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Original Article

Role of Doppler Ultrasonograpgy in Evaluation of Peripheral Arterial Disease with CT Angiography Correlation

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Abstract
Aim: *To assess the role of duplex ultrasonography (DUS) in peripheral arterial disease and compare the accuracy, sensitivity and specificity of duplex ultrasonography (DUS) and multidetector computed tomography angiography (MDCTA) to diagnose peripheral arterial disease (PAD).*
Materials and Methods: *It is descriptive type of observational study done on 40 patients with clinical suspicious of PAD (37 patients with lower limb complaints and 3 patients with upper limb complaints) underwent Doppler ultrasonography and CT angiography. Atheromatous wall changes, steno-occlusive lesions and collaterals (if present) were identified and localized these according to arterial segments.*
Results: *On grey scale, diffuse atheromatous wall changes were noted in 72.5% (i.e. 29) patients with suspected peripheral arterial disease on evaluation by Doppler USG.*
27.5% (11) cases had attenuated calibre of the affected arterial segment. On CTA, diffuse atheromatous wall changes were identified in 82.5% (33) cases and attenuated lumen of the affected arterial segment(s) was identified in 57.5% (23) cases.
Doppler USG identified 47.5% (19) cases as grade 4, 10% (4) cases as grade 2, 12.5% (5) cases as grade 1 and 10% (4) cases as grade 0 stenosis. 20% (8) cases were labelled non-specifically as grade 3 or grade 4 stenosis in proximal segment based on analysis of distal dampened monophasic waveform. MDCTA identified 42.5% (17) cases as grade 4, 32.5% (13) cases as grade 3, 5% (2) cases as grade 2, 7.5% (3) cases as grade 1 and 12.5% (5) cases as grade 0 stenosis. Identification of collaterals was better on CTA as compared to DUS. While on CTA, collaterals were identified in 24 cases, on DUS they were identified in 6 cases. A statistically significant difference ($p<0.05$) between Doppler USG and CTA was found in grades of stenosis ($p<0.05$) in aortoiliac and infrapopliteal region of lower limb in our study. In the present study, the sensitivity, specificity, and accuracy of Doppler USG compared with CTA was 97%, 60%, and 92.2%, respectively.
Conclusion: *Doppler USG can be used as the first investigation for peripheral arterial diseases. In distal arterial disease as Doppler USG overestimates the stenosis, therefore CTA has to be preferred.*
Keywords: *Peripheral arterial disease, Non invasive imaging modalities, Doppler ultrasonography, MDCTA, Stenosis grading.*

Introduction

Peripheral arterial disease (PAD) is a common vascular condition that affects both quality of life and life expectancy with an increased risk of cardiovascular events such as myocardial infarction and stroke. PAD results from any disease causing stenosis or occlusion of the lower limb arteries, with atherosclerosis being the most common etiology.[1]

Risk factors for atherosclerosis include race, male gender, increasing age, smoking, diabetes, hypertension, dyslipidemia, hypercoagulable states, chronic renal insufficiency etc. Prevalance of PAD in adult population is upto 4 to 12% and in elderly population (>70 years old) it may be 20%.[2,3]

Although 65-75% of patients with PAD are asymptomatic, the classic presenting symptom is intermittent claudication which is usually described as muscle cramps, fatigue or pain in the lower limbs induced by exercise and rapidly relieved by rest.

Non-invasive imaging modalities including duplex ultrasonography (DUS), magnetic resonance angiography (MRA) and multi-detector computed tomography angiography (MDCTA) are indicated to identify the location and severity of arterial stenosis when considering possible intervention.[4] Colour assisted duplex ultrasound scan is safe, non-invasive and non-expensive and can provide anatomical as well as functional information.[3]

Magnetic resonance angiography (MRA) and computed tomographyangiography (CTA) could be used to confirm and localize suspected disease, especially where intervention is being considered. Both techniques have been shown to be sensitive and specific for PAD evaluation.[5,6] They are similar in terms of diagnostic accuracy, clinical outcome and ease of use.

Digital Subtraction Angiography (DSA) is the gold standard in the evaluation of PAD. However, it is an invasive method and may lead to morbidity. With the advent of multi-slice CT, 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.[7] Thereby, it has been possible to image the arterial tree with a single injection of contrast agent. Today, 16- and 64-detector CT technology is used in establishing diagnosis as well as treatment planning.

There is increasing recognition that peripheral arterial disease (PAD) is an independent risk factor for both myocardial infarction and stroke and treatment of PAD reduces this risk. Despite the fact that catheter-based digital subtraction angiography is considered the ‘gold standard’ investigation for PAD, it is usually only performed when a concurrent endovascular intervention is anticipated due to its invasive nature. In present study we have attempted to compare two non-invasive modalities of today’s era which are now becoming easily available in urban as well as semi urban areas of India.

Material and Methods

The study was carried out on 40 patients in department of Radiodiagnosis at Dr. S.N. Medical college, Jodhpur, Rajasthan and attached group of hospitals over a period of 12 months. These patients were evaluated using duplex ultrasonography and CT angiography for peripheral arterial system. This study was a prospective study involving patients of more than 18 years of age giving clinical history consistent with that of peripheral arterial disease. Subjects included were willing to undergo the protocol design after written consent. Patients who were allergic to contrast, pregnant, had acute/chronic renal failure, refused the protocol and did not give consent were excluded. Detailed history of each patient regarding name, age, sex, occupation, symptoms, previous medical history if any were taken. All the patients with suspected peripheral arterial disease, OPD/IPD based were evaluated by the clinician. After reviewing the examination findings, patients were evaluated by Doppler ultrasonography as ordered by the clinician, followed by MDCT Angiography.

Doppler ultrasound was carried out on all the patients referred to our department with suspected peripheral arterial disease. It was done on ALOKA PROSOUND USG machine using curvilinear and linear transducer probe. Patients were made to lie on USG couch in supine position for evaluation of infrarenal aorta, common iliac, external iliac, common femoral, superficial and deep femoral, anterior tibial, posterior tibial arteries and popliteal artery and tibioperoneal trunk were evaluated in prone position. The dorsalis pedis artery was not included in the evaluation as it was not usually visualized on CTA. Upper limbs were evaluated in supine position. Patients suspected of compression at the thoracic outlet evaluated in different provocative positions (hyperabduction, extension and deep inspiration). Using linear (5-12MHz) transducer, peripheral arteries evaluated in longitudinal and axial sections in B mode, colour flow, power and pulse wave modes from proximal to distal parts. Curvilinear (3-9MHz) transducers were used for iliac arteries. Pulse repetition frequency (PRF) was set optimally to detect best velocity and colour flow. Affected arterial segments were identified on the basis of following parameters:

-Calibre of vessel- Normal calibre was interpreted by comparing the vessel calibre to adjacent vessel. Any abnormal dilatation or attenuation was noted. Arterial narrowing was graded using B mode images in Doppler USG.

-Atheromatous wall changes were identified in the form of any intimal thickening, mural calcification.

-Lumen of affected arterial segments were assessed for presence of any plaque. Further plaque echogenicity was assessed qualitatively and categorized as low or moderate echogenicity.

-Colour Doppler and duplex imaging was performed to assess and document presence or absence of normal laminar flow within the affected vessel. Affected arterial segments were evaluated for their peak systolic velocities, end diastolic velocities, acceleration time and documentation of peak systolic velocity ratios was done at the stenotic site.

-On spectral imaging, any deviation from normal triphasic waveform was noted in the arterial segments and in cases where the affected segment was not directly visualised, waveform changes distal to the point of stenosis was noted and stenosis grading was done accordingly.

CT angiography was performed using PHILIPS 64 slice CT scanner after removing all the external artefacts from the scanning field. Scan was done in supine position. Patients with lower limb complaints, were placed in feet first position and scout obtained from infrarenal aorta to feet. Anatomical position of one upper limb or provocative position of thoracic outlet compression was preferred for upper limbs.

Scan parameters included slice collimation 0.625 mm, pitch 0.609, rotation time 0.75 s, 100 Kv, 220 mAs, soft reconstruction algorithm. Contrast medium Bolus tracking: 100 ml at 4 ml/s, 50 ml NS at 4ml/s

Apart from those evaluated on Doppler ultrasound, following parameters were assessed:

-Luminal opacification: Normal arteries reveal complete luminal opacification by contrast. Hypodense filling defect within lumen was noted in presence of intraluminal plaque.

-Length of steno-occlusive lesions was noted and documented.

-Presence or absence of collaterals was noted.

Grading of stenosis was done on both Doppler USG and CT Angiography using the following criteria and findings of Doppler USG were compared with that of CTA.

Grade of stenosis	Percentage stenosis
Grade 0	0% stenosis
Grade 1	1-19% stenosis
Grade 2	20-49% stenosis
Grade 3	50-99% stenosis
Grade 4	Occlusion

Observations and Results

The study was carried out on 40 patients, in the department of Radiodiagnosis at Dr. S.N. Medical college, Jodhpur, Rajasthan. In our study, 75 % of patients were in the group of 40 years and above with the mean age of presentation being 50 years. Among all the patients with clinical suspicion of PAD, 30 were males while 10 were females.

Table 1: The distribution of steno-occlusive lesions identified in lowerlimb was as follows

Distribution in lower limb	Frequency	%
Aortoiliac	9	26.4%
Femoropopliteal	16	47.2%
Infrapopliteal	9	26.4%
Total	34	100.0%

Table 2: Frequency distribution of cases based on stenosis grade on Doppler USG and MDCTA (overall)

Stenosis grade on USG	Stenosis grade on MDCTA					P Value
	0	1	2	3	4	
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	
0	3 (60%)	0.00%	0.00%	0.00%	1 (5.9%)	<0.001
1	1 (20%)	2 (66.7%)	1 (50%)	0.00%	1 (5.9%)	
2	1 (20%)	1 (33.3%)	0.00%	1 (7.7%)	1 (5.9%)	
4	0.00%	0.00%	0.00%	8 (61.5%)	11 (64.7%)	
* 3 or 4	0.00%	0.00%	1 (50%)	4 (30.8%)	3 (17.6%)	
Total	5 (100%)	3 (100%)	2 (100%)	13 (100%)	17 (100%)	

Table 3: Frequency distribution of cases based on stenosis grade on Doppler USG and MDCTA in aortoiliac region

tenosis Grade on USG	Stenosis Grade on MDCTA			P Value
	1	3	4	
	Frequency (%)	Frequency (%)	Frequency (%)	
0	0.00%	0.00%	1 (16.7%)	0.043
1	1 (100%)	0.00%	0.00%	
4	0.00%	1 (50%)	5 (83.3%)	
*3 or 4	0.00%	1 (50%)	0.00%	
Total	1 (100%)	2 (100%)	6 (100%)	

Table 4: Frequency distribution of cases based on stenosis grade on Doppler USG and MDCTA as identified in femoropopliteal region

Stenosis grade on USG	Stenosis grade on MDCTA				P Value
	1	2	3	4	
	Frequency (%)	Frequency (%)	Frequency (%)	Frequency (%)	
1	1 (50.0%)	1 (100%)	0.00%	1 (11.1%)	0.345
2	1 (50.0%)	0.00%	1 (25.0%)	1 (11.1%)	
4	0.00%	0.00%	1 (25.0%)	4 (44.4%)	
*3 or 4	0.00%	0.00%	2 (50.0%)	3 (33.3%)	
Total	2 (100%)	1 (100%)	4 (100%)	9 (100%)	

Table 5: Frequency distribution of cases based on stenosis grade on Doppler USG and MDCTA as seen in infrapopliteal region

Stenosis Grade	Stenosis Grade			P Value
	0	2	3	
	Frequency (%)	Frequency (%)	Frequency (%)	
1	1 (50%)	0.00%	0.00%	0.047
2	1 (50%)	0.00%	0.00%	
4	0.00%	0.00%	5 (83.3%)	
*3 or 4	0 (0.0%)	1 (100%)	1 (16.7%)	
Total	2 (100%)	1 (100%)	6 (100%)	

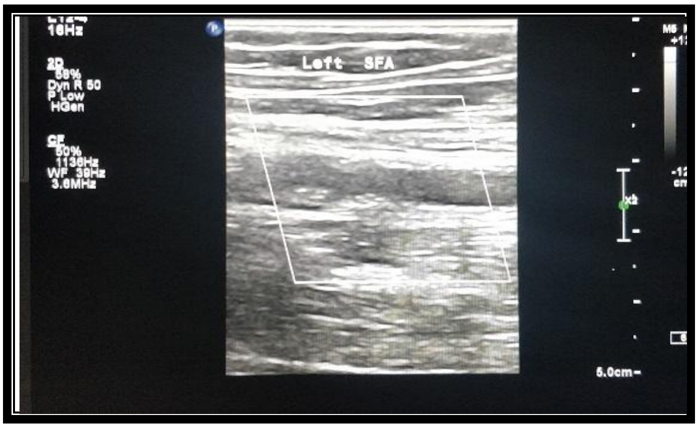

Image 1: Longitudinal grey scale image showing absent flow in left superficial femoral artery

Image 2: Corresponding CT angiography MIP image showing non opacification of distal segment of left superficial femoral artery suggesting grade 4 stenosis. Distal reformation due to collateral formation is seen.

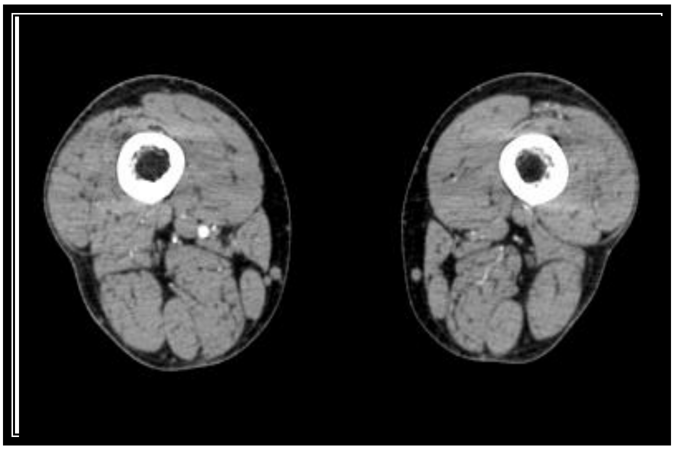

Image 3: Axial reformatted CT angiography image showing occlusion of left superficial femoral artery.

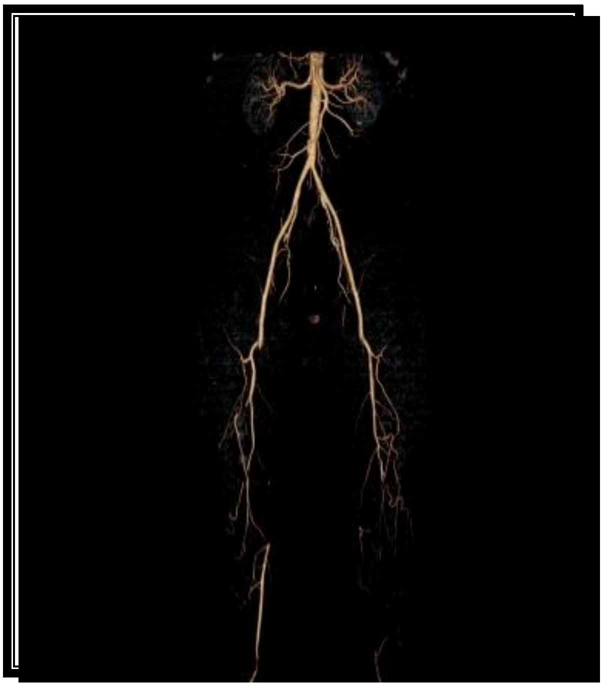

Image 4: Corresponding VR image showing grade 4 stenosis in distal segment of left superficial femoral artery with collateral formation. Poor distal run off is noted.

Discussion

In our study, out of 40 patients with clinical suspicion of PAD, 37 patients had lower limb complaints while 3 patients had upper limb complaints and they had unilateral limb involvement. Majority of patients had complaints of intermittent claudication i.e. 25 out of 40 cases (62.5%), followed by rest pain (22.5%), skin discoloration (7.5%), gangrene (5%) and numbness (2.5%). Out of 25 patients, true claudication was seen in 22 patients as remaining 3 cases were found to have normal Doppler USG as well as CT angiography study (i.e. grade 0 stenosis). This is consistent with Kannel and McGee[7] who showed in their study that intermittent claudication is the most common manifestation of PAD.

In present study, most common affected site in lower extremity was femoropopliteal region with 47.2% (16) cases followed by aortoiliac and infrapopliteal involvement each with 26.4% (9) cases respectively. Majority of patients (13 cases i.e. 81%) had superficial femoral artery involvement. In a study conducted by Anant et al[9], it was also reported that the majority of the lesions were involving the femoral segments with most of them (43.33%) in superficial femoral artery.

In our study, hemodynamically significant stenosis (i.e. grade 3 and 4) were found in 30 patients while non-hemodynamically significant stenosis (i.e. grade 0, 1 and 2) were seen in 10 patients. Among patients with hemodynamically significant stenosis in lower extremity, femoropopliteal involvement was seen in 48.2%, aortoiliac segments in 29.6% and 22.2% in infrapopliteal segments. Ahchong et al[10] also showed that severely stenosed cases of PAD had femoropopliteal involvement.

Evaluation by Doppler ultrasound

On grey scale, diffuse atheromatous wall changes were noted in 72.5% (i.e. 29) patients with suspected peripheral arterial disease on evaluation by Doppler USG.27.5% (11) cases had attenuated calibre of the affected arterial segment. Atherosclerotic plaques were identified in 13 cases, with moderate echogenicity plaques in 61.5% cases and low echogenicity plaques in 38.5% cases.

Hughson et al[11] concluded that atherosclerosis is the most important factor associated in intermittent claudication (IC) and subsequently with PAD. In study conducted by Anant et al[9], plaques were identified in 34 cases, low echogenicity plaques were seen in 23.68% cases while moderate to severely echogenic plaques (seen with disease progression) were seen in 76.32% cases. Findings in the present study were also consistent with the study conducted by Maseri and Fuster[12] who found chronic plaques to predominate in settings of PAD.

On Color Doppler examination it was found that no flow was detected (even on smallest PRF settings) in 19 cases and hence were labelled as grade 4 stenosis. In 4 cases, PSV ratio was calculated and it was found that in these cases PSV ratio was <2:1 and they had non-hemodynamically significant stenosis (as 3 out of 4 cases were identified as grade 1 stenosis and 1 case was identified as grade 2 stenosis).This is consistent with the study done by Cossman et al[13] who concluded that a PSV ratio of more than 2 is seen in hemodynamically significant lesions and severity of stenosis is proportional to the PSV ratio.

On pulsed Doppler examination, dampened monophasic waveform was noted in distal arterial segment in 23 out of 40 cases. 8 out of these 23 cases were labelled as having hemodynamically significant stenosis i.e. grade 3 or grade 4 stenosis in proximal arterial segment. This is consistent with an earlier study which showed that the “blunted” monophasic waveform corresponds to an extension of the ascending systolic phase, with no retrograde diastolic portion and this is found downstream from a proximal obstruction.88

Doppler USG identified 47.5% (19) cases as grade 4, 10% (4) cases as grade 2, 12.5% (5) cases as grade 1 and 10% (4) cases as grade 0 stenosis. 20% (8) cases were labelled non-specifically as grade 3 or grade 4 stenosis in proximal segment based on analysis of distal dampened monophasic waveform. Collaterals distal to steno-occlusive site were identified in 7 cases on DUS.

Comparison of Doppler USG and MDCTA findings

On CTA, diffuse atheromatous wall changes were identified in 82.5% (33) cases and attenuated lumen of the affected arterial segment(s) was identified in 57.5% (23) cases. Although statistically insignificant, MDCTA identified atheromatous wall changes and attenuated calibre of affected vessels better as compared to Doppler USG.

MDCTA identified 42.5% (17) cases as grade 4, 32.5% (13) cases as grade 3, 5% (2) cases as grade 2, 7.5% (3) cases as grade 1 and 12.5% (5) cases as grade 0 stenosis.

Out of 17 cases identified as grade 4 on CTA, Doppler USG correctly identified 11 (64.7%) cases. In rest of the 6 cases, 3 cases were labelled non-specifically as grade 3 or 4 on USG due to poor visualisation of stenosed segment of affected artery (in our case it was distal segment of SFA in adductor canal) causing dampened monophasic flow in distal arteries. In other 3 out of 6 cases, USG underestimated stenosis, where 2 cases in distal SFA segment were incorrectly identified as grade 1 and 2 respectively possibly due to adequate collateral formation and remaining 1 case which was identified as focal grade 4 stenosis in EIA on CTA, was not picked up on USG due to excessive abdominal fat resulting in poor visualisation of iliac arteries.

CTA identified 13 cases as grade 3 stenosis. DUS overestimated stenosis by one grade in 8 cases, while 4 cases were labelled non-specifically as grade 3 or 4 stenosis in proximal segment on the basis of distal dampened monophasic flow. 1 case was under estimated and labelled as grade 2 stenosis. On CTA, 2 cases were identified as grade 2 stenosis, out of which on DUS 1 case was under estimated as grade 1 and the other case was overestimated and labelled non-specifically as grade 3 or 4 proximal stenosis.3 cases were identified as grade 1 stenosis on CTA. Out of these 3 cases, DUS correctly identified 2 cases as grade 1 stenosis while in 1 case, stenosis was overestimated by one grade.5 cases were identified as grade 0 stenosis on CTA out of which, 3 were correctly identified as grade 0. Rest of the 2 cases were overestimated by one and two grades respectively.

In the aortoiliac segment, distribution of stenosis on CTA was as follows: grade 4 stenosis - 6 cases, grade 3 stenosis -2 cases, and grade 1 stenosis- 1 case. Majority of the cases in the aortoiliac region i.e. 6 out of 9 cases were identified as grade 4 stenosis on CTA. On DUS, 6 cases were labelled as grade 4 stenosis, and one case each as grade 0 and 1. One case was labelled non-specifically as grade 3 or 4.7 out of total 9 cases were correctly identified on DUS as grade 4 stenosis. Out of the remaining 2 cases, 1 was undergraded and the other overgraded.

In the femoropopliteal segment, following distribution was seen on CTA- grade 4 in 9 cases, grade 3 stenosis in 4 cases, grade 2 in 1 case and grade 1 in 2 cases. Most common grade of stenosis identified on CTA was grade 4 in the present study with 9 out of total 16 cases. On DUS, 5 cases were labelled as grade 4, 5 cases as grade 3 or 4, 3 cases as grade 2 and 3 cases as grade 1 stenosis. On DUS, stenosis was graded as 3 or 4 in 5 cases on the basis of dampened monophasic flow distally due to non-visualisation of distal segment of SFA in the adductor canal.DUS correctly identified stenosis in 5 cases while it underestimated stenosis in 4 cases: 3 cases were underestimated by one grade, 1 case each by two grades and three grades respectively. On DUS, we overestimated stenosis by 1 grade in 2 cases.

Distribution of grade of stenosis in infrapopliteal region as on CTA was as follows: grade 3 stenosis- 6 cases, grade 2 stenosis-1 case, and grade 0 stenosis- 2 cases. Most common grade of stenosis in our study in infrapopliteal region was grade 3 stenosis. All cases in the infrapopliteal segment were overestimated on DUS as compared to CTA - in 6 cases it was overestimated by one grade while in 1 case it was overestimated by two grades.

It was also shown by Chidambaram PK et al[14] that Doppler USG is valuable in the evaluation of infra inguinal region of lower limbs and there is significant statistical difference between Doppler USG and CTA. They concluded that Doppler USG can be used as the first investigation of peripheral arterial diseases and in multi segmental and distal arterial disease, Doppler USG overestimates stenosis, hence CTA has to be preferred.

In our study, 3 cases of upper limb involvement were seen. In 2 out of 3 cases ulnar artery was affected and in 1 case brachial artery was involved. On CTA, 2 cases identified as grade 4 and 1 case identified as grade 3. On DUS, these 3 cases were labelled as grade 4 stenosis. The above findings are consistent with Netam et al[15] who also showed that grade 3 and grade 4 lesions are accurately demonstrated by MDCTA than DUS.

In present study, the number of segments with greater than 50% stenosis were 27 (67.5%) and 30 (75%) by DUS and CTA respectively. Kayhan A et al [16] also found that the number of segments with greater than 50% stenosis were 27(3.49%) and 35(4.52%) on DUS and MDCTA respectively. In cases with >50% stenosis, the results of our study are comparable to that of Kayhan A et al[16], Hatsukami TS et al[17] and Joshi et al[18] who also found CTA to be more accurate modality in assessing the presence and extent of peripheral arterial disease.

Identification of collaterals was better on CTA as compared to DUS. While on CTA, collaterals were identified in 24 cases, on DUS they were identified in 6 cases.

A statistically significant difference ($p<0.05$) between Doppler USG and CTA was found in grades of stenosis ($p<0.05$) in aortoiliac and infrapopliteal region of lower limb in our study.

In the present study, the sensitivity, specificity, and accuracy of Doppler USG compared with CTA was 97%, 60%, and 92.2%, respectively. Positive predictive value and negative predictive value were 94% and 75.4% respectively. These findings were consistent with Chidambaram PK et al[14] who also showed that ascompared to CTA, Doppler USG has excellent sensitivity in detecting stenosis.

In present study it was found that DUS can be a good screening tool with a sensitivity of 97% which is consistent with earlier studies by Hatsukami TS et al[17] and Sensier Y et al[19] who also found that CDUS as an accurate screening tool for the evaluation of the peripheral arterial disease.

Conclusions

It could therefore be concluded, that there was good agreement between Doppler USG and CTA of upper limbs arteries and proximal outflow arteries of the lower limb. Doppler overestimated stenosis grade predominantly in distal runoff arteries of lower limbs. Doppler USG and CTA findings showed statistically significant correlation in most of the arteries with sensitivity of 97%, specificity 60% and accuracy 92.2%. Positive and negative predictive values were found to be 94% and 75.4% respectively. Doppler USG can be used as the first investigation for peripheral arterial diseases. In distal arterial disease as Doppler USG overestimates the stenosis, therefore CTA has to be preferred.

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