a high arterial gadolinium concentration after a short time and to hold this concentration with a low flow rate for a relatively long time over three stations. The slow injection rate helps to minimize early enhancement of the deep lower leg veins. Our experience with a two-phase contrast material injection protocol is in accord with the results of Czum et al. [20], who studied bolus-chase peripheral MR angiography. Those authors described improvement of the arterial signal and contrast enhancement compared with a single-phase injection, especially at the most peripheral anatomic area, the lower leg. First, a fast increase of the arterial signal is achieved; and second, with the slow injection of the major amount of contrast material, the time with high arterial signal is prolonged. Finally, the deep veins of the lower leg are enhanced later compared with a single-phase injection. However, in contrast to Czum et al., we used a smaller amount of contrast material for the first, faster injection phase.

Comparison with Step-by-Step MR Angiography

The advantage of subtraction used with a step-by-step technique is that already enhanced veins from the measurements of one or two levels above the current region of interest can be subtracted. Furthermore, the first contrast-enhanced gadolinium measurement is performed at each level just at the arrival of a

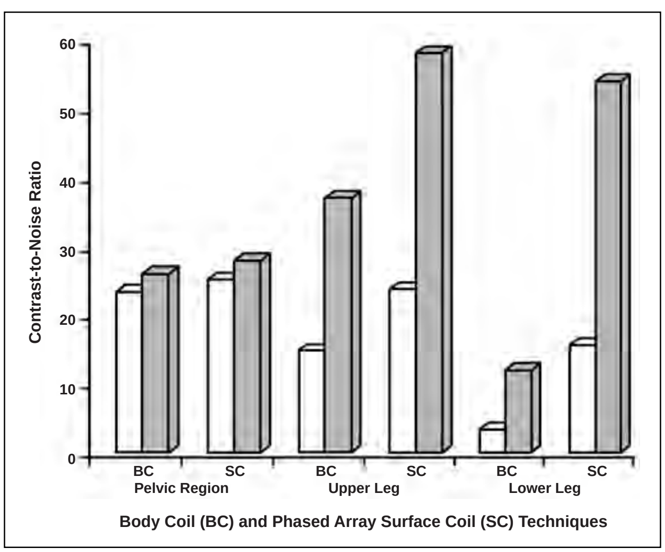


Fig. 5.—Bar chart shows mean contrast-to-noise ratios obtained with body-coil and phased array coil techniques before (*white bars*) and after (*gray bars*) subtraction. Similar values were found for pelvic region. However, significant difference was found between two coil techniques and between subtracted and unsubtracted data sets in upper and lower leg.

new bolus of contrast material. The moving-table technique uses a fixed time table for imaging of the consecutive anatomic regions. The acquisition time for each level, usually 20 sec or more, is longer than the bolus first pass from level to level. Especially in the distal lower leg, deep veins can be enhanced [10] when the gradient strength is too low and the individual positioning of a 3D slab is not possible. In our study, individual positioning of the 3D slab was possible, and we used a two-phase injection of contrast material followed by a saline bolus to minimize enhancement of deep veins. Enhancement of superficial veins could not be avoided in some patients. However, MIP reconstructions of the subtracted data sets allow multiple projections and a clear view of the arteries, even when some of the superficial veins are already enhanced.

With the step-by-step-technique using a phased array coil at three stations [7–9], it is

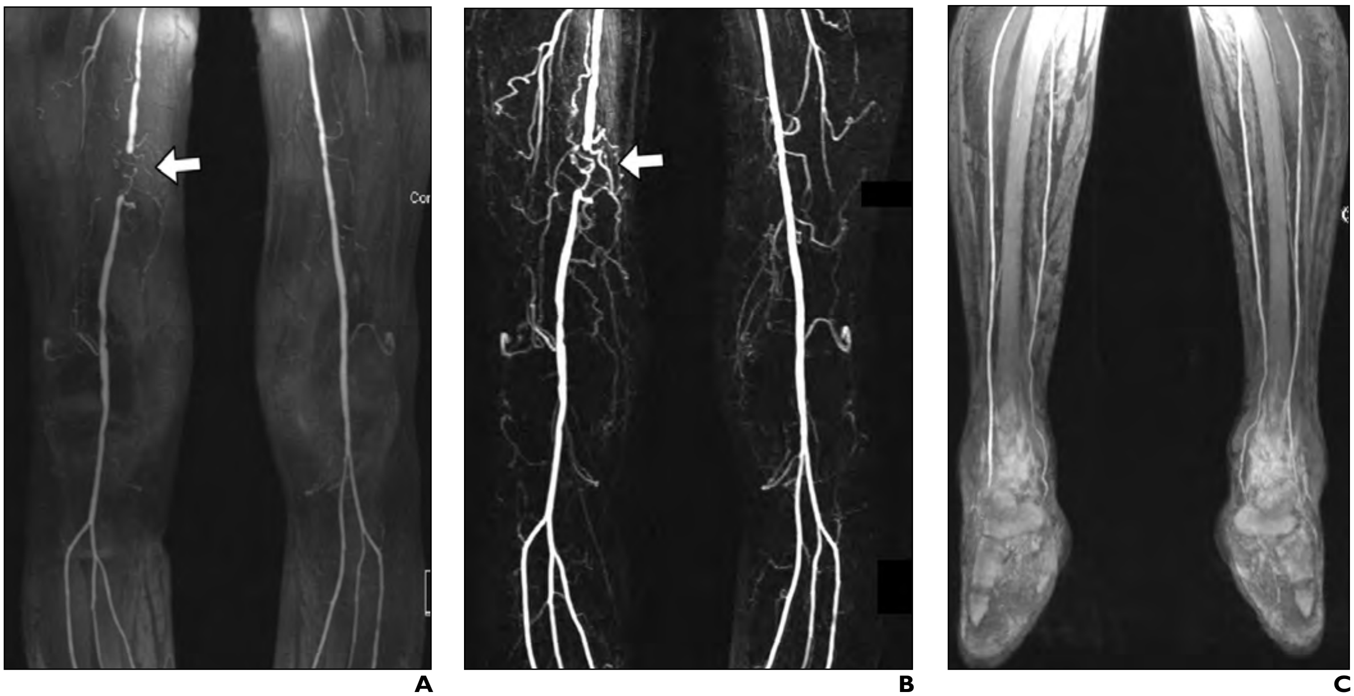


Fig. 6.—62-year-old man with peripheral arterial occlusive disease. Comparison of maximum-intensity-projection (MIP) reconstructions of unsubtracted and subtracted data sets obtained with contrast-enhanced MR angiogram and dedicated surface coil technique.
A, MIP reconstruction of unsubtracted data sets shows occlusion (*arrow*) of right superficial femoral artery.
B, MIP reconstruction of subtracted data sets shows occlusion (*arrow*) of right superficial femoral artery, and small collateral vessels can be detected because of higher contrast-to-noise ratio than in **A**.
C, MIP reconstruction of unsubtracted data sets shows three lower leg arteries with limited contrast-to-noise ratio.
D, MIP reconstruction of subtracted data set of three lower leg arteries shows superior image quality due to higher contrast-to-noise ratio of subtracted data set.

TABLE 1 **Comparison of Digital Subtraction Angiography and MR Angiography for Revealing Hemodynamically Significant Arterial Stenoses (>50%) and Complete Occlusions with Dedicated Phased Array Surface Coil System**

Location	Observer 1		Observer 2		κ	Consensus Interpretation	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)		Sensitivity (%)	Specificity (%)
Common iliac artery	100	97	90	90	0.78	100	97
External iliac artery	91	93	100	96	0.83	100	97
Common femoral artery	100	94	100	94	1.00	100	94
Superficial femoral artery	100	100	97	90	0.88	100	96
Popliteal artery	91	97	100	93	0.90	100	97
Anterior tibial artery	93	96	100	96	0.92	100	96
Posterior tibial artery	100	100	92	94	0.93	100	96
Peroneal artery	100	96	100	100	0.96	100	100
Overall	98	95	97	94	0.95	100	96

Note.—All sensitivity and specificity values refer to the diagnositc accuracy of MR angiography, which is compared with digital subtraction angiography, the gold standard.

TABLE 2 **Comparison of Digital Subtraction Angiography and MR Angiography for Revealing Arterial Stenoses (>50%) and Occlusions with Body Coil System**

Location	Observer 1		Observer 2		κ	Consensus Interpretation	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)		Sensitivity (%)	Specificity (%)
Common iliac artery	91	100	100	97	0.83	100	97
External iliac artery	100	93	100	96	0.95	100	96
Common femoral artery	100	94	100	97	0.94	100	100
Superficial femoral artery	97	91	100	91	0.96	100	91
Popliteal artery	91	90	73	86	0.80	82	90
Anterior tibial artery	88	84	88	84	1.00	88	84
Posterior tibial artery	86	87	91	87	0.95	91	89
Peroneal artery	89	86	85	96	0.88	89	85
Overall	92	92	92	93	0.97	94	94

Note.—All sensitivity and specificity values refer to the diagnositc accuracy of MR angiography, which is compared with digital subtraction angiography, the gold standard.

necessary to position the patient and the surface coil three times and to inject a single dose of gadolinium three times. Thus, the imaging time is prolonged. A high, up to triple, dose of gadolinium is necessary to image the peripheral vascular tree to the ankle with a step-by-step technique. An advantage of the step-by-step technique is that late-enhancing arterial vessel segments can be visualized during a second or third measurement at each level, which can increase diagnostic accuracy. However, to overcome this problem when a moving-table technique is used, a second dynamic measurement may be performed with a separate injection of a single dose of gadolinium at least at one level to visualize late-enhancing arteries that were not seen during moving-table MR angiography. In contrast to DSA, we expect that the difference in diagnostic accuracy between a step-by-step technique and a single bolus moving-table technique is less pronounced because the acquisition time of approximately 20 sec is longer with MR angiography than with stepping-table or C-arm DSA. Thus, the probability to visualize late-enhancing arteries at one level is already higher with moving-table MR angiography compared with moving-table, stepping-table, or C-arm DSA.

Comparison with DSA

Unlike DSA, contrast-enhanced 3D MR angiography acquires an entire data set in a short scanning time, which allows calculation of projection angiograms from many directions without applying additional radiation or contrast material. DSA is a two-dimensional projection technique that often requires additional projections or rotational angiography [21] to ensure that pathologic findings are not hidden behind overlying structures. DSA has a superior spatial in-plane resolution compared with MR angiography. Overestimation of the degree of stenosis with MR angiography is more common in the lower leg than in the upper leg or in the pelvic region, probably because of the lower vessel diameter in the arteries of the lower leg.

No hospitalization of a patient is necessary with the replacement of DSA by MR angiography and the application of IV contrast material. DSA may also be performed without hospitalization when modern catheters with a small caliber are used [22]. Diagnostic accuracy is almost as high as that of DSA when moving-table MR angiography with new software and hardware techniques is used.

In conclusion, moving-table MR angiography with a surface coil system shows a higher signal-to-noise ratio than that of moving-table MR angiography with a body coil system in the upper leg and lower leg and a higher diagnostic accuracy in the lower leg. Moreover, no significant difference is seen in the mean room time of the patient for both techniques. The use of a subtraction technique increases the contrast-to-noise ratio.

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