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Assessment of lower extremity peripheral arterial occlusive disease (PAOD): Comparison of contrast enhanced-3D magnetic resonance angiography and digital subtraction angiography/ digital angiography

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Objective : *The purpose of this study was to evaluate the diagnostic accuracy of contrast-enhanced 3D MR angiography (CE-3D MRA), using digital subtraction angiography (DSA) or digital angiography (DA) as a gold standard, in patients with lower extremity peripheral arterial occlusive disease (PAOD) at King Chulalongkorn Memorial Hospital.*

Materials and Methods : *Two hundred fifty - three arterial segments from 19 patients (21 studies) underwent both CE-3D MRA and DSA/DA retrospectively. CE-3D MRA protocol was performed at three levels-: the abdomen-pelvis- and the thigh, using bolus trigger technique with two-step moving table, and the leg to proximal foot, using time-resolved imaging of contrast kinetics (TRICKS) sequence. The results were reviewed using maximum-intensity-projection (MIP) CE-3D MRA compared with DSA/DA of the matching arterial segments*

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to the CE-3D MRA studies. The vessels were reviewed from abdomen to legs which were divided into 16 segments on each side. The degree of stenosis of each segment was graded as normal or stenosis less than 50%, stenosis more than 50% and occlusion. The accuracy, sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of CE-3D MRA were calculated using DSA/DA as the gold standard. The run - off vessels demonstrated in both studies were also evaluated.

Results : *Among 253 analyzed segments, the accuracy, sensitivity, specificity, PPV and NPV of CE - 3D MRA in depicting arterial occlusion and stenosis that is greater than 50% were 77.47%, 85.57%, 80.13%, 72.81% and 89.93%, respectively. The total numbers of run - off segments detected by CE-3D MRA were 23/33 (69.7%) segments (6 suprapopliteal and popliteal vessels, 17 infrapopliteal vessels): 14/33 (42.42%) segments (7 suprapopliteal and popliteal vessels, 7 infrapopliteal vessels) detected by DSA/DA. Nineteen (57.58%) run - off segments were observed on CE-3D MRA that were not detected on DSA/DA.*

Conclusion : *CE-3D MRA is a reliable method for investigating peripheral arterial disease in selected patients with lower extremity PAOD with very high NPV and can depict run-off arteries not seen on DSA/DA in case of occlusion.*

Keywords : *Contrast-enhanced, 3D, magnetic resonance, angiography, CE-3D MRA, digital subtraction, angiography, DSA, angiography, DA, lower extremity, peripheral, arterial occlusive, occlusion.*

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อนุสรณ์ ติระรัตน์ชัยเลิศ, สมใจ หวังศุภชาติ. เปรียบเทียบการตรวจผู้ป่วยหลอดเลือดขาตีบตัน ระหว่างการตรวจด้วยคลื่นสะท้อนในสนามแม่เหล็กและการฉีดสารทึบรังสีเอ็กซ์เรย์. จุฬาลงกรณ์เวชสาร 2552 ม.ค. – ก.พ.; 53(1): 23 – 37

วัตถุประสงค์ : *เพื่อศึกษาความถูกต้องของการตรวจด้วยคลื่นสะท้อนในสนามแม่เหล็กเปรียบเทียบกับการฉีดสารทึบรังสีเอ็กซ์เรย์ ในผู้ป่วยหลอดเลือดขาตีบตัน*

วิธีการศึกษา : *วิเคราะห์เปรียบเทียบเปอร์เซนต์การตีบตันของหลอดเลือดแดง 253 ส่วน จากผู้ป่วย 19 คน ที่ได้รับการตรวจด้วยคลื่นสะท้อนในสนามแม่เหล็กและการฉีดสารทึบรังสีเอ็กซ์เรย์จากช่องท้อง ต้นขาถึงปลายขา โดยคำนวณความถูกต้อง ความไว ความจำเพาะ positive predictive value (PPV) และ negative predictive value (NPV) ของการตรวจด้วยคลื่นสะท้อนในสนามแม่เหล็ก เปรียบเทียบกับการฉีดสารทึบรังสีเอ็กซ์เรย์ และวิเคราะห์หลอดเลือด run - off*

ผลการศึกษา : *ความถูกต้อง ความไว ความจำเพาะ positive predictive value (PPV) และ negative predictive value (NPV) ของการตรวจด้วยคลื่นสะท้อนในสนามแม่เหล็กของผู้ป่วยหลอดเลือดขาตีบตันมากกว่า 50% เท่ากับ 77.47%, 85.57%, 80.13%, 72.81% และ 89.93% ตามลำดับ พบหลอดเลือด run - off 23/33 (69.7%) ส่วนจากการตรวจด้วยคลื่นสะท้อนในสนามแม่เหล็ก ซึ่งในจำนวนนี้มี 19/33 (57.58%) ส่วนพบเฉพาะในการตวจด้วยคลื่นสะท้อนในสนามแม่เหล็กแต่ไม่พบในการฉีดสารทึบรังสีเอ็กซ์เรย์*

วิจารณ์และสรุป : *การตรวจด้วยคลื่นสะท้อนในสนามแม่เหล็ก เป็นวิธีที่เชื่อถือได้ในการตรวจผู้ป่วยหลอดเลือดขาตีบตัน โดยมี NPV สูงมาก และสามารถตรวจพบหลอดเลือด run - off ได้ดีกว่า*

คำสำคัญ : *คลื่นสะท้อนในสนามแม่เหล็ก, การฉีดสารทึบรังสีเอ็กซ์เรย์, หลอดเลือดขาตีบตัน*

Lower extremity atherosclerotic disease impairs quality of life, initially by causing claudication (which may interfere with work and lifestyle) and later by causing limb threatening ischemia with rest pain, non - healing ulcers, infection, or gangrene.[1] Critical limb ischemia with the risk of major tissue loss is one of the most severe complications in patients with peripheral arterial occlusive disease. The estimated incidence of critical limb ischemia in industrialized countries is 500 -1000 new cases per million persons per year. Patients who have diabetes mellitus in addition to critical limb ischemia have a risk for major tissue loss that is 11 times the risk among the non-diabetic.[2] In such circumstances, angioplasty or bypass surgery may be possible to establish sufficient circulation to save the limb. Otherwise, amputation might be necessary.[1]

Treatment planning for patients who are being evaluated for limb salvage surgery requires high quality images of vessels in the calf and foot. Information about the number, length, severity of vascular lesions, as well as the inflow and outflow of the segments, especially in patient in whom infrageniculate bypass surgery may be considered, are essential. The assessment of the arterial run - off prior to therapeutic procedures has traditionally been performed with intraarterial catheterized digital subtraction angiography (DSA) or digital angiography (DA).[2] The major advantages of intraarterial DSA or DA are high-spatial-resolution images and temporal information regarding delayed filling of the vasculature of interest. The invasiveness of the procedure, nephrotoxicity of iodinated contrast media, and radiation exposure, however it led to the development of noninvasive imaging techniques.[3]

Time-of-flight magnetic resonance (MR) angiography has proved to be accurate in the depiction of vascular pathologic conditions in the peripheral vasculature, particularly in the lower extremities. However, long acquisition times and flow-related artifacts have hindered its widespread application. To overcome these drawbacks, contrast material enhanced-3D MR angiography (CE-3D MRA), which combines the use of a heavily T1 weighted gradient-echo sequence and the intravenous injection of a gadolinium - based agent, has been introduced. This technique permits the acquisition of a full three - dimensional data set within a comfortable breath hold of 30 seconds. The synchronization of contrast agent arrival and data acquisition is crucial for this imaging technique. This is normally achieved by using a test bolus injection and fluoroscopic or automated triggering. In the evaluation of peripheral vascular disease, CE - 3D MRA has been used to display the entire vasculature in a single imaging session. Continuous or repeated contrast agent injections are used to display the abdominal aorta to the pedal arch. Recently, single-injection bolus-chase MR angiography, which combines automated table movement with fast repeated acquisitions at successive levels of the vasculature, similar to bolus-chase conventional angiography, has been introduced. To improve vessel depiction, separate acquisition and subtraction of a pre - contrast mask is required. A relatively fast injection is necessary for the depiction of the renal arteries. Therefore, venous contamination of the distal stations may occur owing to limited first pass extraction of the bolus.[3] A different approach, however, combines the repeated sampling of the low spatial-resolution k-space views with temporal interpolation to produce a series of time - resolved imaging of contrast kinetics (TRICKS), (3D) MR angiographic images. The 3D TRICKS images reveal the dynamics of contrast material arrival and obviate a timing image.[3]

The aims of this study were to assess the diagnostic accuracy of a new MR angiography protocol designed to analyze the peripheral vascular tree in patients with lower limb peripheral arterial occlusive disease (PAOD) at King Chulalongkorn Memorial Hospital and to report the run-off vessels demonstrated on CE-3D MRA but
not on DSA or DA.

Materials and Methods

Patients

From June 2006 to October 2007, nineteen patients (21 studies) who undertook CE-3D MRA followed by DSA or DA within 20 weeks[4] as a part of their diagnosis or interventional study at King Chulalongkorn Memorial Hospital, were eligible for enrollment in the study. These patients were suspected of PAOD of the lower extremity. Inclusion criteria for this study were, namely: intermittent claudication, resting leg or foot pain, non-healing ulceration or focal gangrene which were consistent with peripheral artery disease. Most of these patients had additional chronic diseases including diabetes, hypertension, chronic kidney disease (CKD), stroke or coronary artery disease (CAD) (Table 1). An exclusion criterion was vascular malformation of lower extremity arteries. No interventions or record of changes in the clinical status of the ischemic limb occurred between the two angiographic studies. DSA or DA consisted of selective intraarterial catheterized angiography in clinically relevant extremity correlation for matching arterial segments from CE-3D MRA studies. The patients were requested to provide their informed consent before being evaluated by CE-3D MRA and DSA/DA respectively.

The list of CE-3D MRA studies was searched from the Picture Archives and Communication System (PACS - Agfa PACS, Belgium) of our institution and the list of patient registration of the MRI Unit. Corresponding DSA/DA studies were obtained later. Then the patients' records which matched the two angiographic studies were reviewed.

Table 1. Underlying chronic diseases found in the patients.

Chronic disease		No. of patients	%
Diabetes		18	85.71
Hypertension		17	80.95
CAD		9	42.86
CKD		6	28.57
Stroke		5	23.81
	Dyslipidemia	10	47.62
Others	Gout	5	23.81
	Lumbar spondylosis	1	4.76

The 21 cases of CE-3D MRA included of 13 men and 6 women whose age ranged from 52 to 88 years (mean 69.86 years; median 71 years). The mean patients' body weight was 65.1 kg (ranged 49 - 95 kg) with serum creatinine ranged 0.6-7.9 mg/dL. Most of the patients were presented with ulcer (11 patients, 52.38%) followed by claudication (7 patients, 33.33%), rest pain (3 patients, 14.29%), gangrene and congestive heart failure (1 patient, 4.76%). There were 11 treatments observed in the patients prior to our reviews. One patient received superficial femoral artery bypass graft. Five patients received below-knee or toe amputations. Three patients received renal artery or distal superficial femoral artery or popliteal artery stenting and two patients received balloon angioplasty of the superficial femoral arteries.

MRA protocol

The MR examinations were performed with a 1.5T MR imaging unit (Signa Excite HD; GE Medical System). After obtaining a multiplanar scout image including six slices with a fast imaging with steady - state free precession sequence, we positioned the 3D MRA slab in the coronal plane as required by the anatomy of the vessel at each level.

CE-3D MRA was performed at three levels: first, in the abdomen and the pelvis; second, in the thigh; and third, in the leg to proximal foot. Mask images were acquired from each level prior to contrast-enhanced imaging for subtraction.

The patients were examined with the body coil for the abdomen-pelvis and the thigh levels using 3D fast spoiled gradient-recalled echo (FSPGR) sequences. The eight - channel phase array body coil was used to image the leg to proximal foot with time -resolved imaging of contrast kinetics (TRICKS) CE-3D MRA which revealed the dynamics of contrast material of the leg vessels.

As for the intravenous administration of contrast material, we injected gadopentetric diameglumine (Magnevist; Schering, Berlin, Germany) or gadoteric acid (Dotarem; Guerbet, Aulnay-sous-Bois, France) via a 22 - gauge needle into a vein on the dorsum of the right hand using MR - compatible injector (Spectris; Medrad) The first two levels (two - step moving table, abdomen-pelvis and thigh) were performed with bolus trigger technique, in a breath hold for abdomen - pelvis level, with 20ml of gadolinium injection, flow rate of 1.5ml/sec, followed by 10ml of saline in the same flow rate. The level of the leg to proximal foot was done using TRICKS sequence by injection of 10ml of gadolinium based contrast agent with a flow rate of 1.5ml/sec, followed by 10ml of saline chasing.

We used Smart Prep (GE Medical System) technique for contrast bolus trigger technique in the first two steps. This technique allows a real - time visualization of contrast material entering left atrium during repetitive measurements at the same coronal position with a T1 - weight 2D gradient - echo sequence. MR angiography was started with a mouse - click by the operator with an additional 5 sec of delayed time. As for the third step (leg level), the delayed times of TRICKS protocol were 20 sec in case of no occlusion at the first two steps, or 30 sec in case of occlusion or tight stenosis at the first two steps.

The imaging parameters for acquisition of mask images and those used for acquisition of the contrast-enhanced images were identical; repetition time msec/ echo time msec of 3.9/1.4, flip angle of 35°, fractional echo, field of view of 460 x 360 mm, 320x192 matrix, effective section thickness of 3.2 mm, 0.8 mm interval, receiver band width of 62.5 kHz.

Post processing images were performed together by a radiologist and a technologist. The subtracted images were created using the maximum intensity projection (MIP) algorithm. At each station, a series of MIP images was generated with 15° rotation and contained 12 images per series. All the CE-3D MR angiographic studies were archived into PACS as well as printed out on hard - copy films. Window level setting for all MIP images was adjusted to maximize arterial contrast and minimize the background signal.

Image analysis

The CE - 3D MRA and DSA/DA images were stored on CD - ROMs. The patient's name was obscured and a study number was assigned to each examination. They were randomly organized and were placed so that the interpretations were performed in different orders and on separate days. Interpretation was performed by a radiologist, a reviewer who was blinded to each patient's information including their clinical data and DSA/DA results who independently reviewed the CE-3D MRA and DSA/DA images.

The images, both CE-3D MRA and DSA/DA, were separately reviewed and the data were recorded on case record forms (CRF). The image quality of all examinations was graded on a three - point scale, namely:

0: poor quality and non - confident;

1: fair quality and marginally confident;

2: good quality and highly confident.

The areas of stenosis or occlusion identified in each study were recorded on separate schematic diagrams for review. Sixteen vascular segments were divided on each side [modified from Oliver AM[2]], comprising:

1. the renal artery,
2. the distal aorta,
3. the common iliac artery,
4. the external iliac artery,
5. the internal iliac artery,
6. the common femoral artery,
7. the upper two-thirds of the superficial femoral artery (SFA),
8. the lower third of the SFA,
9. the profunda femoris artery,
10. the above-knee popliteal artery,
11. the below-knee popliteal artery,
12. the upper third of the anterior tibial artery (ATB),
13. the lower two-thirds of the ATB,
14. the tibioperoneal trunk,
15. the posterior tibial artery, and
16. the peroneal artery.

Only arterial segments which had both 3D CE-MRA and DSA/DA images were included in the analysis. The degree of stenosis was grouped according to the severity of obstruction as follows [1, 2, 5 - 7]:

Group A: normal or less than 50% stenosed;

Group B: more than 50% stenosed; and,

Group C: occluded.

The degree of stenosis was measured by dividing the minimal vessel luminal diameter in the segment by the adjacent proximal normal-caliber arterial segment. When two or more stenotic luminal changes were detected in the same vessel segment, the most severe change was used for grading and analysis. Analysis of venous contamination was based on a three - point scale:

1. no contamination;
2. present but does not interfere with diagnostic assessment; and,
3. present and interferes with diagnostic assessment.

Statistical analysis

The diagnostic accuracy of MRA was analyzed to calculate the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) with 95% confidence intervals (CIs), for detecting a stenosis greater 50% and arterial occlusion, using DSA/DA as the gold standard.

Results

A total CE-3D MRA of 253 segments from 32 legs (Table 2) were assessed and compared with the outcomes from the DSA/DA techniques by the reviewer. CE-3D MRA showed 139 arterial segments with normal or stenosis that was less than 50% (group A), 62 segments with stenosis more than 50% (group B), and 52 segments with occlusion (group C). Of 21 DSA/DA. Seventeen studies (80.95%) were performed by cardiologists, and 4 (19.05%) by radiologists. The results of DSA/DA for 253 arterial segments showed 156 segments with normal or stenosis that was less than 50%, 37 segments with stenosis more than 50%, and 60 segments with occlusion. The breakdown of arterial segment-to-segment comparison of CE-3D MRA and DSA/DA in the evaluation was summarized in table 3.

Table 2. Summarized number and location of the arterial segments evaluated.

Structure assessed	Side		Total
	Right	Left	
RA	3	3	6
Distal AO	9		9
CIA	9	9	18
EIA	11	10	21
IIA	10	8	18
CFA	8	10	18
SFA upper 2/3	7	12	19
SFA lower 1/3	6	11	17
PFA	6	9	15
PopA above knee	7	11	18
PopA below knee	6	11	17
ATB upper 1/3	6	10	16
ATB lower 2/3	5	10	15
TPT	6	10	16
PTA	6	9	15
PerA	6	9	15
Total			253

(RA = renal artery, Ao = aorta, CIA = common iliac a, EIA = external iliac a, IIA = internal iliac a, CFA = common femoral a, SFA = superficial femoral a, PFA = profunda a, PopA = popliteal a, ATB = anterior tibial a, TPT = tibioperoneal trunk, PTA = posterior tibial a, PerA = peroneal a)

Table 3. CE-3D MRA and DSA/DA: vessel diseases analysis by location and severity.

DSA/DA	CE-3D MRA		
	Gr. A	**Gr. B**	**Gr. C**
Overall analysis			
Gr. A	125	30	1
Gr. B	11	23	3
Gr. C	3	9	48
Suprapopliteal and popliteal vessels			
Gr. A	110	25	0
Gr. B	9	17	2
Gr. C	1	5	12
Infrapopliteal vessels			
Gr. A	15	5	1
Gr. B	2	6	1
Gr. C	2	4	36

Group A, normal or stenoses less than 50%, group B, stenoses more than 50%, group C, occlusion

The accuracy of CE-3D MRA for depicting arterial stenosis that was greater than 50% (group B) and arterial occlusion (group C) ranged from 76.8% to 79.2% with sensitivity and specificity of both groups ranged from 78.26% to 92.16% and 71.43% to 81.48%, respectively. The positive predictive value (PPV) of group B and C ranged from 59.02% to 88.68% whereas the negative predictive value (NPV) ranged from 78.95% to 91.67%. The accuracy, sensitivity, specificity, PPV and NPV of CE-3D MRA for stenosis that was greater than 50% (group B) and occlusion (group C) were summarized in table 4.

Table 4. Accuracy, sensitivity, specificity, PPV and NPV of CE-3D MRA for group B and C.

Statistical parameter	Overall	Suprapopliteal and popliteal a.	Infrapopliteal a.
Accuracy	77.47%	76.8%	79.2%
Sensitivity	85.57%	78.26%	92.16%
Specificity	80.13%	81.48%	71.43%
PPV	72.81%	59.02%	88.68%
NPV	89.93%	91.67%	78.95%

No difference in interpretation was found between CE-3D MRA and DSA/DA in 196/253 (77.47%) segments. Regarding the suprapopliteal and popliteal vessels, a correlation between CE-3D MRA and DSA/DA was observed in 139/176 segments (79%). Regarding the infrapopliteal vessels, a correlation between CE-3D MRA and DSA/DA was observed in 57/77 segments (74%). Regarding segment-to-segment analysis, discrepant results were obtained in 57 of 253 comparisons (22.53%). Of these 57 discrepancies, 42/57 (73.7%) involved suprapopliteal and popliteal segments and 15/57 (26.3%) involved infrapopliteal segments. The results of segment-to-segment comparison of CE-3D MRA and DSA/DA of the 57 discrepant results, 34/57 (59.65%) was over graded (27 for suprapopliteal and popliteal vessels, 7 for infrapopliteal vessels) and 23/57 (40.35%) was under graded (15 for suprapopliteal and popliteal vessels, 8 for infrapopliteal vessels).

Run-off vessels were observed in 14/21 (66.67%) studies of CE-3D MRA and 9/21 (42.86%) studies of DSA/DA. Regarding segment analysis of 33 run-off vessels, 19/33 (57.58%) segments were observed by CE-3D MRA alone, 10/33 (30.3%) segments were observed by DSA/DA alone and 4/33 (12.12%) segments were observed by both CE-3D MRA and DSA/DA. These resulted in total number of the run - off segments detected by CE-3D MRA and DSA/DA were 23/33 (69.7%) and 14/33 (42.42%), respectively. The summarized run-off segments from CE-3D MRA and DSA/DA are shown in table 5.

Additional findings found in our study were pseudoaneurysm of the common femoral arteries in two patients, arterioveneous fistula in one patient, fusiform aneurysm of abdominal aorta and both common iliac arteries in one patient.

Diagnostic quality of MRA and DSA

As for MRA and DSA/DA analyses of the lower limb vessels, subjective image quality and venous contamination were categorized by the reviewer in table 6 and table 7, respectively.

The image qualities of segment $\geq$ Gr 1 were rated in 21 (100%) of the 21 studies of the MRA and DSA/DA. There was no venous contamination that interfered with the interpretation of all MRA or DSA/DA examinations in our reviews.

Table 5. Summarized run-off segments from CE-3D MRA and DSA/DA.

Examination	Suprapopliteal and popliteal vessels	Infrapopliteal vessels	Total
CE-3D MRA alone	3	16	19
DSA/DA alone	4	6	10
CE-3D MRA and DSA/DA	3	1	4
CE-3D MRA + both techniques	6	17	23
DSA/DA + both techniques	7	7	14

Table 6. Image quality of MRA and DSA/DA for analysis of lower limb vessels.

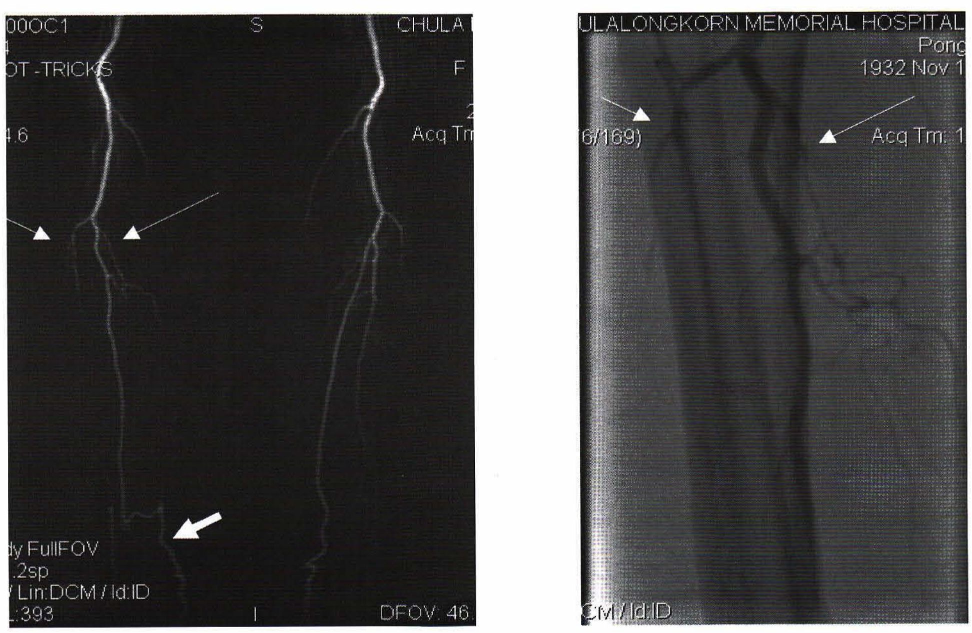
Grade	No. of examination	
	MRA	DSA/DA
0	0 (0%)	0 (0%)
1	1 (4.76%)	0 (0%)
2	20 (95.23%)	21 (100%)

Gr.0, poor quality and nonconfident, Gr.1, fair quality and marginally confident,

Gr.2, good quality and highly confident

Table 7. Venous contamination of MRA and DSA/DA for analysis of lower limb vessels.

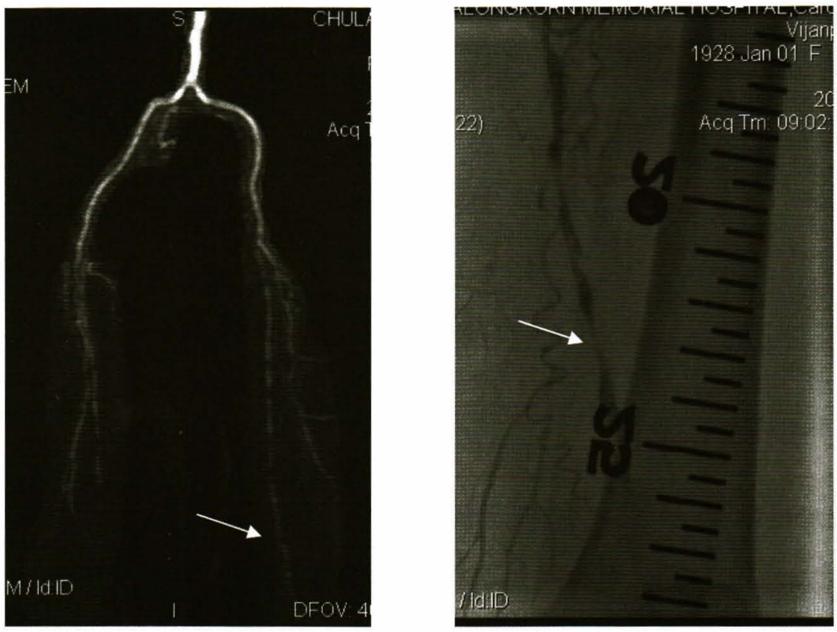
Venous contamination	No. of examination	
	MRA	DSA/DA
None	11 (52.38%)	20 (95.23%)
Present but does not interfere with diagnostic assessment	10 (47.62%)	1 (4.76%)
Interferes with diagnostic assessment.	0 (0%)	0 (0%)



A. CE-3D MRA

B. DA of right leg

Figure 1. Clinical examples of CE-3D MRA image (A) and DA (B) in patient with occlusion of the right anterior tibial (short arrow) and the posterior tibial artery (long arrow). Note the run-off vs. at the right distal posterior tibial artery demonstrated on CE-3D MRA (thick arrow in A) but not demonstrated on late image of DA (not shown)



A. CE-3D MRA B. DA of left thigh

Figure 2. Clinical examples of CE-3D MRA image (A) and DA (B) in patient with Gr. B stenosis of distal left superficial femoral a. (arrow in A and B). Note, the above knee popliteal artery in B is opacified in later image (not shown) and complete occlusion of the distal right superficial femoral artery in A.

Discussion

These results suggest high diagnostic accuracy of CE-3D MRA protocol at King Chulalongkorn Memorial Hospital in the assessment of lower limb PAOD in selected patients. There is also very high NPV in the detection of arterial stenosis that was greater than 50% (group B) and arterial occlusion (group C), especially in the suprapopliteal and popliteal arteries (91.67%). This gives us strong confidence to exclude significant stenosis in these arterial part when CE-3D MRA study showed normal or stenosis that is less than 50% (group A). However, an intermediate PPV of CE-3D MRA for group B and C of suprapopliteal and popliteal a. (59.02%) may need further investigation to confirm our diagnosis. We found the superiority of CE-3D MRA over DSA/DA in the identification of arterial segments in run-off vessels, especially the infrapopliteal vessels, which are not seen on conventional angiography but detected on CE-3D MRA. These vessels may be suitable target vessels for bypass grafting. Several explanations have been proposed for the shortcoming of DSA/DA. CE-3D MRA can image blood flow at velocity as low as 2cm/sec whereas in DSA/DA, the dilution of contrast medium below long-occluded segment leads to insufficient enhancement of distal vessels.[7] This confirms that CE-3D MRA of the lower extremity arteries which is non-invasive may replace invasive DSA/DA in terms of diagnostic purpose for vascular interventionist or surgical planning.

There were, however, some limitations in our study on the selected arterial segments. We could not compare all arterial segments from CE-3D MRA to DSA/DA because the latter were only performed on abnormal extremities or segments. These may cause biases in our selected populations. To overcome this problem, there should be a prospective control study which includes all arterial segments from both extremities in two types of angiographic examinations for evaluation. Furthermore, DSA should available from all stenotic segments or segments which are not clearly demonstrated from DA.

MRA has markedly changed the diagnostic approach to arterial disease since the advent of contrast-enhanced ultrafast studies, however, no single technique for peripheral MRA has been universally accepted. At King Chulalongkorn Memorial Hospital we use a hybrid protocol which focus separately on pelvis-to-thigh arteries and calf arteries. The hybrid protocol composes of a bolus chase technique to image the pelvis-to-thigh arteries, and a TRICKS (time-resolved imaging of contrast kinetics) sequence, to image the calf arteries. The diagnostic quality of calf images is significantly higher with the hybrid technique due to high temporal resolution permitting pure arterial phase with dynamic imaging of TRICKS technique from arterial to venous phases. The TRICKS technique requires fast imaging that repeated over and over during the arrival of contrast bolus. 2D projection MRA accelerates data acquisition by eliminating slice encoding, allowing imaging to be obtained every 1 - 2 sec with high in - plane spatial resolution. This improvement in quality correlates with significantly higher sensitivity and specificity of calf analysis with the hybrid technique compared with other techniques. Our study confirms the good performance of a TRICKS MRA protocol in peripheral arterial disease associated with lower limb PAOD in patients. The TRICKS MRA enables an acquisition focused on calf vessels, thus reducing the presence of early venous enhancement more frequently encountered with bolus chase MRA alone. Furthermore, optimal detection of contrast medium in distal vessels can be achieved through the Smart Prep bolus technique applied to the TRICKS MRA protocol.

Unlike DSA/DA, CE-3D MRA acquires the entire data set in a short scanning time, which allows calculation of projection angiogram from many directions without applying additional radiation or contrast material. DSA/DA is a two dimensional projection technique that often requires additional projections or rotational angiography to ensure that the pathologic findings are not hidden behind the overlying structures. DSA/DA has superior spatial in-plane resolution compared with MRA. In the literature, overestimation of the degree of stenosis with MRA is more common in the leg than the thigh or the pelvic region, probably because of the smaller vessel diameter in the arteries of lower leg.[8] However, in our results, we observed overestimation in the suprapopliteal and popliteal vessels more common than the infrapopliteal vessels.

Recently, MDCT angiography was proposed for evaluation of peripheral vascular disease. New developments in multidetector technology increase the speed of acquisition and offer high spatial resolution. MDCT of the entire arterial supply of the legs from the suprarenal aorta to the ankles in a single helical acquisition is now possible. However, misinterpretations are observed in cases of severe diffuse calcifications, particularly in small vessels such as the calf or ankle vessels. Moreover, MDCT angiography requires injection of iodinated contrast material with the risk of contrast-related renal failure.

Recently, new improvements of MRA have been described. Partially parallel acquisition imaging offers faster acquisition and will probably find many applications in MRA. A multichannel radiofrequency system with multicoil technology provides the whole body contrast enhanced MRA with high-spatial-resolution data set with high diagnostic image quality for the evaluation of arterial occlusive disease in most vascular territories.[9] With the application of improvements in high gradient technology and the use of dedicated vascular contrast medium, the accuracy of MRA will probably improve. In conclusion, our results suggest that CE-3D MRA is a reliable method for investigating peripheral arterial disease in selected patients with lower extremity PAOD with very high NPV. Moreover, hybrid MRA visualizes lower extremity vessels that are not seen in conventional angiography. It also requires no iodinated contrast material - induced renal failure which is useful for treatment planning in terms of arterial run-off demonstration better than DSA/DA.

References

1. Zhang HL, Khilnani NM, Prince MR, Winchester PA, Golia P, Veit P, Watts R, Wang Y. Diagnostic accuracy of time - resolved 2D projection MR angiography for symptomatic infrapopliteal arterial occlusive disease. AJR Am J Roentgenol 2005 Mar;184 (3): 938 - 47
2. Meissner OA, Rieger J, Weber C, Siebert U, Steckmeier B, Reiser MF, Schoenberg SO. Critical limb ischemia: hybrid MR angiography compared with DSA. Radiology 2005 Apr; 235(1): 308 - 18
3. Hany TF, Carroll TJ, Omary RA, Esparza-Coss E, Korosec FR, Mistretta CA, Grist TM. Aorta and runoff vessels: single-injection MR angiography with automated table movement compared with multiinjection time-resolved MR angiography—initial results. Radiology 2001 Oct; 221(1): 266 - 72
4. Khilnani NM, Winchester PA, Prince MR, Vidan E, Trost DW, Bush HL Jr, Watts R, Wang Y. Peripheral vascular disease: combined 3D bolus chase and dynamic 2D MR angiography compared with x-ray angiography for treatment planning. Radiology 2002 Jul; 224(1): 63 - 74
5. Ruehm SG, Hany TF, Pfammatter T, Schneider E, Ladd M, Debatin JF. Pelvic and lower extremity arterial imaging: diagnostic performance of three-dimensional contrast-enhanced MR angiography. AJR Am J Roentgenol 2000 Apr; 174(4): 1127 - 35
6. Swan JS, Carroll TJ, Kennell TW, Heisey DM, Korosec FR, Frayne R, Mistretta CA, Grist TM. Time - resolved three-dimensional contrast-enhanced MR angiography of the peripheral vessels. Radiology 2002 Oct; 225(1): 43 - 52
7. Lapeyre M, Kobeiter H, Desgranges P, Rahmouni A, Becquemin JP, Luciani A. Assessment of critical limb ischemia in patients with diabetes: comparison of MR angiography and digital subtraction angiography. AJR Am J Roentgenol 2005 Dec; 185(6): 1641 - 50
8. Huber A, Scheidler J, Wintersperger B, Baur A, Schmidt M, Requardt M, Holzknecht N, Helmberger T, Billing A, Reiser M. Moving-table MR angiography of the peripheral runoff vessels: comparison of body coil and

dedicated phased array coil systems. AJR Am J Roentgenol 2003 May; 180(5): 1365-73

9. Nael K, Ruehm SG, Michaely HJ, Saleh R, Lee M, Laub G, Finn JP. Multistation whole-body high-spatial-resolution MR angiography using a 32-channel MR system. AJR Am J Roentgenol 2007 Feb; 188(2): 529-39