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Original Research Article

Role of multidetector computed tomography angiography in evaluation of peripheral arterial disease

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ABSTRACT

Background: Diagnostic imaging plays an important role in the evaluation of peripheral arterial disease. Many imaging modalities are available ranging from conventional modalities to the cross-sectional modalities like Doppler ultrasound, DSA, CT and MRI. The main principles of imaging are to characterize the all lesions detected including type of plaques, no. of lesions, length of stenosis, diameter of vessel in pre-stenotic and post-stenotic segments, degree of wall calcification, assisting in pretreatment planning with respect to route of access, selection of balloon and demonstrates size, extent, neck dimention, and presence of thrombosis in cases with aneurysm.
Methods: A Cross-sectional observational study was done in 30 patients. Clinically suspected patients of peripheral arterial disease based on history, sign and symptoms and patients diagnosed with peripheral arterial disease on color doppler were included in our study. Both modalities were compared for detecting the occlusion and stenotic segments.
Results: A total of 476 vessel segments were imaged by both modalities. When all arterial segments were considered, MDCTA detected stenosis or occlusion lesions in 30% of arterial segments, versus 18.8% compared to DUS. MDCTA showed 9.8% (95% CI:[4.3%, 15.3%]) more lesions than DUS when all arterial segments were considered together, 11.2% (95% CI: [2.7%, 22.1%]) more lesions when only the iliac arteries were compared, 9.1% (95% CI: [3.2%, 17.2%]) more lesions when only the femoropopliteal arteries were compared, 8.9% (95% CI: [1.5%, 16.3%]) more lesions when only infrapopliteal arteries were compared and 13% (95% CI: [2.6%, 25.4%]) more lesions when only the upper limb arterial segments were compared, ($p <0.05$ for all comparisons).
Conclusions: MDCTA may be used as a screening tool in patients with peripheral arterial disease as it is a non-invasive and more accurate modality when compared to DUS and plays important role in management.

Keywords: Diagnostic imaging, Doppler ultrasound, Multidetector computed tomography angiography, Peripheral arterial disease

INTRODUCTION

The term-peripheral artery disease is recommended to describe disease that affects the lower or upper-extremity arteries.[1] Peripheral artery disease is a common condition affecting 12-20% of people older than 60 years of age.[2] PAD is defined as a clinical disorder in which there is a stenosis or occlusion of aorta or arteries of the limbs. The disorder affects lower limbs eight times more than upper limbs.[3] Multilevel disease and bilateral involvement are common.[4] The disease may manifest as claudication, rest pain, ulceration, gangrene of limb.[5] Critical limb ischemia is mainly due to multi-segment plaque whereas intermittent claudication is due to single segment plaque.[6] The most common cause of PAD is atherosclerosis which is less common in younger patients. Other common causes include trauma, thrombo-embolism, acute thrombotic occlusion, micro-embolism, vasculitis including vasospastic disorders and Buerger's disease.[7] Imaging plays an important role in the management of PAD because it is essential to know the arterial anatomy, extent and severity of pathology. Imaging is necessary for planning interventions in patients with lower extremity PAD.[8] Those who are at highest risk for PAD are- >50 years, History of diabetes, High blood pressure, High cholesterol/lipid levels, High homocysteine levels, Obesity and Physical inactivity. Family history of vascular disease such as PAD, aneurysm, heart attack or stroke.[7]

Pathologies related to PAD are atherosclerosis, diabetes, buerger's disease, athero-embolism, aneurysms, arteriovenous fistula, thoracic outlet compression syndrome, popliteal entrapment syndrome and fibromuscular dysplasia.[3]

Role of doppler ultrasound

Doppler ultrasound is one of the cheapest, readily available, non-invasive technique to assess the status of peripheral arteries in symptomatic patients.[9] It has a high specificity and lower sensitivity. It is an operator dependent and time consuming, and obese patients or patients with excessive bowel gas or calcified arteries are difficult to examine.[10] Duplex US does not provide a road map equivalent to that obtained with conventional DSA, or MR or CT angiography.

Role of MDCT angiography

MDCTA is an outstanding non-invasive imaging test in the evaluation of patients with peripheral arterial disease and is currently the modality of choice in patients with intermittent claudication. It has been shown to have high diagnostic performance and reproducibility in evaluating PAD. Shorter acquisition times, thinner slices, higher spatial resolution, and improvement of MDCT scanners enable scanning of the whole vascular tree in a limited period with a decreasing amount of contrast medium.[11] It is less costly, faster and does not require team of cardiologists to perform angiography. Hence problems related to much more invasive technique like hematoma, sepsis etc. are avoided with MDCT and radiation dose given to patient is also 4 times lesser than conventional angiography. Recently, MDCT angiography has been shown to be a reliable tool in quantifying length, number, and grade of stenosis in PAD.[12-14] A decrease from 120 to 100 kVp results in a 34% reduction in radiation dose without affecting diagnostic image quality.[15]

METHODS

This Cross-sectional Observational study was conducted in the Department of Radio-diagnosis at P.G.I.M.E.R and DR. Ram Manohar Lohia Hospital, New Delhi from 1st November 2016 to 31st March 2018. A Cross-sectional observational study was done in 30 patients. Clinically suspected patients of peripheral arterial disease based on history, sign and symptoms and patients diagnosed with PAD on color doppler were included in our study.

Patients who had history of allergy to intravenous contrast agents, deranged kidney function tests and, pregnant women were excluded from our study.

A written informed consent was taken from all patients. A detailed history was taken with complete physical and systemic examination of the patient. Relevant biochemical investigations were done wherever required.

CT angiography examination protocol

CT angiography was performed on Philips 40-slice Multi-detector scanner (Brilliance). Scanning range was planned with a scout view with scan taken in supine position with head first will be used for upper limbs and supine position with feet first for lower limbs. The scan direction will be cranio-caudal for lower limb CT angiography with range from the level of infrarenal aorta to pedal arch while for upper limb CT angiography direction would be caudo-cranial from the level of aortic arch upto palmar arch.

Scanning technique

Firstly a single non enhanced low dose (20mAs) scan of abdominal aorta at the level of origin of renal arteries was obtained (descending thoracic aorta for upper limb evaluation). On this image a 10-15 sqmm region of interest (ROI), was placed in the lumen of aorta. This ROI will help to optimize the intraluminal contrast enhancement. The delay time from contrast material injection to scanning was determined individually for each patient using bolus tracking technique.

A total of 150 ml of nonionic iodinated water soluble contrast material (iopromide), was administered with the use of automated injector (medrad), at a flow rate of 3.5-4 ml/sec through a 18-20 gauge cannula placed in antecubital vein. At the same flow rate 30 ml saline was injected afterwards to maintain contrast enhancement for prolonged period. After the preset contrast enhancement of 120 HU was reached in the ROI placed in the aorta, CT scanning was automatically started 5 seconds later.

Data acquisition was performed using gantry, 0.5 s; pitch, 0.85; detector configuration, 40x0.6, table speed of 32 mm/s, scan time, 45 s and slice thickness: 1.25 mm. Tube voltage, tube current and radiation dose were 120kV, 200mAs and 9.3 mSv respectively. Raw data was transferred to workstation and CT angiography was produced using MIP algorithm, all images underwent segmentation for bone removal. MIP images of the total volume were created in frontal and oblique views to provide DSA like images. Similarly 3D volume rendered images and curved multiplanar reformations in both coronal and sagittal projections were obtained for evaluation.

Image interpretation

After acquiring the VRT, MIP, CPR images along with axial images in cine scroll mode, inflow and runoff vessels were evaluated (Figure 1).

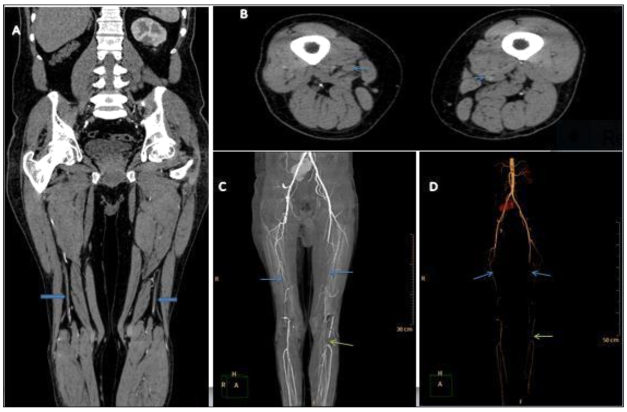

Figure 1: (A) MPR coronal and (B) axial images: showing the complete occlusion of bilateral SFA (arrow). (C) MIP and (D) VR images: showing the complete occlusion of bilateral SFA (blue arrow) and left popliteal artery (green arrow) with distal segment reformed by collaterals.

The steno-occlusive lesions were examined primarily by visual inspection as 'diameter stenoses'. The readers also detected the degree of stenosis using electronic calipers. Irregular vessel walls with >50% stenosis of vessel diameter were noted. The data for each arterial segment were evaluated and classified as normal, >50% stenosis or occlusion (Figure 2)

Figure 2: (A) MPR coronal image: shows diffuse, thickened, iregular mural calcified plaques in discending abdominal aorta and its branches (arrow). (B) MPR axial image: showing complete occlusion right external iliac artery (black arrow). (C) MIP and (D) VR images: showing the complete occlusion of left renal, bilateral common iliac (black arrow), right external arteries, CFA and bilateral SFA (green arrow) with distal segment refoemed by collaterals.

Color doppler ultrasound

Doppler ultrasound of the limbs of the patient was performed as an initial modality in patients with suspected peripheral arterial disease. Doppler ultrasound was performed on Phillips 3500 HDI ultrasound machine using linear probe 5-12 MHz and curvilinear low frequency probe wherever necessary. Acoustic gel was used for skin transducer coupling.

The transducer was transverse to the arterial segments with 60 degrees angulation to vertical plane to encode the arterial color signal. A segment was considered as normal when the normal triphasic velocity profile with late diastolic reversal was detected. Suspicious areas with a reduced diameter were detected via higher blood velocities, seen as a shift in the color representing the blood flow on the computer screen. Stenosis was noted when a pre-stenotic, low velocity, monophasic flow pattern was detected in the proximal vessel segment. A segment with no flow signal was noted as occluded.

Statistical analysis

The statistical analysis was performed with SPSS software package (version 20.0). Simple summative statistics were used to calculate the number and proportion of arteries identified as stenotic or occluded. The McNemar's test, was then used to compare the proportions of segments identified as significant stenotic or occluded by MDCT angiography vs. Color Doppler ultrasound. A significant test result, defined as $p<0.05$, rejects the null hypothesis that MDCTA and Color Doppler ultrasound identify the same proportions of arteries as significantly stenotic or occluded.

RESULTS

The present study was conducted in the Department of Radiodiagnosis, PGIMER, Dr. Ram Manohar Lohia Hospital, New Delhi. A total of 30 cases suspected of having peripheral arterial disease on the basis of clinical profile, prior imaging profile underwent CT examination. The cases encountered in our study were in the age range of 27-76 years (Mean age-50.6). A total of 476 vessel segments were imaged by both DUS and MDCT Angiograhy in 30 patients. All arterial segments were successfully analyzed by both modalities. The number of segments with greater than 50% stenosis were 54 (11.34%) and 77 (16.17%) on DUS and MDCTA, respectively. The number of segments with occlusion were 41 (8.61%) and 65 (13.65%) by DUS and MDCTA, respectively. The total number of diseased segments found with DUS was 95 (20%) versus 142 (29.8%) identified by MDCTA.

When DUS and MDCTA are compared in identifying stenotic or occlusive lesions, MDCTA showed 9.8% (95% CI:[4.3%, 15.3%]) more lesions than DUS when all arterial segments were considered together, 11.2% (95%

CI: [2.7%, 22.1%]) more lesions when only the iliac arteries were compared, 9.1% (95% CI: [3.2%, 17.2%]) more lesions when only the femoropopliteal arteries were compared, 8.9% (95% CI: [1.5%, 16.3%]) more lesions when only infrapopliteal arteries were compared and 13% (95% CI: [2.6%, 25.4%]) more lesions when only the upper limb arterial segments were compared, ($p < 0.05$ for all comparisons).

Table 1: McNemar Test Tables comparing DUS and MDCT findings of stenosis or occlusion (+: positive, -: negative) in all arteries together, iliac arteries only, femoro-popliteal arteries only, infrapopliteal arteries only and upper limb arteries only.

DUS occlusion or stenosis		MDCTA occlusion or stenosis		Total
		MDCTA-	MDCTA+	
All arterial segments	DUS-	308	73	381
	DUS+	26	69	95
	Total	334	142	476
Iliac arterial segments	DUS-	52	13	65
	DUS+	4	11	15
	Total	56	24	80
Femoro-popliteal arterial segments	DUS-	97	18	115
	DUS+	5	24	29
	Total	102	42	144
Infrapopliteal arterial segments	DUS-	121	32	153
	DUS+	15	24	39
	Total	136	56	192
Upper limb arterial segments	DUS-	38	10	48
	DUS+	2	10	12
	Total	40	30	60

Table 2: Summary of McNemar test values computed from the data in (Table 1).

Test group	McNemar's p value	MDCTA %	DUS %	% Diff.	95%CI
All arteries	0.015	29.8	20	9.8	(4.3, 5.3)
Iliac AS	0.049	30	18.8	11.2	(2.7, 22.1)
Femoro-popliteal AS	0.011	29.2	20.1	9.1	(3.2, 17.2)
Infrapopliteal AS	0.02	29.2	20.3	8.9	(1.5, 16.3)
Upper limb AS	0.039	33	20	13	(2.6, 25.5)

(Corresponding p values, DUS and MDCT detection percentages, and 95% confidence-intervals are also reported. Significance is indicated by $p < 0.05$. (AS- Arterial segments).

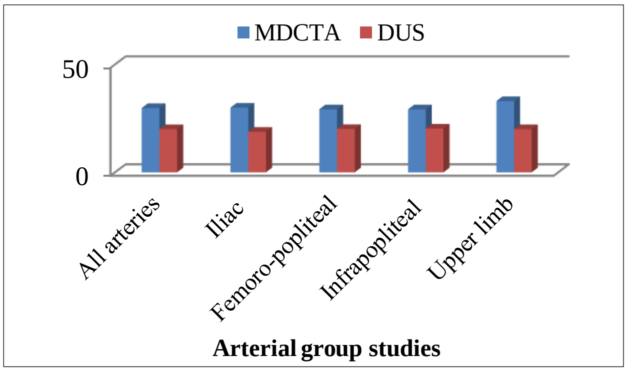

Figure 3: Percentage of stenotic or occluded arterial segments detected by MDCT Angiography (blue columns) and DUS (red columns). Differences between groups are statistically significant as reported in (Table 2).

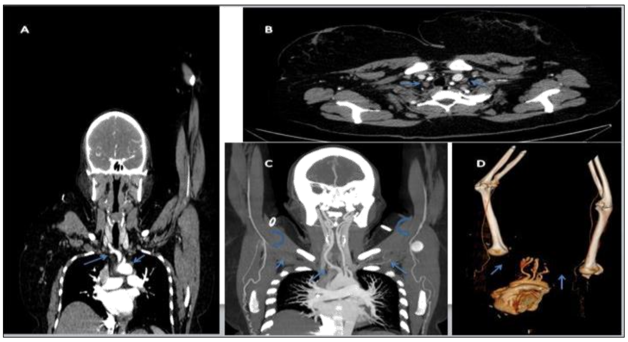

Figure 4: (A) MPR coronal and (B) axial images: complete occlusion of bilateral subclavian arteries (arrow). (C) MIP and (D) VR images: complete occlusion of bilateral subclavian (arrow) and proximal axillary arteries (curve arrow) with distal axillary arteries reformation via collaterals.

The measurement comparisons between DUS and MDCTA modalities in all arteries, iliac, femoropopliteal, infrapopliteal arteries and upper limb arteries only, are shown on (Table 1) and summarizes the McNemar test results (Table 2). The percentage of lesions detected by MDCTA versus DUS as a function of arterial group (Figure 3).

Clinically suspected patients of peripheral arterial disease based on history (smoking), sign (pulse is not palpable) and symptoms and patients diagnosed with PAD on color doppler in upper limb to better see the involvement of aorta by the MDCT angiography (Figure 4).

DISCUSSION

Multidetector computed tomography angiography (MDCTA) remains the most widely available and most effective modality for detection, characterisation and evaluation of peripheral arterial disease.

Color doppler USG is considered as the first choice modality and screening method in assessing PAD, it has several limitations. Furthermore, DUS struggles to assess sequential multisegmental stenosis. The sensitivity of DUS in detection of one segment stenosis is high, as compared to multisegmental disease because stenosis in proximal arterial segments decreases peak systolic velocities and reduces post-stenotic and post-occlusive flows.16 In recent studies, it has been shown that the median sensitivity and specificity of DUS for whole leg are 88% and 96% for >50% stenosis and 90% and 99% for occlusion, respectively.[16] In another series, sensitivity, specificity, positive and negative predictive value for correctly detecting a >50% stenosis by DUS were 0.81, 0.93, 0.84 and 0.9, respectively.[17] The median sensitivity and specificity MDCTA for whole leg are 91% and 91% for >50% stenosis and 97% and 99.6% for occlusion, respectively.[12,18] In segmental analysis a sensitivity and specificity ranging from 91-100% and from 81-100%, respectively was reported including distal pedal arteries.[19]

In our study, in which 40-row MDCTA was performed, sensitivity and specificity values could not be calculated because DSA was not performed as well.

Clinical distribution

In our study of 30 patients with indications were ischemic pain and claudication (50%), gangrene (33.33%) and pulse not palpable (16.66%). Our findings are in agreement with many studies earlier by Algazzar et al, and Polak et al.[9,11]

Risk factors/comorbid condition

Smoking was seen in 63.33% of the patients. History of diabetes mellitus was seen in 50% of cases, while hypertension and CAD was seen in 16.66% and 20% of patients respectively. Our findings are in concordance with many other studies conducted earlier by Algazzar et al (56.7%).[11] in which patients had history of smoking. We found that in our study the incidence of diabetes mellitus was more in PAD than hypertension which is similar to studies done by Premalatha et al, Shirol et al and Joshi et al.[20,7,21]

Our study showed significant correlation between the frequency of severe intermittent claudication and smoking. Similar correlation was found by Premalatha et al.[20]

Limb wise distribution

About 24 patients presented with complaints in lower limbs (80%) and 6 patients (20%) presented with complains in upper limb. Our study is agreement with many studies conducted earlier by Joshi et al and Chidambaram et al.[21,22]

MDCT Angiography and Doppler ultrasound was done in all 30 cases and later the findings obtained by two modalities were compared on different parameters like severity and length of stenosis, presence of calcified plaques and presence of collaterals.

There are total 96 iliac artery segments in 24 patients. In CTA all iliac artery segments were visualized properly, while in colour Doppler total 16 iliac artery segments (16.6%) were not visualized properly due to patients body habitus and excessive bowel gases due to bad bowel preparation, excessive fat in obese patient and excessive gases in bowel loops. Similar problem is faced by by Polak et al and Chidambaram et al Since 15/24 cases showed calcific plaques (62.5%) and in some cases it was very extensive, calcification in CT causes blooming and overestimation of stenosis grade thus causing erroneously false positive results.[9,22] Similar findings was noted by Klingenbeck-Regn.[23]

The number of diseased segments were higher with MDCTA [30.0% (24/80)] as compared with colour Doppler [18.80% (15/80)], respectively i.e. MDCTA showed 11.2% (95% CI: 2.7% to 22.1%) more lesions than colour Doppler (p=0.049). Peedikayil et al evaluated PAD in detecting the aorto-iliac occlusion. MDCTA (2.7%) has detected more lesions in occlusion as compare to Colour Doppler (2.57%).[24] Femoro-popliteal arterial segments including CFA and SFA and popliteal artery were assessed by both modalities. The number of diseased segments were higher with MDCTA [29.2% (42/144)] as compared with Doppler [20.1% (29/144), respectively i.e. MDCTA showed 9.1% (95% CI: 3.2% to 17.2%) more lesions than colour Doppler (p=0.015). Our results were comparable with the studies by Kayhan et al in which MDCTA showed 4% (95% CI: 1.3%, 6.8%) more lesions than colour Doppler (p<0.01).[25]

A total of 192 infra-popliteal arterial segments were evaluated including anterior tibial, posterior tibial, common peroneal and dorsalis pedis arteries. The number of diseased segments were higher with MDCTA [29.2% (56/192)] as compared with Doppler [20.3% (39/192)], respectively i.e. MDCTA showed 8.9% (95% CI: 1.5% to 16.3%) more lesions than colour Doppler (p=0.02). Our results were comparable with the studies by Kayhan et al. in which MDCTA showed 8.3% (95% CI: 4.6%, 12.0%) more lesions than colour Doppler (p<0.01).[25]

In our study only 6 cases of upper limb arterial disease were encountered, subclavian, axillary, brachial, radial and ulnar branches were evaluated by using both modalities. The number of diseased segments were higher with MDCTA [33.0% (20/60)] as compared with Doppler [20.0% (12/60)], respectively i.e. MDCTA showed 13% (95% CI: 2.6% to 25.4%) more lesions than colour Doppler (p=0.039).

Our study is comparable with many studies conducted earlier by:

Shirol et al and they found MDCTA is better than Doppler in detecting the length of stenosis, calcification and collaterals in the arterial system.[7]

Netam et al performed a study of 50 patients with 550 vessels segments by colour Doppler and MDCTA and they concluded that CT angiography detected 2.7% more lesions than colour Doppler (total no. of segments with >50% stenosis were 8.7% and 11.45% by colour Doppler and CTA respectively).[26] As regards >50% stenosis, the results of our study is comparable to that of Collins et al and Met R et al who also found CTA to be more accurate modality in assessing the presence and extent of PAD.[8,27]

More number of calcified plaque are detected by CTA than Colour Doppler, as seen by Joshi et al.[21]

Chidambram et al in their study of 50 patients with 619 arterial segments and concluded that Doppler ultrasound overestimate the stenosis in multisegmental segments.[22] Peedikayil et al did a study of 29 patients with intermittent claudication and showed MDCTA (7.4%) detected more number of lesions of supra-popliteal group of vessels with total occlusion as compared to colour Doppler (6.3%).[24]

In this study we found that MDCTA is a very useful modality in detecting peripheral arterial disease of the extremities and as compared to Colour Doppler, MDCTA detected more number of disease segments, MDCTA has the advantages of being more widely available as compared to DSA which is invasive and requires more operator expertise and experience.

CONCLUSION

MDCT angiography is an outstanding, fast, accurate and non-invasive imaging test in the evaluation of patients with PAD. It have high diagnostic performance and reproducibility in evaluating PAD. MDCTA is able to depict whole of the arterial anatomy right from the aorto-iliac region upto distal crural vessels in lower limbs and from arch of aorta to digital vessels distally in upper limbs. It provides a complete arterial map of the limb affected and gives a bird's eye view to the surgeon before he can do any surgical intervention. The contrast and radiation dose was well tolerated by all the suitable patients and excellent image quality is obtained. MDCTA has been shown to be a reliable tool in quantifying length, number, and grade of stenosis in PAD.

Colour Doppler ultrasound though being the initial imaging modality, has certain limitations like in evaluation of aorto-iliac and femoro-popliteal arterial segments. It is an operator dependent modality with a variable learning curve and it does not provide a proper arterial map a more definite imaging modality is required especially before surgical intervention has to be offered to the patients.

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