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ORIGINAL ARTICLE

Comparative study between multi-detector CT angiography and digital subtraction angiography in evaluation of peripheral arterial occlusive disease

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KEYWORDS

Lower extremity arteries;
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Abstract *Objective:* The aims of the study were the evaluation of peripheral arterial occlusive disease with multidetector or multi-slice CT angiography (MDCTA) and comparison of the results with the results of digital subtraction angiography (DSA), a standard reference.
Patients and method: The written informed consent of the patients and ethics committee approval were obtained. The prospective study group consisted of 10 patients complaining of peripheral arterial disease. Using MDCT-A, the arterial tree of the lower extremity was evaluated for the presence of steno-occlusive lesions that might have led to luminal stenosis. The diagnostic accuracy of MDCTA was calculated and compared with that of DSA.
Results: In the segment-based analysis, the sensitivity, specificity, and accuracy of MDCT angiography in determining significant stenoses were 100%, 99.3%, and 99.6.3%, respectively. The compatibility between MDCTA and DSA methods in grading stenosis was calculated as 0.896 ($P < 0.007$) and it was statistically significant.
Conclusion: MDCT angiography is significantly compatible with DSA method in the evaluation of peripheral arterial diseases. It is a non-invasive method and can be an alternative to DSA.
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1. Introduction

Peripheral arterial disease (PAD) is briefly defined as the atherosclerosis of the arteries other than the coronary arteries. The arteries of the lower extremity are the most commonly involved arteries; thus, the arteriosclerotic obstructions of the distal aorta and arteries of the lower extremity are the most common forms of PAOD (1). Nearly 3–4% of males over

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60 years of age also suffer claudication pain secondary to PAOD (2). In PAOD cases, for a proper treatment plan, determination of significant stenoses and occlusion severity as well as correct mapping of the vascular anatomy is of great importance. DSA is the golden standard in the evaluation of PAOD. However, it is an invasive method and may lead to morbidity (3–5). With the advent of MDCT in the last decade, short scanning time, thin slice, and high spatial resolution were achieved, facilitating the development of 3D reformatted images using the original images in a relatively shorter time (6). Thereby, it has been possible to image the arterial tree with a single injection of contrast matter. Today, 16- and 64-detector CT technology is used in establishing diagnosis as well as treatment planning.

The aim of our study was to compare the results of multidetector CT angiography with the results of DSA as gold standard in patients with lower limb ischemia.

2. Patients and methods

Between June 2013 and June 2014, 10 patients diagnosed as PAOD were evaluated by MDCT angiography. All 10 patients had undergone DSA on the basis CT angiographic findings; all patients had chronic ischemia. The renal function test results of the all enrolled patients were within normal limits. Patients were 6 males and 4 females. The mean age of the patients was 56.3 years. All the patients were suffering from chronic ischemia. Their indications for MDCTA were chronic ischemia in 10 patients. The risk factors were hypertensions in 2, diabetes in 3, and smoking in 2, combined diabetes with hypertension in 1, combined hypertension with smoking in 1 and combined diabetes with smoking in 1. All the patients were informed of study protocol in details and written consents were obtained.

2.1. MDCT technique

For the evaluation of the lower extremity arteries, 64-detector multi-sliced CT (Toshiba Aquilion, Toshiba Medical systems, Tokyo, Japan) was used. Every patient was placed in supine position and in a neutral position with the feet in the gantry first. The area evaluated was extended from the suprarenal aorta to the ankle joint. The scanning parameters were set as follows: tube voltage: 120 kV; effective tube flow: 250 mAs, rotation time: 0.4 s, table speed: 29 mm/s; pitch: 0.844 mm; section thickness: 0.5 mm, and reconstruction interval: 0.5–1 mm. To achieve optimal contrasting in the vascular structures, automatic bolus tracking was used in the determination of the delay time. At the level of the renal artery orifice, ROI was placed. After the injection of contrast material, scanning was automatically started when the density in the abdominal aorta reached the level of 180 HU. Scanning time was about 32 s; therefore, we injected approximately 130 mL of contrast medium (Ultravist 360 mg or Scanlux 300 mg). We also used a saline flush of 30 mL injected at the same rate (4 mL/s). The reconstruction field of view was 34 cm, and the matrix size was 512×512, resulting in a voxel size of $0.6 \times 0.6 \times 0.6$ mm; a mean of 5720 transverse images (range, 5160–6225 images) was generated for each patient. Image reconstruction was routinely performed with a medium soft-tissue algorithm (Vitrea workstation).

2.2. DSA

Catheter angiography was performed using a digital subtraction angiography device (Philips Integris, the Netherlands and Siemens artis FA, Germany). All the patients were evaluated through DSA within one week of MDCT evaluation.

In all the patients, the arterial catheterization was achieved by Seldinger method using a 4-French pigtail catheter. In 10 patients, the catheter was inserted into the superior aortic bifurcation using transfemoral approach. Patients with Leriche's syndrome require transbrachial approach.

2.3. Evaluation of the images and findings

The CT images obtained were transferred onto the workstation (vitrea), and the data were processed by using maximum intensity projection (MIP), multiplanar reformatting (MPR), curved multiplanar (CPR), and volume rendering (VR) techniques. All the arterial segments, particularly the axial segments, were studied based on multiplanar reformat (MPR) images. The grading was made using all the algorithms. Two radiologists interpreted the images in the computer medium. MIP and VR reconstructions were formed by removing the bone structures semiautomatically and using the 3D function of the workstation.

Because of the proximity between the arteries and bone structures at the foot and ankle level, the evaluation was made without the removal of the bone structures.

In the DSA, all the arterial segments, including the distal aorta and proximal foot segments were imaged in the posteroanterior projection. DSA images were interpreted by two radiologists. In the presence of incompatible findings, a consensus was reached. The radiologists were blinded to the MDCT findings.

The steno-occlusive lesions in the main arterial segments were graded by CTA and DSA. The maximum number of segments evaluated for each patient was 23. These segments were the infrarenal aorta, common iliac arteries, external iliac arteries, internal iliac arteries, common femoral arteries, deep femoral arteries, superficial femoral arteries, popliteal arteries, tibioperoneal arteries, anterior tibial arteries, peroneal arteries and posterior tibial arteries.

All the lesions were evaluated using a 5-point scale depending on the stenosis in the lumen diameter. The stenosis in the lumen diameter was measured by visual observations, using a ruler when needed (DSA), and electronic measurements (CTA). The points in the scale represented the following: grade 0, normal arterial lumen and regular arterial wall; grade 1, mild stenosis, irregularities in the arterial wall, and less than 50% stenosis in the arterial diameter; grade 2, moderate stenosis and 50–74% stenosis in the arterial diameter; grade 3, severe stenosis and 75–99% stenosis in the arterial lumen, and grade 4, occlusion. More than 50% stenosis ($\geqslant$grade 2) was considered significant. In the presence of multiple lesions within one arterial segment, the stenotic lesion that caused the most significant stenosis was graded (7).

2.4. Visualization of the collateral vessels

Collateral vessels were scored for CTA and both CTA and DSA (in 10 patients) on the basis of arterial levels when stenoocclusive lesions of grade 2 or higher were present in the main arterial segment. A 3-point scale was used in which 0 meant no collaterals; 1, any number of collaterals of $\leqslant$1 mm in caliber or up to two parallel collaterals of > 1 mm in caliber; and 2, three or more parallel collaterals of > 1 mm in caliber (8).

2.5. Statistical analysis

The acquired data were entered in database (Office Excel 2003 SP1, Microsoft) and exported to a statistics program (SPSS Incorporation, Chicago, IL, USA).

The diagnostic accuracy of CTA in determining significant stenoses (more than 50%, grades 2, 3 and 4) was assessed. DSA results were taken as the standard reference, and for total examined levels, the sensitivity, specificity and Accuracy values were calculated.

3. Results

DSA and MDCT angiography were successfully performed in all patients. A total of 230 segments in 10 patients were examined, none of those patients had a vascular variant or amputation.

On digital subtraction angiography, 130 diseased segments (56.5%) were identified: 72 mildly stenotic, 27 moderately stenotic, 19 severely stenotic and 12 occluded segments. Using CTA, 132 out of 230 examined segments were classified as diseased arteries (57.4%): 73 mildly stenotic, 28 moderately stenotic, 18 severely stenotic, and 13 occluded segments. So, there was two segments underestimated as normal by MDCT (one mild and one moderate stenosis by DSA), one segment overestimated as occlusion by MDCT (evaluated by DSA as severe stenosis). Of the three segments over/underestimated by MDCT angiography, one was segment of the superficial femoral artery with severe and dense calcification and was detected by MDCT as occluded segment while the DSA revealed severely stenotic. And the other two segments of the anterior tibial artery were classified by DSA as mild and moderate stenosis while by MDCT were normal (Table1, Fig. 1).

We had calculated the sensitivity, specificity, and accuracy of MDCT angiography for the detection of stenosis of 50% or more in all 230 segments. So to calculate that (50% or more stenosis), the results of the degrees of stenosis were subgrouped into two groups, one < 50% stenosis including normal and mild stenosis, the other group of significant stenosis > 50% including moderate, severe stenosis and occlusion at the CT angiograms (volume-rendered and transverse sections) obtained with the three different section widths as follows: set 1 (2.0 mm SW), set 2 (1.0 mm SW), set 3 (0.5 mm SW) (see Figs. 2–5).

Sensitivities for the detection of stenoses were 98.2%, 100%, and 100%, for CT data sets 1, 2, and 3, respectively. These differences were not statistically significant (P > .017). The corresponding specificities were 96.5%, 97.9%, and 99.3%. The differences in specificity were not significant between CT data set 1 and CT data set 2 or between CT data set 2 and CT data set 3 (P > .017). However, the differences in specificity were significant between CT data set 1 and CT data set 3 (P < .017). The accuracy, positive predictive value, and negative predictive value for each of the three CT angiography techniques, as compared with DSA, are listed in Table 2.

Comparing the ratings at DSA with MDCTA sets, stenosis grade was rated higher in 4 arterial segments with CT data set 1 (These 4 segments were classified as grade 0 in DSA but were classified by MDCT as: three out of four segments were grade 2 and one segment was grade 4), 3 segments with CT data set 2 (these three segments were evaluated by DSA as grade 0 while were graded by MDCT as grade 2), and 1 segment with CT set 3 (this was evaluated by DSA as grade 1 stenosis and by MDCT as grade 4). Hence, detection of hemodynamically significant stenoses (> 50%) resulted in 4, 3, and 1 false-positive classifications for CT data sets 1, 2, and 3, respectively compared with DSA. All false-positive classifications regarding hemodynamically significant stenoses (eg, a grade 1 stenosis classified as a grade 2 stenosis and a grade 1 stenosis classified as occlusion) occurred with calcified vessel segments. The relative low rate of false-positive findings of hemodynamically significant stenoses in CT data sets 1 and 2, as compared with the rate in CT data set 3, was caused by more severe partial volume artifacts that caused "blooming" of the calcified plaques in the former data sets .The sensitivity in the detection of stenoses was excellent for all three reconstruction techniques (> 95%), and no particular reason for misclassification could be found for the small number of false-negative ratings.

4. Discussion

To determine the proper treatment for PAOD cases, determination of the location stenotic segments and the occlusion severity in the iliac and lower extremity arteries is required. DSA, known as a gold standard in diagnosis of PAOD, is an invasive method; thus, it presents some risks and limitations (3–5). MDCT-A has been shown to be reliable in the evaluation of occlusion pathologies in the arteries of the lower extremity, and its clinical use has been increasing. With CT

Table 1 Assessment of degree of stenosis of lower limb arteries using MDCT angiography and digital subtraction angiography.

MDCT	DSA					
	Normal	Mild	Moderate	Severe	Occlusion	Total
Normal	98	0	0	0	0	98
Mild	1	72	0	0	0	73
Moderate	1	0	27	0	0	28
Severe	0	0	0	18	0	18
Occlusion	0	0	0	1	12	13
Total	100	72	27	19	12	230

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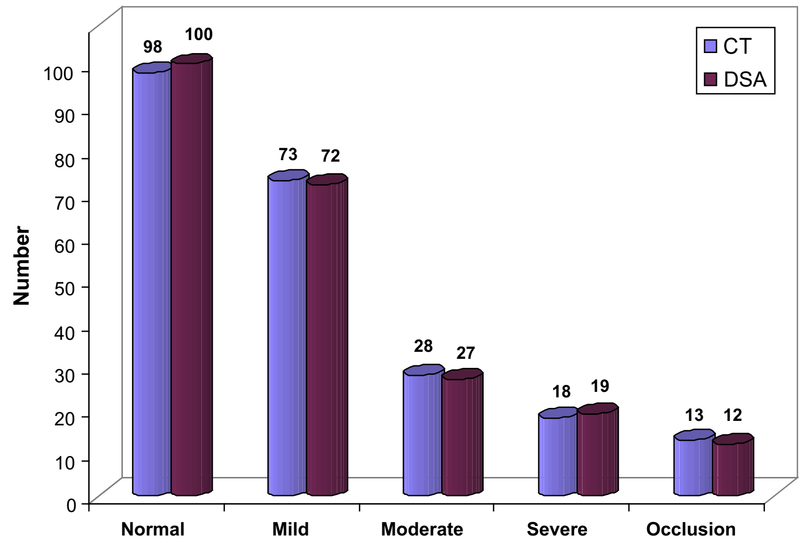

Fig. 1 Bar chart showing number and degree of stenosis depicted by MDCT and DSA.

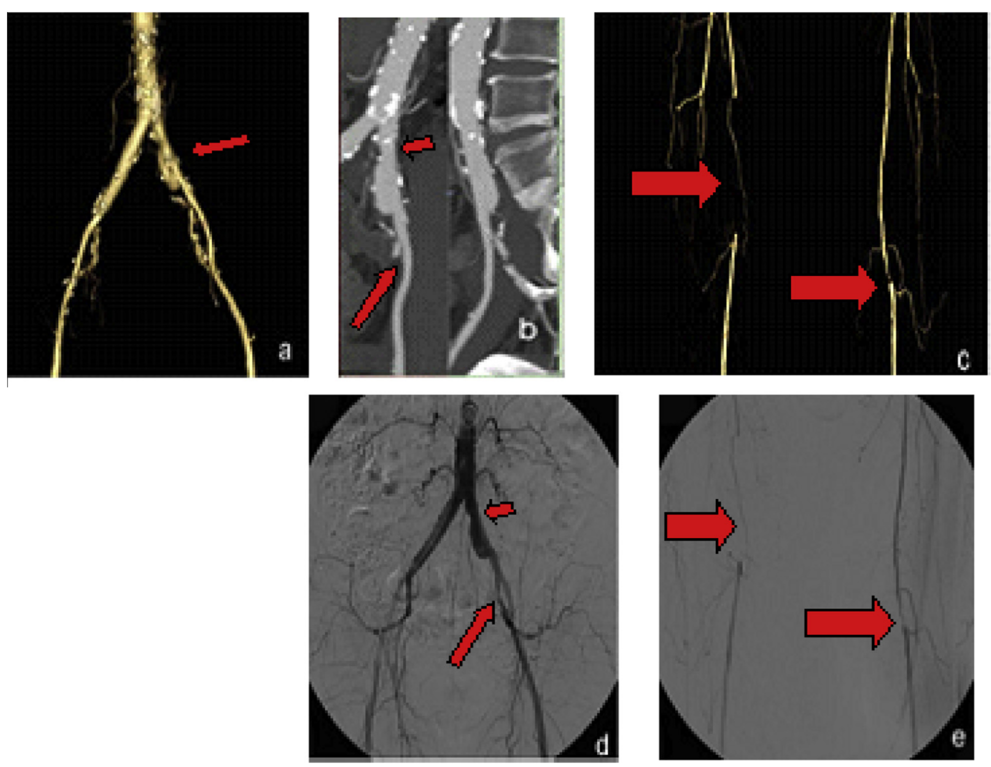

Fig. 2 On the VR MDCT images of a 75-year-old patient (a) and (b), widespread nonstenotic calcifications are in the bilateral iliac arteries. Mild and severe stenosis of the left CIA and EIA seen in VR (small red arrows in a). The VR MDCT images obtained at the femoral level show a grade 4 occlusion on the distal right superficial femoral artery and a grade 3 stenosis in a short segment of the left popliteal artery (red thick arrows in b). DSA results were compatible with the results of MDCT (c) and (d).

techniques before the advent of MDCT, it was not possible to image the entire arterial tree of the lower extremity with only one injection of the contrast material. Because of relatively slower image gain of single-detector CT device and its low z-axis resolution, not all the arteries from the renal area to the foot in the lower extremity could be imaged. With the advent of multi-detector CT technique, significant advantages were gained, particularly in scanning time and section thickness, allowing the evaluation of pathologies in the peripheral arteries.

Cernic et al., compared the 64-MDCT-A results with the results of DSA, a standard reference in the evaluation of stenoocclusive lesions in PAOD cases (3). In that study, the sensitivity and specificity of 64-MDCT in determining the

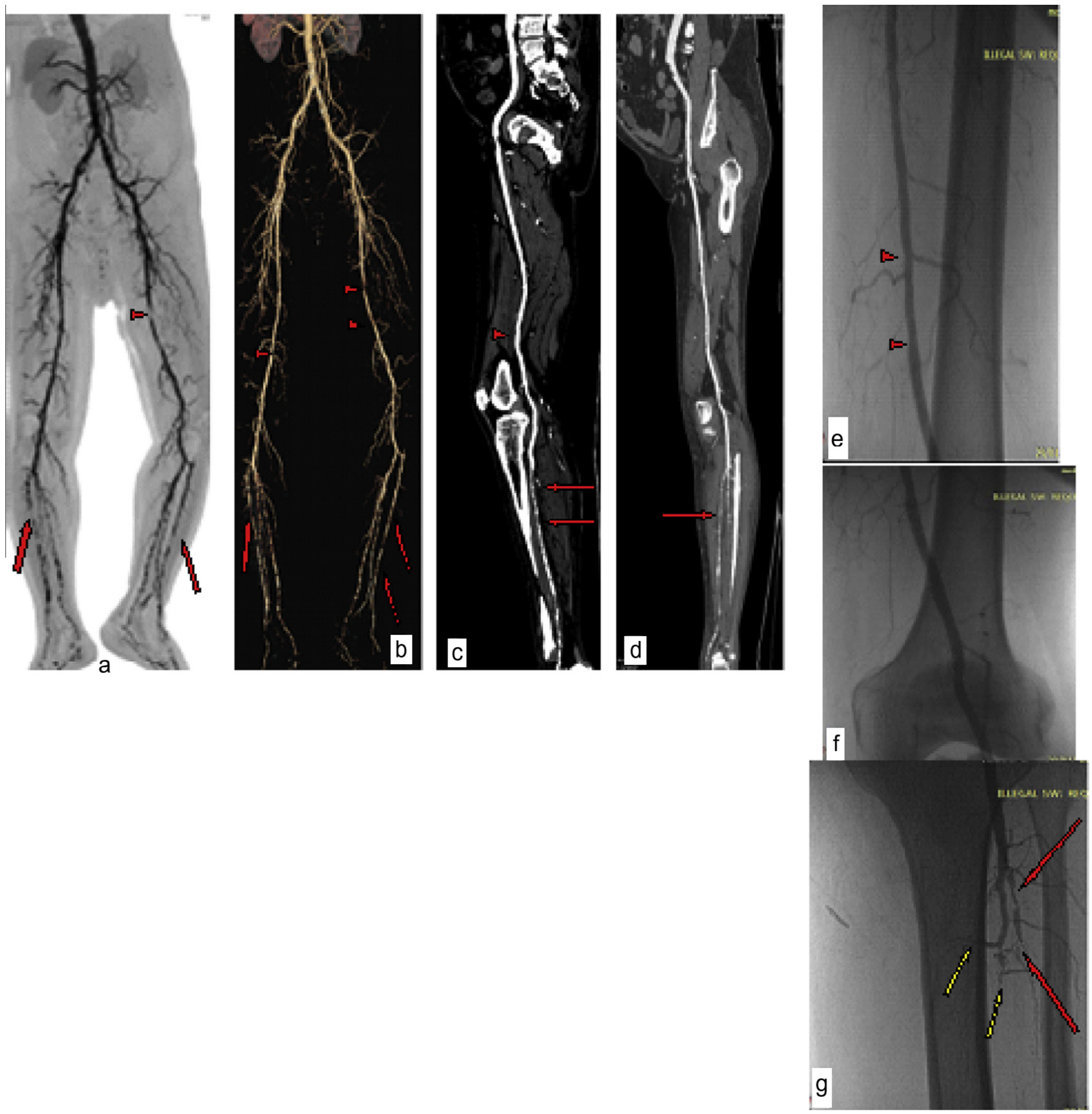

Fig. 3 MDCT angiography of 68 years old patient with left sided claudication pain revealed: Atherosclerotic changes was noted at arterial levels of SFA and infrapopliteal levels in both sides seen as wall irregularities with no significant stenosis (arrow heads in MIP a, VR b). Multiple short (1 cm) mild to moderate stenoses along the whole course of the ATA, PTA and peroneal artery in both sides (thin red arrows in a and b). Direct antero-posterior projection DSA revealed: Severe stenosis of the proximal part of the left ATA with complete occlusion distal to this stenotic segment (red arrows in e). Complete occlusion of the left PTA and peroneal artery (yellow arrows in e). Wall irregularities of the left SFA are noted but they were nonstenotic (arrow heads in c).

significant stenosis were found to be 97.2% and 97%, respectively. In 2010, Shareghi et al. and in 2011 Fotiadis et al. studied 28 and 41 patients with hemodynamically significant disease respectively. They found similar results about diagnostic performance of CTA. The sensitivity, specificity, and accuracy were 99%, 98% and 78% respectively (9,4). In our study, similar results were found. The sensitivity, specificity and accuracy were 100%, 99.3% and 99.6% respectively.

With 64-MDCT, shorter scanning time and less contrast material use are provided, by which sufficient arterial contrast is achieved without a venous circulation. Moreover, 64-MDCT provides thinner sections and higher spatial resolution.

In our study, the scanning was realized by determination of the delay time through bolus timing method. The images of all the arterial segments, including the leg arteries, were of high quality in all the patients including the complex patients (those with multiple stenosis and widespread occlusions). None of the patients developed venous contamination. Nevertheless, in two patients with severe unilateral stenoocclusive lesions, delayed contrast material passage resulted in false positive findings.

In a study done by Hideki et al., 2004, in five segments stenotic lesions were overestimated by two grades on MDCT angiography. Four of them were superficial femoral

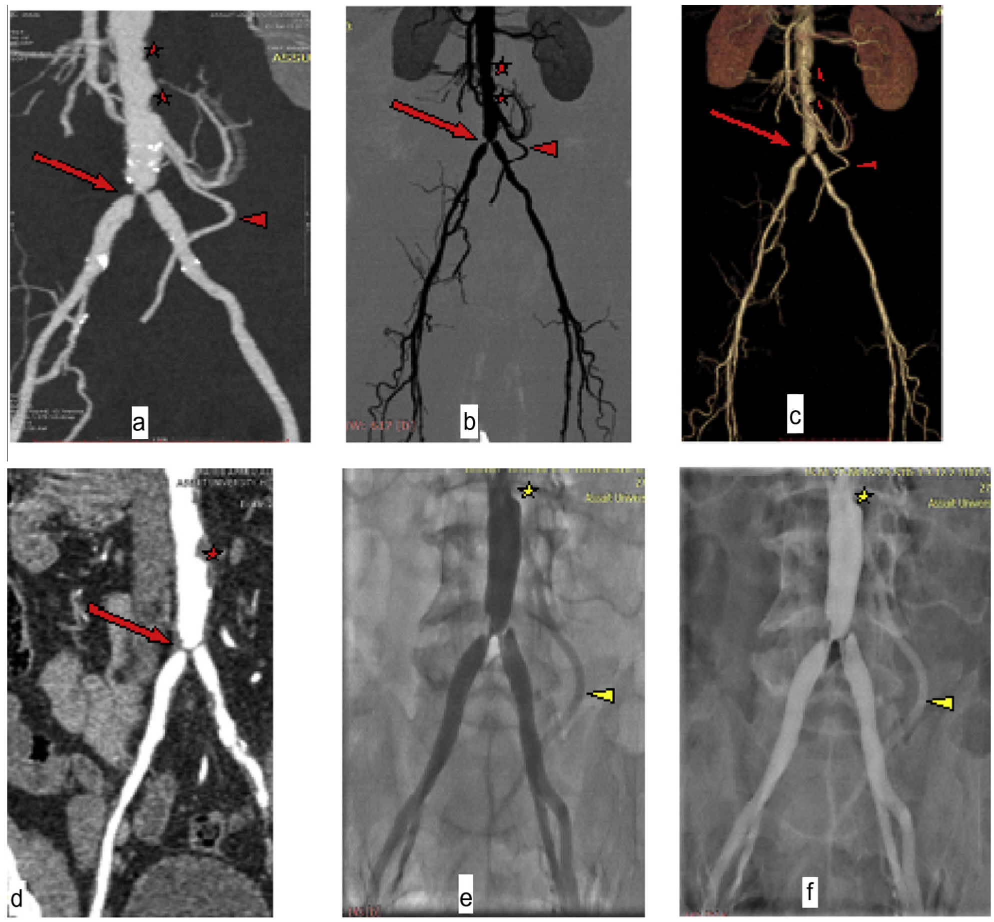

Fig. 4 MDCT angiography of 65 years old male patient with bilateral claudication pain revealed: Mild atherosclerotic changes were noted at aortoiliac arteries. MIP images (a and b) demonstrate short severe stenosis of both CIA (red arrows). Mild stenosis of the infrarenal aorta was noted in the left side (asterisk in a and b). Collateral vessels are noted from lumbar arteries in the left side (arrow heads in a and b). Direct antero-posterior projection DSA revealed: severe stenosis of both CIA (yellow arrows in c and d) and was identical to MDCT angiography findings. Collateral in the left side was depicted (arrow heads in c and d). Mild infrarenal aortic stenosis (asterisk in c and d). DSA was identical to MDCT Angiography.

artery segments with severe and dense calcifications, resulting in strong beam-hardening artifacts, which might have hindered precise evaluation. The remaining one was a peroneal artery segment in a patient with popliteal artery entrapment syndrome (10).

In our study, in three segments stenotic lesions were falsely estimated by MDCT. Two segments were underestimated as normal (one mild and one moderate stenosis by DSA). The remaining segment was overestimated by MDCT as occlusion (while DSA evaluation of this segment was severe stenosis). Of the three segments over/underestimated by MDCT angiography, one was segment of the superficial femoral artery with severe and dense calcification and was detected by MDCT as occluded segment while the DSA revealed severely stenotic and the other two segments of the anterior tibial artery were classified by DSA as mild and moderate stenosis while by MDCT were normal. This could be explained by relative suboptimal MDCT evaluation of the distal leg vessels and sometimes, the continuous wall calcification of the small arteries has the same density of luminal contrast giving false patency of these vessels.

Another disadvantage of CTA is the challenges experienced at times in the evaluation of severely calcified arteries. Ota et al. have emphasized that in the presence of severe calcification, grading of the stenosis is more difficult (2). On the other hand, 64-MDCT yields images with thinner sections and higher spatial resolution, and thus, this problem is avoided. In the present study, the characteristics of the plaque structure and their area of involvement could not be evaluated in detail. However, in patients with severe arterial calcifications, with careful evaluations of the multiplanar images, no problems were encountered in the assessment of stenosis at the aortoiliac and femropopliteal levels. In the evaluation of crural arteries with thin calibers, however, severely calcified plaques led to false positive results. The statistical evaluation showed significant compatibility between MDCT and DSA results.

Portugaller et al. reported that when volume rendering technique was used alone, the sensitivity and specificity rates in detecting the high-grade stenosis (>75%) were 84% and 78.5% respectively. With the use of MIP, however, the sensitivity and specificity rates were 89% and 74%. In the same study, the best results were obtained by evaluation of the axial

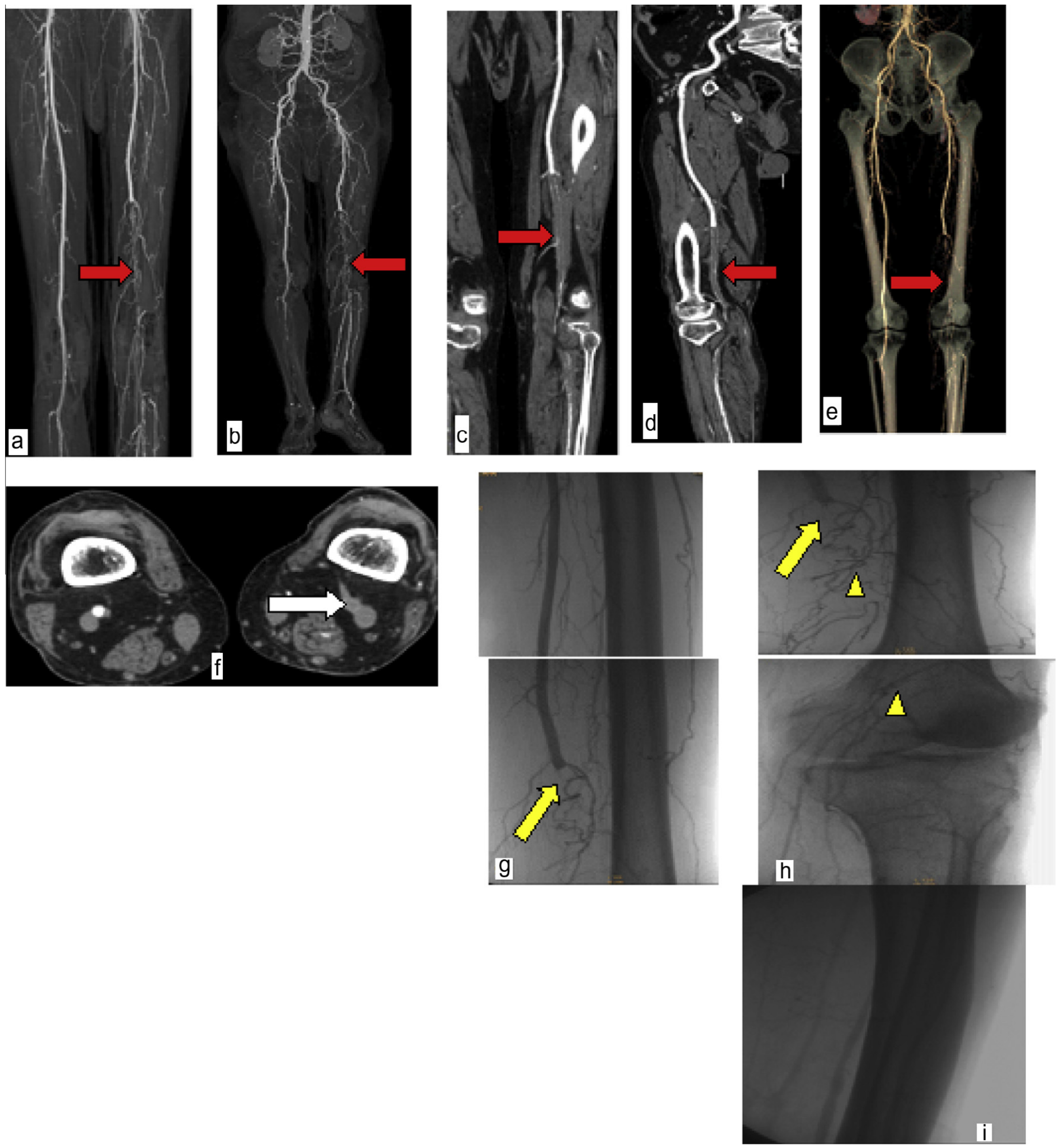

Fig. 5 MDCT angiography of 73 years old male patient with left claudication pain MDCT angiography revealed: Long segment occlusion of the left femropopliteal artery (thick red arrows) seen at MIPs (a and b). Axial images (c) confirm complete occlusion of the artery (arrow). Refilling of the infrapopliteal arteries distal to the occlusion from collateral vessels. Direct antero-posterior projection DSA revealed: Occlusion of the left femropopliteal artery (thick yellow arrows in d and e) was identical to MDCT angiography findings. Extensive collateral was depicted (arrow heads in e). Relative poor filling of the infrapopliteal vessels despite good collateral (f).

images and the sensitivity and specificity rates were found to be 92% and 83% (11). Schernthaner et al. used 16-detector CT as reconstruction algorithm in MIP and multipath CPR techniques and found sensitivity and specificity rates of 99.2% and 100% (12). In our study, The MPR axial images of all the segments were carefully studied and 3D reconstructions were formed and evaluated.

Visualization of collateral vessels was not as good on CTA as on DSA. Although, to our knowledge, no previous peripheral CTA study has quantitatively evaluated the visualization of collaterals, it has frequently been stated that CTA is superior to DSA in depicting peripheral collateral circulation and in revealing enhancement distal to arterial occlusions because of collateral circulation (2,7,13). The fact that these assertions may not necessarily be true, however, is evident not only from the absence of published data but also from published comparative images that often show more extensive collateral vessels on DSA than on CTA (2,7). In the present study, we can agree with these published data about depiction of collateral circulation by MDCT in comparison with DSA. But, in our study we found significant difference between DSA and MDCT angiography on depiction of collateral circulation, and the visualization of the vessels distal to occluded segments was better at MDCT than at DSA.

Table 2 Results of grading of luminal narrowing and stenosis as a comparison between DSA and MDCT angiography.

	DSA	MDCT angiography		
		Set 1 (2.0 mm SW)	Set 2 (1.0 mm SW)	Set 3 (0.5 mm SW)
No. of segments	230 (100.0%)	230 (100.0%)	230 (100.0%)	230 (100.0%)
Normal (grade 0)	100 (43.5%)	97 (42.2%)	95 (41.3%)	98 (42.6%)
Mild (grade1)	72 (31.3%)	71 (30.9%)	74 (32.2%)	73 (31.7%)
Moderate (grade 2)	27 (11.7%)	29 (12.6%)	30 (13.0%)	27 (11.7%)
Severe (grade 3)	19 (8.3%)	18 (7.8%)	17 (7.4%)	19 (8.3%)
Occlusion (grade 4)	12 (5.2%)	15 (6.5%)	14 (6.1%)	13 (5.7%)
Sensitivity (%)	NA	98.21	100	100
Specificity (%)	NA	96.53	97.92	99.31
Accuracy (%)	NA	97.4	98.7	99.6
PPV (%)	NA	91.7	94.9	98.2
NPV (%)	NA	99.3	100	100

*SW = section width, PPV = positive predictive value, NPV = negative predictive value *NA = not applicable. DSA was the reference-standard examination; *$P < .007$ for differences between all three CT angiography data sets.

In conclusion, MDCT-A is successful in the imaging of peripheral arterial occlusive disease of the entire arterial tree of the lower extremity, including the distal leg arteries, and it can be considered a noninvasive alternative to DSA.

Conflict of interest

We have no conflict of interest to declare.

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