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Diagnostic Accuracy of Multi-detector CT Angiography in Evaluation of Lower Limb Arterial Diseases: Comparative Study with Conventional Angiography

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Abstract

Purpose: To assess the diagnostic accuracy of multi-detector CT angiography in the assessment of lower extremity arterial diseases by comparing the results with the standard of reference, conventional angiography.

Patients and Methods: The studied group included 140 patients with suspected diagnosis of lower limb arterial disease on the basis of clinical examination or Doppler study with no age or sex predilection between March 2011 and November 2013. All patients were evaluated with lower limb angiography by multi-detector computed tomography and conventional angiography. The data obtained was statistically analysed to assess the accuracy of diagnosis of lower limb arterial diseases by MDCT angiography compared to conventional angiography that described in terms of count and percentage.

Results: MDCT angiography findings showed 90.3% overall agreement with CA findings regarding the degree of stenosis while regarding the stenosis length MDCT angiography results showed 87.5% overall agreement with CA results. The overall sensitivity of MDCT angiography was 94.5%, specificity was 92.2%, and accuracy was 95.3%.

Conclusion: Multi–detector row CT angiography can be used as an alternative to conventional angiography in the evaluation of aortoiliac and lower extremity arteries in patients with peripheral arterial disease.

Key words: Computed Tomography (CT), Conventional Angiography (CA), Multi-detector computed tomography (MDCT).

Introduction

Initial diagnosis of peripheral arterial disease (PAD) typically relies on patient history and physical examination of the patient. If PAD is suspected, a number of tests needed to be performed to detect the presence of atherosclerosis, as well as to localize areas of stenosis and to estimate the degree of the stenosis [(1)]. Selecting the appropriate treatment option for symptomatic patients relies heavily upon accurate visualization of the peripheral vascular anatomy. While conventional angiography (CA) is considered as the gold standard for imaging of peripheral vessels, its invasive nature and inherent risks of vascular complications limits use. Therefore, there remains a significant need for an accurate non-invasive imaging method in patients with peripheral arterial diseases [(2)]. Computed tomography angiography is increasingly attractive due to rapid technical developments. Shorter acquisition times, thinner slices, higher spatial resolution, and improvement of multi-detector computed tomographic (CT) scanners enable scanning of the whole vascular tree in a limited period with a decreasing amount of contrast medium [(3)].

Patients & Methods: The study was done in Nasr City Health Insurance Hospital and specialized private center in Cairo during the period from March 2011 till November 2013. One hundred and forty patients with suspected diagnosis of lower limb arterial disease on the basis of clinical examination or Doppler study were included in this study with no age or sex predilections. Thirty patients were excluded from the study population because of allergic reactions to contrast materials, renal impairment or some patients had done CT angiography without complementary CA. The study was performed after approval of the Ethical Committee of Scientific Research, Faculty of Medicine, Ain Shams University and after taking consent from all patients. All patients were subjected to full history taking, clinical examination and laboratory investigation (serum creatinine).

<u>Multi-detector row CT scanning:</u> The study was performed using 16–detector row scanner (Asteion, Toshiba, Tokyo, Japan). After obtaining an initial scout image (120 kV, 100

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mA), the scanning range was planned to encompass the aortoiliac vascular system starting from the diaphragm, down to the end of both lower limbs (mean coverage, 35 inch; range, 32–38 inch). A single non-enhanced low-dose scan (20 mAs) at the level of the proximal abdominal aorta was obtained first. On the basis of this transverse image, a region of interest with an area of 10–15 mm^2 was set in the lumen of the proximal abdominal aorta. This region of interest served as a reference for the following dynamic measurements of contrast enhancement. Subsequently, a nonionic iodinated contrast medium (300 mg of iodine per milliliter of iopromid) was administered via a 20 gauge needle that was placed into a superficial vein located in the antecubital fossa. The volume of contrast medium (mean, 130 mL; range, 120–140 mL) was subsequently adjusted for the scanning length of each patient to establish a bolus duration that was equivalent to the scanning duration. The contrast medium was administered as monophasic injection of 120-160 ml with an automated injector at a flow rate of 2-4 mL/sec followed by 40-60 mL of saline administered at the same flow rate. Two spiral sets of views with a scan delay of 3 seconds between the two spiral sets was taken using Tube voltage 120 kV, Tube current 150 mA and Slice thickness 5 mm. After images taking the raw data were processed using MIP, Volume Rendering and Shaded Surface Display.

<u>Conventional Angiography Examination:</u> Catheter angiography for both lower limbs was performed with the use of 5-French pigtail catheter inserted through the femoral or brachial artery, the femoral route is chosen if a normal femoral pulse existed on one side and the trans-brachial approach was used in patients with absent femoral pulse on both sides, by using Seldinger technique. Power injector was used for administration of an iodinated contrast material. The flow rate was 15 mL/sec. with a total dose of 100-200 mL. The views were obtained at all levels. Oblique views were obtained when necessary. In all series, image acquisition was continued until no further filling of vessels was observed.

Image evaluation: When interpreting the images, two readers were allowed to individually adjust window width and level settings for image analysis, the first reader radiologist (with at least 7 year experience in CT interpretation) write a primary report, then another, more senior radiologist (with at least 25 year experience in CT interpretation), who is blinded to the first report interpret the images for grade of stenosis or occlusion according to Four-point Likert scale (Score 0 for normal, score 1 for 10-49% stenosis, score 2 for 49-99% stenosis, and score of 3 for complete occlusion), for length of stenosis (Score of 0 indicated no stenosis, score of 1 for stenosis of less than 1 cm in length, score of 2 for stenosis of 1–5 cm in length, score of 3 for stenosis more than 5 cm in length, and score of 4 for multiple stenosis), and for associated findings. Evidence of the presence and location of aneurysmal changes was noted separately. An aneurysmal change was diagnosed in the presence of a focal increase in arterial diameter that exceeded the diameter of the adjacent arterial segment by more than 50%. Results are correlated with CTA findings.

Analysis: The arterial vascular system was divided into the infrarenal aorta (one segment), the common iliac arteries (two segments), the external iliac arteries (two segments), the common femoral arteries (two segments), the deep femoral arteries (two segments), the superficial femoral arteries (two segments), the popliteal arteries (two segments), the anterior tibial arteries (two segments), the peroneal arteries (two segments), and the posterior tibial arteries (two segments). Total of 19 segments were examined for each patient x 140 patients, with a resulting 2660 segments, however, five patients had above knee amputation with actual assessment of 2640 segments. The data obtained was statistically analyzed to assess the accuracy of diagnosis of lower limb arterial diseases by MDCT angiography compared to conventional angiography described in terms of count and percentage. The following measures were then calculated: sensitivity, specificity, and an overall diagnostic accuracy.

Results: The study included 140 patients, 102 male (73%) and 38 females (27%). The age of the patients ranged from 32-85 years old (mean, 58.5 years old). These cases presented mainly with intermittent claudication. MDCTA could detect arterial affection in 1188 out of 2640 segments (45%), with 1452 out of 2640 segments (55%) were rated as normal (score 0) **(Table1)**.

Table 1: Grading of arterial lesions in140 patients with lower extremity arterial disease.

MDCT arterial grading	Number of segments	Percentage
Score 0 (Normal)	1452	55 %
Score 1 (1-49 % stenosis)	403	34 %
Score 2 (49-99 % stenosis)	419	35.25 %
Score 3 (Total occlusion)	345 (four within stent)	29 %
Other findings:		
Aneurysm	18	1.5 %
Aneurysm with dissection	2	0.17 %
Arteriovenous fistula	1	0.08 %

The abnormal segments were rated higher by MDCTA than Conventional Angiography (CA) in 116/1188 segments (9.7 %) (**Table 2)**.

Table 2: Variability in grading stenosis percent between CTA and CA findings.

Number of segments	MDCTA grading	CA grading
42 segments/116 (36 %)	Grade 2 (49-99% stenosis).	Grade 1(10-49% stenosis).
74 segments /116 (64 %)	Grade 3 (complete occlusion).	Grade 2 (49-99% stenosis).

Regarding the infra-renal aorta; 127 segments (90.7%) were considered completely normal or with haemo-dynamically insignificant atherosclerotic changes, 11 segments (7.9%) showed abdominal aortic aneurysm (AAA), 2 segments (1.4%) showed abdominal aneurysm accompanied with dissection.

Regarding the common iliac artery, MDCTA results showed 179 (64%) segments were rated normal, 38 (13.5%) segments showed non-significant stenosis (Score 1), 30 (11%) segment showed significant narrowing (Score 2), 32 (11.2%) segments showed occlusion (Score 3), 1 (0.3%) segment showed aneurysm, 7 patients had CIA grafts, and were patent and 4 patients had CIA stents, 3 were patent and one was occluded. When results compared to those of CA we found that five segments were over rated as grade 3 stenosis by CTA, while by CA they were grade 2.

Regarding the external iliac artery (EIA), MDCTA results showed 168 (60%) segments were rated normal, 39 (14 %) segments showed non-significant stenosis (Score 1), 44 (16%) segment showed significant narrowing (Score 2) and 29 (10%) segments showed occlusion (Score 3). When results compared to those of CA we found that four segments were over rated as grade 2 stenosis by CTA, while by CA they were grade 1 and two segments were over rated as grade 3 stenosis by CTA, while by CA they were grade 2.

Regarding the common femoral artery (CFA); MDCTA results showed 157 (56%) segments were rated normal, 49 (17.5%) segments showed non-significant stenosis (Score 1), 41 (14.5%) segment showed significant narrowing (Score 2), 31 (11.3%) segments showed occlusion (Score 3) and 2 (0.7%) segments showed aneurysms. When results compared to those of CA we found that six segments were over rated as grade 3 stenosis by CTA, while by CA it was grade 2.

Regarding the superficial femoral artery (SFA); MDCTA results showed 129 (46%) segments were rated normal, 45 (16%) segments showed non-significant stenosis (Score 1), 48 (17.3%) segment showed significant narrowing (Score 2), 56 (20%) segments showed occlusion (Score 3), 2 (0.7%) segments showed aneurysms, 4 patients have femoro-femoral bypass graft, which were patent and 15 patients have stent in the SFA, three of them were totally occluded. When results compared to those of CA we found that nine segments were over rated as grade 2 stenosis by CTA, while by CA they were grade 1 and sixteen segments were over rated as grade 3 stenosis by CTA, while by CA they were grade 2.

Regarding the deep femoral artery (DFA); MDCTA results showed 229 (82%) segments were rated normal, 31 (11%) segments showed non-significant stenosis (Score 1), 16 (5.5%) segment showed significant narrowing (Score 2) and 4 (1.5%) segments showed occlusion (Score 3) which was the same results as CA.

Regarding the popliteal artery; MDCTA results showed 156 (56%) segments were rated normal, 34 (12.5%) segments showed non-significant stenosis (Score 1), 44 (16%) segment showed significant narrowing (Score 2), 39 (14.8 %) segments showed occlusion (Score 3) and 2 (0.7%) cases had popliteal aneurysm. When results compared to those of CA we found that six segments were over rated as grade 2 stenosis by CTA, while by CA they were grade 1 and eight segments were over rated as grade 3 stenosis by CTA, while by CA they were grade 2.

Regarding the posterior tibial artery (PTA); MDCTA results showed 113 (41%) segments were rated normal, 51 (18.5%) segments showed non-significant stenosis (Score 1), 58 (21%) segment showed significant narrowing (Score 2), 52 (19.2%) segments showed occlusion (Score 3) and 1 (0.3%) segment showed arteriovenous fistula (AVF). When results compared to those of CA we found that nine segments were over rated as grade 2 stenosis by CTA, while by CA they were grade 1 and twelve segments were over rated as grade 3 stenosis by CTA, while by CA they were grade 2.

Regarding the peroneal artery; MDCTA results showed 101 (36%) segments were rated normal, 54 (20%) segments showed non-significant stenosis (Score 1), 68 (25%) segment showed significant narrowing (Score 2), and 52 (19%) segments showed occlusion (Score 3). When results compared to those of CA we found that seven segments were over rated as grade 2 stenosis by CTA, while by CA they were grade 1 and eleven segments were over rated as grade 3 stenosis by CTA, while by CA they were grade 2.

Regarding the anterior tibial artery (ATA); MDCTA results showed 93 (34%) segments were rated normal, 62 (22.5%) segments showed non-significant stenosis (Score 1), 70 (25%) segment showed significant narrowing (Score 2), and 50 (18.5%) segments showed occlusion (Score 3). When results compared to those of CA we found that seven segments were over rated as grade 2 stenosis by CTA, while by CA they were grade 1 and fourteen segments were over rated as grade 3 stenosis by CTA, while by CA they were grade 2.The overall sensitivity of MDCT angiography was 94.5%, specificity was 92.2%, and accuracy was 95.3% with those for each segment shown in **table 4**.

Table 3: Sensitivity, specificity, and accuracy of CTA in 140 patients with lower extremity arterial disease.

Arterial affection	Number of segments affected	Sensitivity	Specificity	Accuracy
Aorta	13	100 %	100 %	100 %
CIA	101	96 %	97.2 %	97 %
EIA	112	98.2 %	98.8 %	98.5 %
CFA	123	93.6 %	96.1 %	95 %
SFA	151	92 %	86.3 %	91 %
DFA	51	100 %	100 %	100 %
Popliteal A.	119	93 %	90 %	94 %
PTA	162	91 %	88 %	90 %
Peroneal A.	174	90.2 %	86.5 %	89 %
ATA	182	91.3 %	80 %	88.5 %

Illustrative cases:

Case 1:

56 year old female, with right femoral stent insertion 2 years ago, presented with dry gangrene of left 2nd toe.

a c d b e f

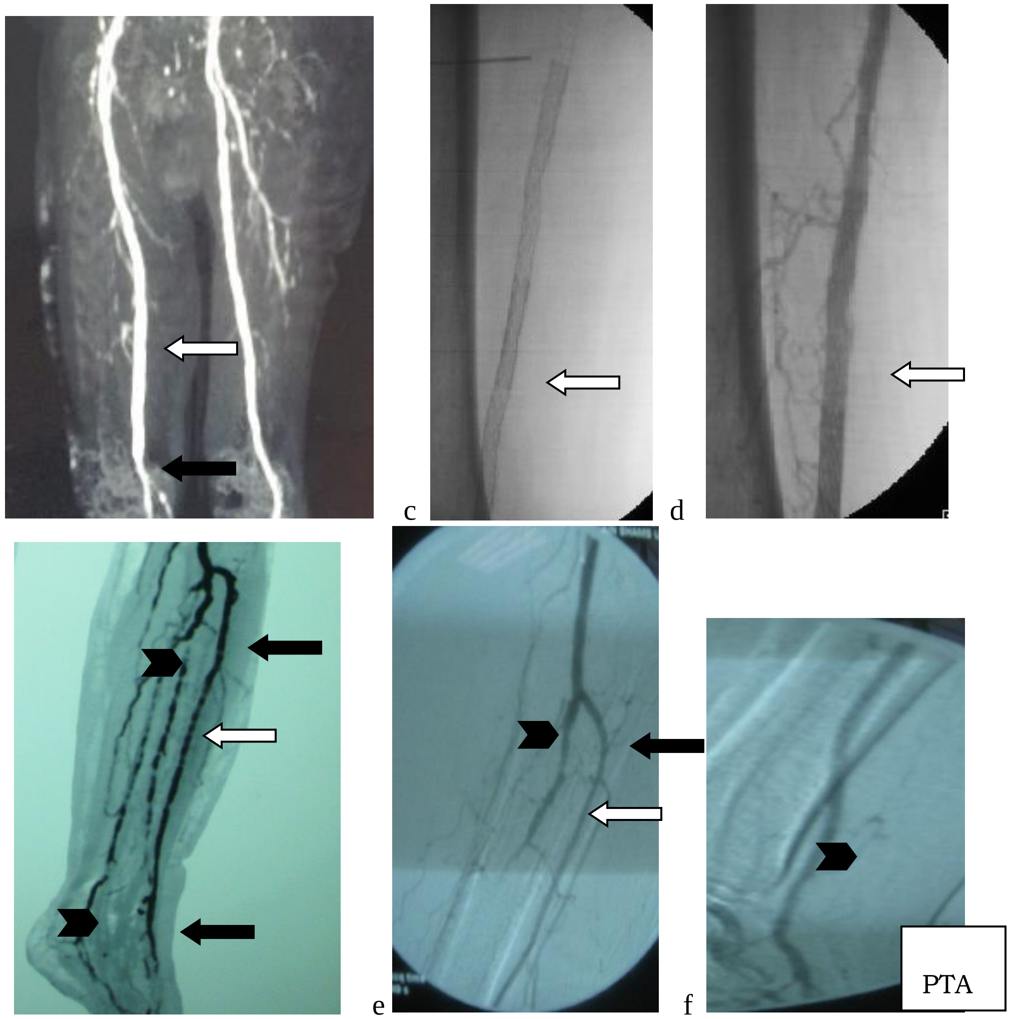
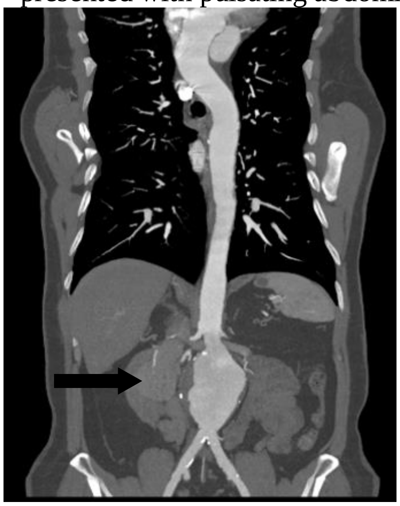


Figure 1: MDCTA (a) Coronal MIP of both SFAs shows the right femoral stent (white arrow) which is patent with good distal femoral flow (black arrow), (b) Sagittal MIP shows patent ATA along its course down to the ankle level (black arrow), occlusion of proximal part PTA with refilling of its distal part through collateral vessels along the leg (arrow heads), visualization of proximal part of peroneal vessel with attenuated course of its distal part (white arrows). **CA** (c), (d), (e) and (f) show the same findings.

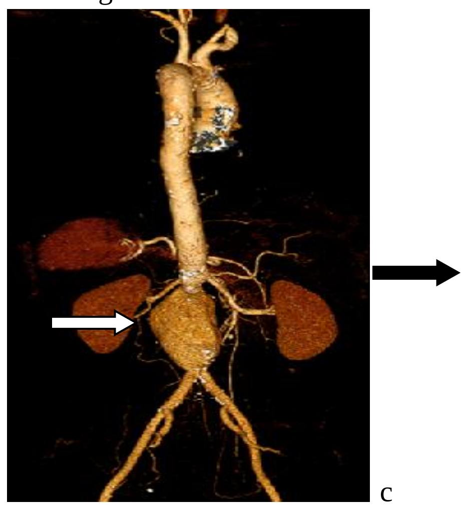
The case diagnosed as Patent right SFA stent, with left proximal PTA occlusion and peroneal attenuation.

Case 2:

55 year old male patient, with long history of uncontrolled hypertension and with hyperlipidemia presented with pulsating abdominal swelling and intermittent claudication of both lower limbs.



a



b

c

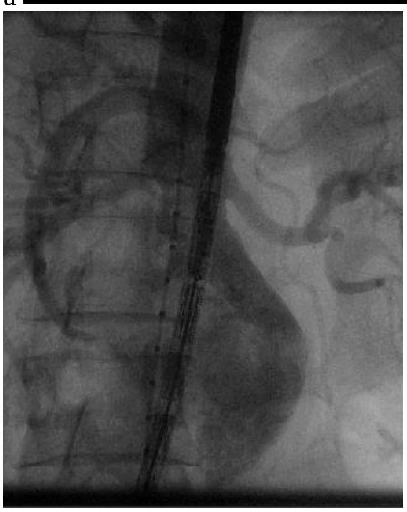


Figure 2: CTA (a) coronal MIP (b)3D volume-rendered display image showing abdominal aortic aneurysm of the infra-renal region, with mural thrombus (c) **CA** showing the abdominal aneurysm. The case diagnosed as abdominal aortic aneurysm

Discussion:

Peripheral arterial disease (PAD) is a consequential health problem of developed countries that has influence on a large segment of the adult population [(4)]. Surgical revascularization is the preferred strategy. Determination of the severity and anatomic mapping of vasculature is fundamental for the diagnosis. Although conventional angiography is the gold standard and diagnostic modality of choice for PAD, it is invasive, expensive and associated with morbidity and mortality. It results only in luminograms, and thus information about plaque constituents and vessel surroundings cannot be acquired. Hence, other non-invasive methods are more preferable [(3)]. Computed tomographic (CT) angiography is increasingly used for diagnostic imaging in patients with peripheral arterial disease. The use of multi-detector row technology has resulted in shorter acquisition time, increased volume coverage, lower dose of contrast medium, and improved spatial resolution for assessing small arterial branches [5].

In this study, the mean age is 58.5 years; there is male sex predominant affection. Liang et al. [6] found that most of the patients with PAD were significantly have associated hypertension, diabetes, high cholesterol and smoking history and this is consistent with this study findings, 60% of the patients in this study were presented with intermittent claudication, and less frequent rest pain or tissue loss.

Discordances between grading stenosis in conventional angiography and CTA is elicited in 116 arterial segments out of 1188 abnormal segments (9.7%) comparative with Met et al. [3] in which discordances was 4%.

The over rated segments of arterial lumen narrowing were due to calcified segments, the calcified plaques produce blooming effect, causing partial volume artifacts and hence false positive results .

Rating of stenosis length differed between conventional angiography and CTA. CTA underestimated 149/1188 segments (12.5%) as grade 2, that were grade 4 in conventional angiography [3].

According to similar previously published results of Inaba et al.[8], who explained that the discordance in grading the length of the stenotic segments was caused mainly by the presence of asymmetrical stenosis.

In this study, the prevalence of arterial affection (in a descending order) is that ATA, Peroneal, PTA, SFA, CFA, Popliteal, EIA, CIA, DFA, and Infra-renal aorta matching the results of Laswed et al.[9].

This study included 13 cases of arterial aneurysms, in all cases; CTA could accurately detect the type of the aneurysm, diameter, neck, and internal thrombosis, precisely. There is agreement with Braverman et al.[10] in that Abdominal CT is extremely accurate for the detection of AAAs and measurement of aneurysmal diameter. CTA is especially useful for demonstrating the extent of aneurysm disease; the relationship of the Abdominal Aortic Aneurysm (AAA) to the renal, visceral, and iliac arteries; and patterns of mural thrombus, calcification, or coexisting occlusive atherosclerosis that might influence surgical AAA repair.

Perisinakis et al.[11] stated that the use of 16-slice MDCT systems or higher has increasingly gained approval of the radiology community as a valuable non-invasive alternative to conventional angiography for the follow-up of stents in lower limb arteries.

This study covered examination of 19 arterial stents, four of which were totally occluded and confirmed on bases of conventional angiography and CTA. MDCT could detect the stent patency and the distal runoff flow.

The study included 11 patent grafts, and in a study carried out by Willmann and his co-investigators [12]; they demonstrated in a prospective blinded comparison that multi-detector row CT angiography is feasible, accurate, and reliable in the assessment of peripheral arterial bypass grafts and detection of graft-related complications, including stenosis, aneurysmal changes, and arteriovenous fistulas. They conclude that, because of its non-invasive nature and lower effective dose, multi-detector row CT angiography may replace conventional angiography as a technique to be used after performance of duplex US to help physicians plan further treatment of peripheral arterial bypass grafts.

This study revealed that CTA could detect incidental extra-arterial findings e.g. Cirrhotic liver, Splenomegaly, Uterine fibroids, Splenic focal lesions, Ascites, lung mass, Pleural effusion, metastases. Al-Qaisi et al.[7] stated that computed tomography allows simultaneous angiographic as well as anatomical volume acquisition in seconds whilst maintaining high spatial resolution. This allows both luminal and extra-luminal pathology to be shown simultaneously.

The additional use of advanced post-processing techniques may also be important for the evaluation of lower extremity arterial disease. Assessment of vascular abnormalities is facilitated when the arterial tree is displayed in an angiographic fashion. This can be accomplished with Maximum intensity projection (MIP) and volume rendering (VR) techniques. However, the main limitation of MIP and VR is that vessel calcifications and stents may completely obscure the vascular lumen. So at these conditions cross-sectional views are essential for better assessment. Transverse source images, sagittal, coronal, or oblique multi-planar reformations (MPRs) are useful in an interactive setting, such as in conjunction with VR [13].

In our study, the post-processed images, including MIP and volume rendered images are used as a road map to quickly assess the whole arterial tree, then precise correlation with axial images is done with special concern is given to the site of the lesion. Peach et al.[14] further explained that the use of 360^{o} views with volume-rendered images as well as the assessment of axial CT images enabled the detection, in contrast to conventional angiography images, of very small segments that were in a strict antro-posterior orientation not detected by conventional angiography.

A MDCT angiographic study easily generates over a thousand axial images. For the majority of patients with PAD, axial image viewing is time-consuming, inefficient and often less accurate than viewing reformatted images. Therefore, a dedicated 3D workstation to enable a real-time interactive approach to image manipulation and interpretation has now become a necessity. Archiving only reconstructed images is not an option for managing the huge amount of data because transverse images are necessary for the assessment of calcified stenosis. Picture archiving and communication system (PACS) offers the best solution for image storage and display [15].

One of the potential pitfalls of CT angiography is that metallic aneurysm clips and stents attenuate the X-ray beam, allowing too few photons to reach the X-ray detectors, and corrupting the system's ability to map the projection. Those few photons that do reach the detectors are the ones with higher energies, therefore resulting in "beam hardening". Traditional filtered back-projection algorithms used to reconstruct spiral computed tomography images are degraded by streaking and "star artifacts" in the plane of a metallic implant [7].

Albrecht et al.[16] in his study using 16-MDCT, mentioned that there was poor visualization of the collateral circulation on CTA, which might be due to the fact that the caliber of these vessels is typically very small, often reaching the limits of spatial resolution on CTA. This matches with our study results.

This study stated that CTA has a sensitivity of 94.5%, specificity of 92.2%, and accuracy of 95.3%. Duan et al.[17] estimated that multi–detector row CT angiography has a sensitivity of 100% for evaluation of the complete peripheral arterial system, a specificity of 93.5%, and accuracy of 96%.

Met et al.[3] found that the summary estimates of sensitivity and specificity for aortoiliac disease were 96%, and 98% respectively, for femoropopliteal disease were 97% and 94% respectively and for distal runoff in the tibial arteries were 95% and 91% respectively. While our study found the summary estimates of sensitivity and specificity for aortoiliac disease were 98% and 98.7% respectively, for femoropopliteal disease were 94.7% and 93% respectively and for distal runoff in the tibial arteries were 90.8%, and 85% respectively.

Unfortunately, neither the CT scanner, nor conventional angiography unit was equipped with radiation dosimeters, and thereby, it was difficult to accurately compare the radiation exposure in both modalities. However, Willmann et al.[12] directly compared radiation dose exposure to patients undergoing peripheral MDCTA with a 16-detector CT versus that of Conventional Angiography and determined a mean effective radiation dose of 3.0 mSv (range, 2.1–3.9 mSv) in men and 2.3 mSv (range, 1.6–3.0 mSv) in women for MDCTA versus 11 mSv (range, 6.4–16.0 mSv) for both sexes for DSA.

Kanematsu et al.[14] stated that low-concentration contrast material (240mg/ml) at low tube voltage (80kVp) seems appropriate for routine whole-body CTA and beneficial for reduction of iodine load and radiation dose.

The diagnostic cost in the MDCTA was lower than that in the conventional angiography in agree with Duan et al.[17] who concluded that MDCTA is less expensive than conventional angiography owing to lower investment, supply, and personnel costs.

Advantages of CTA compared to standard catheter based angiography include the ability to look at vessels from an unlimited number of angles, and from both inside and outside the vessel wall. Using a variety of imagine techniques such as multiplanar reconstructions, volume rendered (VR) images, and maximum intensity projections (MIP), vessels walls, not just the vessel lumen, can be evaluated. The morphology of atherosclerotic plaque can clearly be visualized, which in some cases may be a more important factor in determining clinical outcome than simply the degree of luminal narrowing [19]. Since it is less invasive than catheter based angiography, the pre and post procedure requirements associated with conscious sedation are eliminated, the anticoagulation status of the patient is no longer important, there is no post procedure recovery time, and the risks associated with the procedure are greatly reduced [19]. Visualization of extravascular structures sometimes adds key information about the cause or significance of a vascular problem. Visualization of the soft tissues and skeletal structures provided by CT imaging can be a valuable adjunct to evaluating arterial or venous lesions in some cases [19]. Also advantages of MDCTA include wide availability, short examination time, the ability to perform the study in an outpatient setting, patient ease and relatively low overall imaging costs [20].

Recent technologic advances in MDCT now allow rapid image acquisition with excellent spatial and temporal resolution. Advanced post-processing workstations enable rapid image manipulation and assessment [20].

The disadvantages of CT angiography are the use of ionizing radiation, although still less than conventional angiography, and potentially nephrotoxic contrast agents [21]. Potentially nephrotoxic adverse effects for iodinated contrast agents used, can be reduced by hydration and, although still under debate, administration of acetylcysteine [22].

The current study limitations include improper arterial assessment in the presence of extensive arterial calcifications, which lead to false-positive interpretations and a decreased reproducibility. Another limitation is lack of accurate evaluation of patient radiation dose in each procedure, due to absence of patient dosimetry in CT and conventional angiography units.

In spite of these limitations, the overall results suggest that use of noninvasive multi–detector row CT angiography instead of conventional angiography as the initial diagnostic imaging test for PAD provides sufficient information for therapeutic decision making and reduces imaging costs.

In conclusion, multi–detector row CT angiography can be used as an alternative to conventional angiography in the evaluation of aorto-iliac and lower extremity arteries in patients with peripheral arterial disease.

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