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Assessment of occlusive disease of lower extremity arteries on the basis of anatomic region: Value of 128-slice multidetector CT angiography in comparison with digital subtraction angiography

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ABSTRACT

Background & Objectives: The Previous studies of multidetector CT (MDCT) of the lower extremities for the detection of peripheral vascular disease showed high diagnostic accuracy but were performed with older generation systems. Our study aimed at assessing the diagnostic value of 128 MDCTA compared with that of digital subtraction angiography (DSA) in the grading of focal arterial disease of lower extremity arteries on the basis of anatomic regions. **Materials & Methods:** Forty-two patients with peripheral arterial occlusive diseases underwent both MDCTA and DSA. Lower extremity arteries depicted at MDCTA and DSA were graded separately for the degree of stenosis into 3 anatomic regions and 33 segments. Grading by MDCTA and DSA was done independently. Homogeneity analysis was used between MDCTA and DSA measurements in each patient. The sensitivity, specificity, positive predictive value and negative predictive value for detection of stenotic lesions were calculated for all anatomic regions, with findings at DSA used as the reference standard. **Results:** No statistically significant difference (P>.05) between DSA and MDCTA was present in Aorto-iliac and poplitiofemoral regions while there was statistically significant difference (P<.05) in the infrapopliteal region. The Sensitivity, Specificity, Positive Predictive Value and Negative Predictive Value based on a reading of MDCTA were 84.3%, 93.8%, 89.4% and 90.6% for aorto-iliac 86.6%, 94.7%, 84.1% and 94.7% for poplitiofemoral and 95.7%, 86.1%, 85.6% and 95.9% for infra-popliteal region respectively.
Conclusion: MDCTA is excellent alternative in diagnosing lower extremity arterial occlusive diseases above the knee. DSA remains better on illustrating distal runoff vessels.

Key words: Digital Subtraction Angiography; Multidetector CT Angiography; Peripheral Arterial Occlusive Disease

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INTRODUCTION

Lower extremity arterial diseases (also known as peripheral arterial disease or PAD) represent a significant health problem with increased morbidity and mortality. It can be sub-classified into; steno-occlusive, aneurysmal, vasculitis, traumatic vascular injuries and abnormal arterio-venous communications. In occlusive disease lumen is narrowed either in an acute or chronic manner.[1]
Digital sub-traction angiography (DSA) has been considered as gold standard of diagnosing peripheral vascular diseases. However, it is invasive and exposes the investigator and patient to a lot of ionizing radiation.[2] DSA also is a time and cost consuming procedure. Finally, DSA results only in luminograms, and thus information about plaque constituents and vessel surroundings cannot be acquired.[3]
Multi-detector computed tomography angiography (MDCT angiography) of the lower extremity has

high accuracy for detection of steno-occlusive diseases compared with DSA.[4] Its advantages over DSA includes minimal invasiveness, smaller required volume of contrast material, shorter scan time and fast data acquisition. Other advantages of MDCT angiography include three dimensional (3D) volumetric data analysis and display, visualization of mural plaque and calcium. Unlike catheter angiography, MDCTA not only depicts the vessels but also allows assessment of perfusion in adjacent organs. These advantages have led to CTA replacing DSA for diagnosis at many centers.[5] However, there is a paucity of studies comparing the 128-slice MDCTA with DSA on the basis of region of blood vessel regarding grading in lower extremity.

The purpose of the present study was to evaluate the diagnostic accuracy of 128-slice MDCTA in comparison with DSA in patients with PAD depending on the region of blood vessel.

MATERIALS AND METHODS

Subjects

This retrospective study was performed between May 2011 and May 2013. There were a total of 42 patients who underwent both MDCTA and DSA for PAD. The mean age of the patients was 70 years, (range, 38 to 89 years), and 32 were male (76.19%) and 10 female (23.81%). The local institutional review board approved this retrospective study.

MDCTA

MDCTA was performed on a Sensation 128-slice CT system (Siemens Somatom Definition AS+). Patients were in the feet first supine position on the CT table with their legs held together. The scanning range was planned to encompass the entire vascular system from the diaphragm to the level of the ankles.

For optimal intraluminal contrast enhancement, the delay time between start of contrast material administration and start of scanning was obtained for each patient individually by using a bolus-tracking technique (CARE-Bolus, Siemens). Subsequently, a nonionic contrast media (Iohexol injection 100ml:35g)was administered through a 20 gauge cannula that was placed into the patient’s antecubital vein for a total volume of 120 ml. The contrast agent was administered with an automatic power injector (Ulrich medical missouri) at a flow rate of 4ml/sec. Data acquisition was performed craniocaudally with the following parameters: collimation 0.6 mm, pitch 0.5, tube voltage 100KV, current 83mAs, slice thickness 0.75mm at an interval of 0.4mm. Two orthogonal curved planar reformations were created along the longitudinal axis of the aorta through both common and external iliac arteries and the common femoral artery. All data were then transferred to a workstation (Syngo Multimodality Workplace, VE36A) for post processing. The reconstructions were performed by the technologists experienced in 3D post processing and segmentation techniques. Segmentation was performed of both bony structures and vessel wall calcifications resulting in images containing the contrast enhanced vascular lumen without vessel wall calcifications and bones. Of these data sets rotating volume MIP images were generated.

DSA technique

DSA was performed using an angiography system (Siemens Artis zee). All the angiograms were performed as part of a therapeutic intervention. The arterial access site and the extent of image coverage were guided by the clinical need of the patient. One patient had only one side examined, and 41 patients had bilateral imaging of only the clinically relevant vascular segments. For bilateral studies 5F pigtail catheters were placed into the abdominal aorta. Fifteen to twenty millilitres of ioversol (320mg iodine/ml) were injected at a rate of 10ml/s, with two frames per second for the aorto-iliac segments and one frame per second for the infra-inguinal segments. For infrapopliteal segments the amount of contrast medium injected per run could be increased to 30 ml at the discretion of the interventionist. Unilateral studies were performed with automatic injector (Mark V ProVis) through a 4 or 5 F sheath or catheter of 10-20 ml ioversol 320. A 50% dilution was used for the poplitiofemoral segments and no dilution for the infra-popliteal segments. One frame per second was used for most injections. Anteroposterior and bilateral 35o oblique views were routinely obtained for the aorto-iliac segments. For the infra-inguinal segments oblique views were obtained only when it was clinically necessary.

Image and Data Analysis

The arterial tree was divided into 32 segments for the evaluation of steno-occlusive disease as shown in the figure 1. The arterial segments were divided into three subgroups, which included the aorto-iliac, poplitiofemoral and Infra-popliteal segments. All 32 segments were evaluated with MDCTA for all 42 patients, in a picture archiving and communication system(PACS) workstation (FUJITSU computers Siemens). For the interpretation of the CT angiograms, the axial

Table 1 Diameter Grading System

Grade	Degree of Stenosis
1	No Stenosis
2	<50%
3	50-75%
4	75-99%
5	Occlusion

Table 3 Comparison of CTA with DSA Performance on Regional Basis

Vascular Region	CTA Median	DSA Median	P Value
Aorto-iliac arteries	2.00	2.00	0.642
Poplitiofemoral arteries	2.00	2.00	0.461
Infra-popliteal arteries	2.00	2.00	0.001

Table 2 Assessment of Degree of Stenosis with DSA and Multi–Detector Row CT Angiography in Aorto-iliac and Lower-Extremity Arteries

		DSA Grade					Total
		1	2	3	4	5	
CTA Grade	1	155	10	2	0	0	167
	2	33	219	8	1	0	261
	3	2	14	22	7	1	46
	4	2	4	3	15	4	28
	Grade 5	0	0	4	8	145	157
Total		**192**	**247**	**39**	**31**	**150**	**659**

images and thin MIPs were routinely evaluated. Segments that were not of diagnostic quality due to inadequate opacification, extreme calcification, or artifacts were excluded from the analysis. In every segment, the most severe lesion was graded using a five-point scale (Table 1). The DSA images were also measured with the same five-point scale after calibration. All segments that were adequately evaluated with both techniques were included in the comparative analysis. Analysis of steno occlusive disease was performed using a lesion-based approach rather than an arterial segment–based approach, as has been used in other studies (6-8).

5.Statistical analysis

The acquired data were entered in a data sheet (Excel 2010, Microsoft) and exported to a statistics program (SPSS 20 for Windows, SPSS, IL, USA). Paired non-parametric statistical analysis (homogeneity analysis) was used between MDCTA and DSA measurement, and the probability of type I error was set at 0.05. Calculations of sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for the detection of the degree of all stenotic lesions were made by using DSA findings as the reference standard.

RESULTS

Forty-two patients were evaluated with both MDCTA and DSA. A total of 659 segments were covered by both CTA and DSA. On DSA images, 467 diseased segments (70.86%) were identified: 247 with grade 2 stenosis, 39 with grade 3 stenosis, 31 with grade 4 stenosis, and 150 with occlusion. In 70 segments the degree of stenosis was overestimated at MDCTA. In 58 segments (37 of which were considered normal at DSA but were

Table 4 Performance of 128-Detector Row CT Angiography Compared with Conventional DSA in the Detection of Arterial Stenosis

Vascular Region	Sensitivity (%)	Specificity(%)	Positive Predictive Value(%)	Negative Predictive Value(%)
Aorto-iliac	84.3%	93.8%	89.4%	90.6%
Poplitiofemoral	86.6%	94.7%	84.1%	95.7%
Infra-popliteal	95.7%	86.1%	85.6%	95.9%

diagnosed as mildly stenosed at MDCTA), the degree of stenosis was overestimated at MDCTA by one grade; in 10 segments, the degree of stenosis was overestimated by two grades and in 2 segments, the degree of stenosis was overestimated by three grades. In 33 segments the degree of stenosis was underestimated at MDCTA. The degree of stenosis was underestimated by one grade in 29 segments and by two grades in 4 segments.

The comparison of CTA performance with DSA performance on regional basis by paired non-parametric statistical analysis (homogeneity analysis) was done(Table 3). For larger arteries like aorto-iliac and femoro-popliteal the P value is >0.05. While it is <0.05 for smaller arteries like infra-popliteal. Figure 2 and Figure 3 were true positive cases for aorto-iliac region. Figure 4 was a true positive case for poplitiofemoral region. Figure 5 was a false positive case for infra-popliteal region. Figure 5 showed the need of delayed imaging. Table 4 shows Sensitivity, Specificity, Positive Predictive Value and Negative Predictive Value.

DISCUSSION

Recent technologic advances in MDCT now allow rapid image acquisition with excellent spatial and temporal resolution.[9] Advanced post-processing workstations enable rapid image manipulation and assessment. Previous studies using older generation MDCT scanners (4 and 16 slice) found adequate accuracy to detect lesions within the peripheral vasculature.[10]

In current study, we extend these findings by evaluating the accuracy of the newest iteration in CT scanner, 128 MDCT. In a cohort of 42 patients with intermittent claudication, we found Sensitivity, Specificity, Positive Predictive Value and Negative Predictive Value based on a reading of multi–detector row CT angiograms(Table 4).

Several previous studies have evaluated the use of peripheral CT angiography and revealed excellent correlation between MDCTA and DSA (Table 5)[4, 8, 11-17] Met et al.[18] performed a systematic review and meta-analysis for 20 studies published through 2008, that included 957 overall patients. The summary estimates of sensitivity and specificity for aorto-iliac disease provided in five studies were 96% and 98% respectively. The summary estimates of sensitivity and specificity for femoropopliteal disease provided in five studies were 97% and 94% respectively. The summary estimates of sensitivity and specificity for distal runoff in the tibial arteries provided in six studies were 95% and 91%.

In the current study data was stratified on the basis of region i.e. aorto-iliac, poplitiofemoral and infra -popliteal region. Then homogeneity test was applied. There was statistically significant difference (P<.05) between DSA and MDCTA for infra-popliteal region while there was no statistically significant difference (P>.05) between DSA and MDCTA in case of aorto-iliac and poplitiofemoral region. This means MDCTA is consistent and accurate as DSA in the assessment of patients with peripheral occlusive disease of arteries and can be reliably used to grade disease severity and plan treatment in case of aorto-iliac and poplitiofemoral arteries while MDCTA is not so good as DSA in case of infra-popliteal arteries. This difference is thought to be due to close relation to bone causing more artifacts (e.g. Partial volume averaging) and small diameter of the arteries of infra-popliteal region giving rise to more error. The diameter of the proximal (8–12 mm diameter), mid (5–7 mm diameter), and distal (1.5–4 mm diameter) arteries are 8-12mm, 5-7mm, 1.5-4mm.[19]

The sensitivity and specificity in our study bears excellent comparison as compared to other studies although it's slightly lower as compared to those studies. The scanning range in our study is larger than these studies. Our study can provide more overall idea for the clinician and interventional

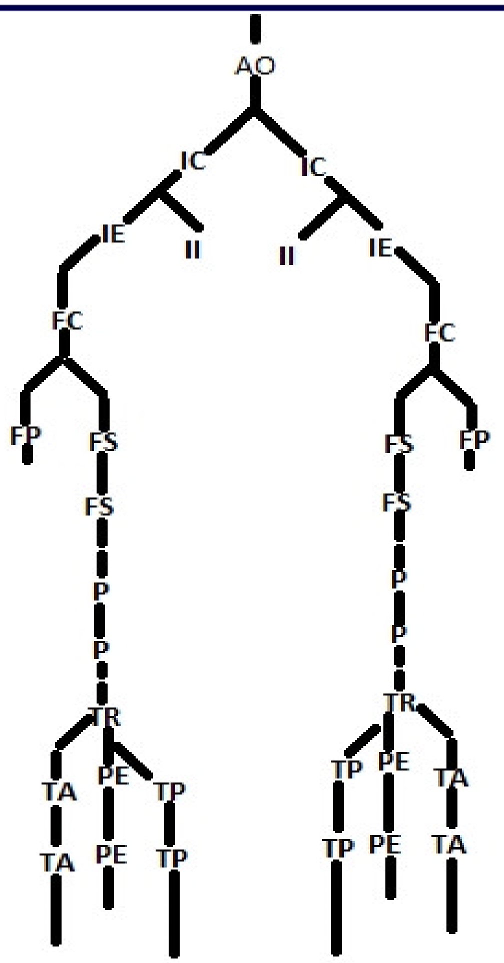

Figure 1 Segmentation of the arterial tree of lower limb in our study. Infrarenal aorta (AO),common iliac (CI), internal iliac (II),external iliac (EI), common femoral (CF), deep femoral(DF), proximal (SF1) and distal superficial femoral (SF2),supra-articular (P1) and subarticular popliteal (P2), proximal(AT1) and distal (AT2) anterior tibial, tibioperoneal(TR), proximal (PE1) and distal peroneal (PE2), and proximal(TP1) and distal (TP2) posterior tibial.

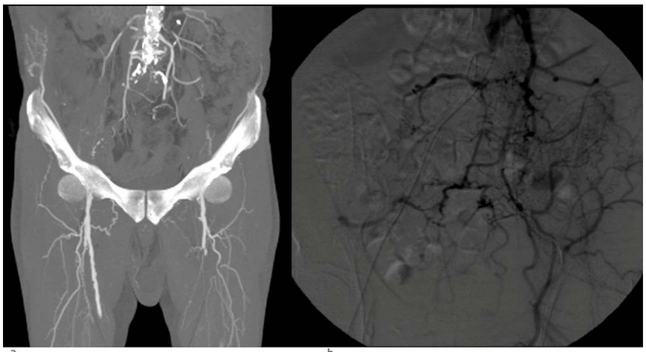

Figure 2 A 64-years-old man with intermittent claudication (stage 4) of lower limbs bilaterally. (a) Maximum intensity projection(MIP) demonstrates complete obstruction(Grade 5) of common iliac artery bilaterally. (b) Digital subtraction angiography(DSA) frontal projection view confirmed the complete obstruction(Grade 5). This was a true positive case as DSA was taken as gold standard.

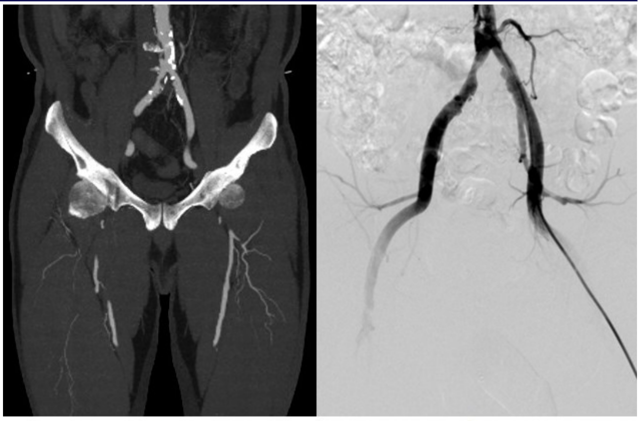

Figure 3 A 70-year-old man with rest pain and gangrene of his right toes. (a)MIP demonstrates grade 3 stenosis of right common iliac artery with left common iliac artery dissection (b)DSA frontal projection confirmed the findings in MDCTA. This is a true positive case as DSA was taken as gold standard.

Figure 4 An 82-year-old diabetic man with rest pain of lower limb bilaterally. (a)MIP demonstrates short but multiple grade 1 stenoses of right superficial femoral artery and normal left superficial artery (b)On DSA frontal projection view the right superficial femoral artery was graded as grade 1 (c)On DSA frontal projection view the left superficial femoral artery was graded normal. This was a true positive case, as DSA was considered the gold standard.

radiologist. Delayed scan is needed less often even in case of compromised heart function as care bolus was used. Focusing in the smaller arteries of the lower leg gives information that is useful to the clinician for diagnosis. But current study focused more in the larger arteries whose study gives benefit for the patient by giving more practical information to the clinician and interventional radiologist. So we used delayed scanning technique less often. This could be the reason why the sensitivity and specificity in our study is slightly lower. Moreover, these values also bear excellent comparison with values of 92

Table 5 Comparison of Studies Using MDCTA for the Detection of Stenosis

			Aorto-iliac		Femoro-popliteal		Infra-popliteal	
Author	No. of patients	Slices	Sens(%)	Spec(%)	Sens(%)	Spec(%)	Sens (%)	Spec(%)
Ota et al.[9]	24	4	97	100	100	96	100	100
Catalano et al.[22]	50	4	95	90	98	96	96	93
Portugaller et al.[23]	50	4	88	75	95	70	86	74
Laswed et al.[10]	34	16	95	100	95	95	91	96
Willmann et al.[19]	39	16	99	98	98	96	97	96
Schernthaner et al.[24]	50	16	100	100	97	99	98	100
Fine et al.[12]	107	64	86	95	90	90	90	96
Shareghi et al.[25]	28	64	100	99	100	99	97	99
N. Fotiadis et al.[15]	41	64	100	100	100	97	98	97
Current study	42	128	84	93	86	94	96	86

to 100% and 91 to 99%, respectively, for contrast-enhanced MR angiography.[20] Segments that were not of diagnostic quality due to inadequate opacification, extreme calcification, or artifacts were excluded from the analysis.

Finally our study shows that for larger arteries which the clinician and interventional radiologist are more concerned, MDCTA appears consistent and accurate in the assessment of patients with peripheral occlusive disease of larger arteries like aorto-iliac and poplitiofemoral region and can be reliably used to grade disease severity and plan treatment while it is less consistent and less accurate for smaller arteries like infra-popliteal region.

It should also be borne in mind that whereas MDCTA is a 3D technique permitting image reconstruction in multiple planes, DSA is solely a 2D technique in which images are obtained in just two or three planes at best. But recent advances in DSA like rotational DSA which can produce 3D images can overcome limitations of projection images taken from few angles in our study. So MDCTA is better than 2D DSA in this aspect.

In the present study diagnosis and grading of stenoocclusive disease was performed with routine analysis of the axial images and thin coronal, sagittal, and oblique MIPs. Curved planar reconstructions were performed only when needed and volume-rendering images were not used for diagnosis. Evaluation of axial and cross-sectional images is critical in grading the severity of stenotic disease in patients with diabetes and chronic renal failure due to extensive calcifications, which can often make standard reconstructive views deceptive.[7, 11, 21] Radiologists are familiar with cross-sectional images, and with appropriate window adjustment it is possible to evaluate the patency and degree of stenosis even in small calcified tibial vessels.

Limitations

There were several limitations of the present study. First, it is limited principally by its retrospective nature further prospective work is certainly warranted to confirm our findings. Second the DSA images were all acquired as part of a therapeutic intervention and only the clinical relevant segments were imaged. However, all the DSA images included in the analysis were of high quality and represent the true extent of the disease.

CONCLUSION

MDCTA is an excellent alternative in diagnosing lower extremity arterial occlusive diseases above the knee. DSA remains better on illustrating distal runoff vessels. Larger is the size of arteries better is the performance of MDCTA as compared to DSA.

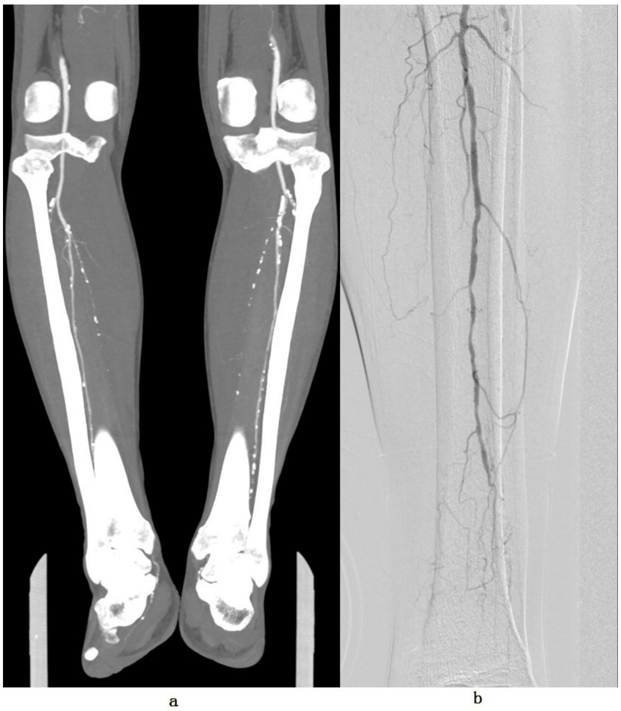

Figure 5 A 70-year-old diabetic man presented with left lower limb intermittent claudication. (a)MIP demonstrates calcification obscuring some portion of the left peroneal artery while the visible portion appears smooth and normal (b)On DSA frontal projection view the left peroneal artery was graded as grade 3 stenosis at multiple sites. This was a false positive case, as DSA was considered the gold standard.

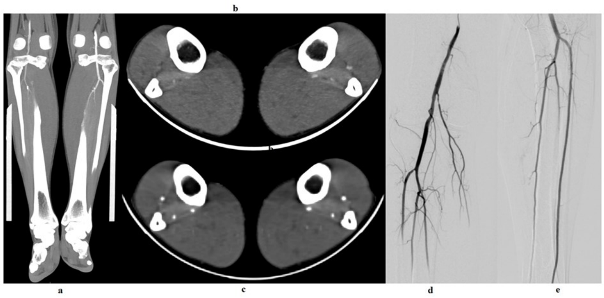

Figure 6 A 67-years-old man with bilateral intermittent claudication. (a)MIP does not demonstrate the branches below tibioperoneal trunk in regular scan (b) The cross-sectional MIP shows better contrast enhancement of the run-off vessels in the left side (c)the cross-sectional MIP of the run-off vessels on delayed scan shows normal enhancement bilaterally .On DSA frontal projection view the run off vessels enhance normally bilaterally(d,e)

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