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Segmental Comparison of Lower Limb Arteries By Doppler Ultrasound and Ct Angiography in Peripheral Arterial Diseases.

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ABSTRACT:
Aim: to evaluate the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of Doppler ultrasound compared to CT angiography in lower limb arteries segment wise (i.e. Common femoral artery, Superficial Femoral Artery, Deep Femoral Artery, Popliteal Artery) in terms of Percentage of stenosis, Length of stenosed segment/extent of involved segment, detection of collateral flow, detection of thrombus and detection of plaque and wall calcifications.
Methods: The study was conducted in department of Radiology, Apollo hospital, Jubilee Hills, Hyderabad over 24 months from June 2017 to May 2019. It was a Prospective, comparative study.Patients with signs and symptoms of PADs referred for colour Doppler ultrasound and CT angiography to the department were included. Total numbers of cases included were 50. Polytrauma patients with suspected acute arterial injury, those having allergy to contrast, or with acute/chronic renal failure, or with past history of lower limb vascular surgery were excluded from study.
Results:
- Overall sensitivity, specificity, PPV and NPV of CDUS compared to CTA in femoropopliteal segments for percentage stenosis was found to be 92.25%, 87.75%, 91% and 89.5% respectively.
- Overall sensitivity, specificity, PPV and NPV for detecting collaterals was 90%, 88%, 46% and 99% respectively.
- Doppler USG is excellent modality in evaluating the extent of disease with overall sensitivity, specificity, PPV and NPV of 94% and 98.5%, 99% and 92.5% respectively.
- Overall sensitivity, specificity, PPV and NPV of Doppler USG compared to CTA for detecting thrombus was found to be 57.25%, 96%, 72.5% and 91.25 respectively.
- Overall Sensitivity, specificity, PPV and NPV of Doppler USG for plaque detection was found to be 89%, 96%, 89% and 93% respectively.
- Overall Sensitivity, specificity, PPV and NPV of Doppler USG compared to CTA for wall calcification was found to be 92%, 93.75%, 87.75% and 92.5% respectively.

Conclusion: In our study we found CDUS to have good correlation with CTA in evaluation of PADs in lower limb vessels. Thus CDUS favors to be the 1st line investigation for evaluation of PADs followed by CT before planning any interventional treatment.
KEYWORDS: Peripheral arterial disease, Colour Doppler, CT Angiography, Common femoral artery

I. INTRODUCTION

Peripheral artery diseases (PADs)/Peripheral vascular disease (which include both arteries and veins) refer to diseases of the blood vessels located outside the heart and brain. Risk factors include Cigarette smoking, Hypertension, C-reactive protein, Diabetes and family history of past diseases. The most common cause of lower limb arterial occlusive disease is atherosclerosis[1]. Less common causes include thromboembolism, acute thrombotic occlusion,

trauma, vasculitis including vasospastic disorders and Berger's disease.

The natural history of PAD indicates that among patients with intermittent claudication, 7% will undergo lower extremity bypass surgery, 4% major amputations and 16% worsening claudication. However, Non-fatal cardiovascular events (MI, stroke) occur in approximately 20% over a 5-year period and the 5-year mortality rate is estimated to be 30% (versus 10% in controls), of which 75% were cardiovascular deaths[1]

With advances in the field of vascular surgery, better affordability of the patients' vascular imaging has a great role to play in this field, to help in accurately explaining the extent of the disease before any intervention is planned. Invasive peripheral vascular imaging **conventional digital subtraction angiography (DSA)** is now largely obsolete as a diagnostic tool. Drawbacks of DSA are its invasiveness because of arterial puncture, possible need for hospitalization, high radiation dose, and potential nephrotoxicity secondary to iodinated contrast agents. It does not estimate the hemodynamic significance of lesions. However it gives an accurate anatomical description of obstructive arterial lesions. In today's era it is used for imaging in only those cases where along with imaging any therapeutic intervention is also planned [2].

Colour Doppler ultrasound (CDUS) is in today's era 1st line investigation for suspected or evaluation of PVDs. It is safe, popular, cost effective, repeatable, non-invasive procedure for investigating lower limb arteries. Duplex ultrasound with spectral tracing provides a measurement of blood velocity through a vessel and enables the rapid localization of arterial stenosis and occlusions. Lower extremity **CT angiography (CTA)** is a fairly new technique when compared to duplex ultrasonography. It is a reliable noninvasive tool in quantifying the length, number and grade of stenosis. It mainly delineates the presence or absence of significant obstruction to the blood flow, the site and anatomical extent of obstruction, the status of collaterals and distal vasculature which is crucial for planning the treatment as well as to monitor the results of therapy and disease progression[3].Recently, **Magnetic resonance angiography (MRA)** has also been started in investigating the PADs. Contrast-enhanced MRA has high accuracy for identifying or excluding clinically relevant arterial steno-occlusions in adults with PAD symptoms. It cannot be used in patients with Cardiac pacemaker, Implantable cardioverter defibrillators, Neurostimulators, Cochlear implants and claustrophobic patients. Clinically, a normal **ankle: brachial pressure index (ABPI)** virtually excludes the presence of significant PVD and is mandatory part of vascular assessment.

Hence, there is pressing need for identifying non-invasive method of evaluation of PADs which is accurate, reliable, reproducible and cost effective. Doppler ultrasound fulfills most of these criterions with the advantage of being radiation free. Therefore, we have compared in our study the Doppler ultrasound which is generally the 1st line investigation in PADs with CT angiography characteristics in lower limb arteries, segment wise and tried to evaluate where Doppler ultrasound stands in comparison with CT(which is nowadays investigation of choice prior to any intervention in PADs).

Aim of our study was to evaluate the sensitivity, specificity, positive predictive value(PPV) and negative predictive value(NPV) of Doppler ultrasound compared to CT angiography in lower limb arteries segment wise (i.e. Common femoral artery, Superficial Femoral Artery ,Deep Femoral Artery, Popliteal Artery) in terms of Percentage of stenosis, Length of stenosed segment / extent of involved segment, detection of collateral flow, detection of thrombus and detection of plaque and wall calcifications.

II. MATERIAL AND METHODS

The study was conducted in department of Radiology, Apollo hospital, Jubilee Hills, Hyderabad over 24 months from June 2017 to May 2019. It was a Prospective, comparative study.Patients with signs and symptoms of PADs referred for colour Doppler ultrasound and CT angiography to the department were included. Total numbers of cases included were 50. Polytrauma patients with suspected acute arterial injury, those having allergy to contrast, or with acute/chronic renal failure, or with past history of lower limb vascular surgery were excluded from study.

After taking informed consent and brief history, Doppler USG and CTA were scheduled and instructions were explained to patient. The study duration of investigations for each patient was approximately 2 days. All CDUS were performed using PHILLIPS IU 22 ultrasound machine and the arteries were scanned with a linear phased array(5-12MHZ) transducer. 128 slice MDCT angiography was performed using Phillips ingenuity CT machine using bolus tracking technique , the scan direction is craniocaudal from the level of coeliac axis aorta to the pedal arch. Images were taken in arterial phase with following parameters-Patient position Supine in suspended respiration, Slice

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collimation 2.5 mm, Slice width 0.90 mm, Reconstruction interval 1.5 mm, Table feed 7.5 mm/sec, Pitch 0.70, Rotation time 0.6 s, kV-120, mA-159 ,Gantry rotation period-0.75 sec, Average scan time - 30 to 40 seconds and Reconstruction algorithmSoft. Image reconstruction were done in VR and MIP for overview, MPR/CPR for calcific stenosis. study outcome measured were percentage stenosis, length of stenosed segment, presence of collateral flow, thrombus, plaque and wall calcifications. On CTA cross-sectional and reconstruction profile images were used to assess minimum luminal diameter for grading stenosis. On Doppler ultrasound cross-sectional images were obtained perpendicular to the vessel wall to assess minimal luminal diameter for grading stenosis. Length less than 25 mm was considered as short segment and more than 25 mm was considered as long segment in our study.

III. RESULTS:

Out of 50 patient studied 40 (80%) were males and rest females. A total of 100 limbs were studied which included 400 arterial segments. Majority of patients were of middle to elderly age group with highest number in 61-70 years age group i.e. 16 patients (32%). Major risk factor associated were diabetes (88%) and hypertension (54%). Rest risk factors seen were smoking and tobacco chewing. Clinically, 78% patients suffered from some grade of intermittent claudication while 12% patients had gangrenous features.

Sensitivity, specificity, positive predictive value(PPV) and negative predictive value(NPV) of doppler ultrasound compared to CT angiography in lower limb arteries segment wise (i.e. Common femoral artery, Superficial Femoral Artery ,Deep Femoral Artery, Popliteal Artery) in terms of Percentage of stenosis, Length of stenosed segment / extent of involved segment, detection of collateral flow, detection of thrombus and detection of plaque and wall calcifications were recorded and tabulated as below.

Table 1: Stenosis grading (Doppler USG and CT Angiography)

Grade	Criterion
1	Normal patency
2	Mild (≤50% diameter) stenosis
3	Moderate (≥50 to 70% diameter) stenosis
4	Severe(≥70% diameter) stenosis
5	Occlusion

Table 2: The segment wise sensitivity, specificity, PPV and NPV of the arterial segments in present study for stenosis estimation:

S.NO.	SEGMENT	SENSITIVITY	SPECIFICITY	PPV	NPV
1	**CFA**	92.45%	91.49%	92.45%	91.49%
2	**SFA**	95.31%	86.11%	92.42%	91.18%
3	**DFA**	89.29%	86.36%	89.29%	86.36%
4	**PA**	93.10%	88.10%	91.53%	90.24%
5	**OVERALL**	**92.25%**	**87.75%**	**91%**	**89.75%**

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Table 3: Under and over estimation of stenosis grade on comparing Doppler and CT angiography in present study:

S.NO.	DOPPLER	UNDERESTIMATON						OVERESTIMATION				
	ARTERY	**-5**	**-4**	**-3**	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**+4**	**+5**
1	**CFA**	0	0	0	0	8	53	8	0	0	0	0
2	**SFA**	0	0	0	0	8	64	6	0	0	0	0
3	**DFA**	0	0	0	0	10	44	8	0	0	0	0
4	**PA**	0	0	0	0	7	41	6	1	0	0	0

TABLE 4: Segment wise sensitivity, specificity, PPV and NPV of the arterial segments for collaterals:

S.NO.	SEGMENT	SENSITIVITY	SPECIFICITY	PPV	NPV
1	**CFA**	100.00%	95.83%	50.00%	100.00%
2	**SFA**	100.00%	83.95%	59.38%	100%
3	**DFA**	60.00%	91.58%	27.27%	97.75%
4	**PA**	100.00%	83.72%	50.00%	100.00%
	OVERALL	90%	88%	46%	88%

Table 5:Segment wise sensitivity, specificity, PPV and NPV of the arterial segments for length of involvement :

S.NO.	SEGMENT	SENSITIVITY	SPECIFICITY	PPV	NPV
1	**CFA**	92.45%	100.00%	100.00%	92.16%
2	**SFA**	95.31%	100.00%	100.00%	92.31%
3	**DFA**	96.43%	97.73%	98.18%	95.56%
4	**PA**	93.10%	97.62%	98.18%	91.11%
5	**Overall**	**94%**	**98.5%**	**99%**	**92.5%**

Table 6: Segment wise sensitivity, specificity, PPV and NPV of the arterial segments for thrombus detection

S.NO.	SEGMENT	SENSITIVITY	SPECIFICITY	PPV	NPV
1	**CFA**	40.00%	97.78%	66.67%	93.62%
2	**SFA**	70.83%	96.05%	85.00%	91.25%
3	**DFA**	62.50%	93.48%	45.45%	96.63%
4	**PA**	57.14%	98.61%	94.12%	85.54%
5	**Overall**	**57.25%**	**96%**	**72.5%**	**91.25%**

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Table 7: The segment wise sensitivity, specificity, PPV and NPV of the arterial segments for Plaque detection

S.NO.	SEGMENT	SENSITIVITY	SPECIFICITY	PPV	NPV
1	**CFA**	77.36%	94.74%	83.67%	96.43%
2	**SFA**	94.83%	100%	100.00%	93.33%
3	**DFA**	96.08%	93.88%	94.23%	95.83%
4	**PA**	90.20%	97.96%	80.70%	90.57%

Table 8: The segment wise sensitivity, specificity, PPV and NPV of the arterial segments for wall calcification

S.NO.	SEGMENT	SENSITIVITY	SPECIFICITY	PPV	NPV
1	**CFA**	97.14%	87.69%	80.95%	98.28%
2	**SFA**	85.42%	98.08%	97.62%	87.93%
3	**DFA**	96.08%	93.88%	94.23%	95.83%
4	**PA**	**90.20%**	**97.96%**	**80.70%**	**90.57%**

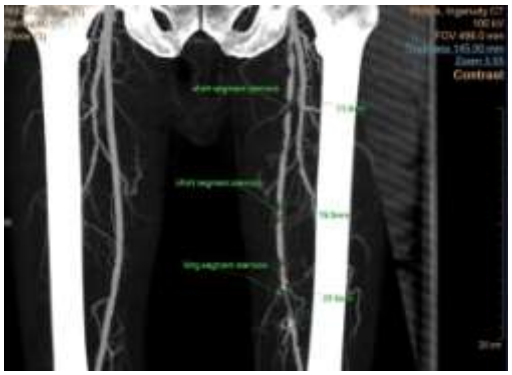

Figure 1: CT Angio shows short segment narrowing in proximal and mid SFA and long segment stenosis in distal SFA.

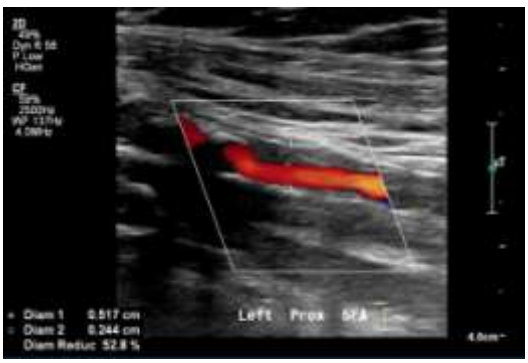

Figure 2: Doppler USG show around 52% narrowing in proximal SFA by plaque.

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Figure 3: volume rendered (VR) images of lower limb arterial tree . Figure 4: Curved planer Reformations (CPR) of lower limb vessels

IV. DISCUSSION

Catheter-based DSA used to be the reference standard for evaluation of limb ischemia. CTA has now replaced catheter based angiography for clinical assessment of the aorta and its branches.

Doppler USG has many advantages, like no radiation, repeatability, functional evaluation of blood flow, velocity quantification and direct measurement of thrombus, dilatation or narrowing. Use of Doppler USG is limited by a small window; wide interobserver variability, limited reproducibility and long examination time. CTA using single shot intravenous injection of non-ionic contrast medium reproduces entire arterial anatomy within 2-3 minutes. Interpretation of axial, multiplanar reconstructed images, maximum intensity projection and volume rendered technique requires approximately 10-15 min. Depiction of arterial reformation and collaterals are better with CTA, however limited to ascertain the direction of flow. Radiation, compromised renal function and repeatability also limit its use.

I. **DEMOGRAPHIC DATA:**

A. **Sex:** 50 patients (100 limbs) were included in our study, out of which, 40 patients (80%) were male and rest females. Sex ratio observed was 4:1(M: F). **Gareth Morris and his co-workers in 20114[15]** studied variations in the anatomical distribution of PADs according to gender and found that there were 310 males and 190 females giving a male to female ratio of 1.6:1. The most common distribution for both genders was multiple bilateral lesions. Our study is in concordance with this study. However the male to female ratio came out to be high compared to this study (4:1). High sex ratio can be attributable to the short sample size compared to the above study.

B. **Age**: In our study majority of the population affected was middle age and elderly with 37 patients (74%) falling in age group 51-80 years. Only 10 patients were below 40 years of age. **Premalatha et al. 2000[4]** studied prevalence of PVD in the Chennai Urban Population and they found that PVD was uncommon until middle-age and then the prevalence rate increased dramatically. This is in concordance with our study.

II. CO MORBIDITIES: We found diabetes (88% pts) and hypertension (54% pts) to be majorly associated with patients in PAD. Smoking (14%) and tobacco chewing (24%) were the other two important factors associated with patients.

Premalatha et al. 2000[4] studied risk factors of PVD in the Chennai Urban Population Their analysis showed age >50 years (P<0.001) and hypertension (P = 0.08) to be associated with PAD, whereas smoking showed no association. Known diabetic subjects had a higher prevalence of PVD (7.8%) compared with newly diagnosed diabetic subjects (3.5%). This is in concordance with our study. However in our study significant number of symptomatic patient also had smoking associated with them which is discordant with the above study.

Price JFet al. 1999[5] studied the relationship between smoking and cardiovascular risk factors in the development of peripheral arterial disease and coronary artery disease (Edinburgh Artery Study).The incidence of peripheral arterial disease was 5.1% in 594 patients studied. This is in

agreement with our study where 14% smoking association was found in 50 patients.

III. SEGMENTAL COMPARISON OF ARTERIALS SEGMENTS:

A. **Percentage Stenosis**: Out of 400 arterial segments studied on both CTA and CDUS in our study, CTA picked up abnormality in 231 cases (57.75%) whereas colour Doppler was positive in 251 cases (62.75%). CDUS detected <50% stenosis in 138 arterial segments, 50-75% stenosis in 31 arterial segments, 75-99% stenosis in 6 arterial segments and occlusion (100% stenosis) in 56 arterial segments. Doppler overestimated the stenosis by 1 grade in 29 arterial segments and 2 grades in 1 arterial segment. Doppler underestimated the stenosis by 1 grade in 33 arterial segments. The overall sensitivity and specificity of CDUS compared to CTA in femoro popliteal segments was found to be 92.25% and 87.75% respectively. Overall PPV and NPV was 91% and 89.5% respectively.

In present study we found more number of the cases of PADs positive for stenosis with CDUS than CTA. That is because of the ability of CDUS to detect more number of the segments with < 50% stenosis in early PAOD.

Prem Kumar Chidambaram et al. 2016[7]conducted a similar study of segmental comparison of peripheral arteries by CDUS and CTA and found the following observations segment wise.

Table 9: Under and over estimation of stenosis grade on comparing Doppler and CT angiography Prem Kumar Chidambaram et al. 2016[7]study:

S.NO.	ON DOPPLER	UNDERESTIMATON						OVERESTIMATION				
		-5	**-4**	**-3**	**-2**	**-1**	**0**	**+1**	**+2**	**+3**	**+4**	**+5**
1	**CFA**	0	1	0	1	5	60	2	0	1	2	0
2	**SFA**	0	1	0	0	4	66	2	0	0	1	0
3	**PA**	0	1	1	4	2	53	4	3	3	0	0

This study is in agreement with our study where CDUS in majority of cases is in agreement with CTA. In our study Doppler has under or overestimated the stenosis by predominantly 1 grade whereas they found Doppler under or overestimating the cases by 4 grades also. This difference can be due to quality of machines and experience of radiologist performing the scan. Another similar study was done by **Amlendu nagar and his coworkers in 2016**[8]**,**results of which are in agreement with our study where Doppler in majority of cases is in agreement with CTA.

Prem Kumar Chidambaram et al 2016[7] studied 619 arterial segments with CT angiography and CDUS out of which 226 diseased segments were identified in CT angiography. The sensitivity, specificity and accuracy of Doppler USG compared with CT angiography was 93.36%, 82.44%, and 86.42%. This is in concordance with our study.

Amlendu Nagar et al. [8] analysed 75 patients (1071 arterial segments) having symptoms related to lower or upper limb peripheral arterial occlusive disease by Doppler USG and CT angiography. The data was analysed in 13 arterial segments. (5 in upper limb and 8 in lower limbs). The sensitivity, specificity, and accuracy of MDCT angiography was 92.9%, 82.2%, and 85.6%, respectively. This is in agreement with our study.

TABLE 10: COMPARISON WITH PREVIOUS STUDIES:

	Done by	**Sensitivity %**	**Specificity %**	**Accuracy %**	**Agreement**	**Study**
CTA v/s DSA	Carlo catalano et al [9]	96	93	94	NA	n=50 4 MDCT

	Jurgen K et al [10]	96	97	NA	-	n=39 16 MDCT
Doppler v/s DSA	Sensier et al [11]	98	81	-	K=0.81	PSV considered
	Koelemay et al [12]	86(74-91)	97 (94-99)	NA	-	Meta-analysis
Doppler v/s CTA	Amlendu Nagar et al 2016[8]	92.9	82.2	85.6	73.4 %	n=75 PSV&CFI considered 128 MDCT
	Prem Kumar Chidambaram et al 2016[7]	93	82	86	75%	n=50, 64 MDCT
	OUR STUDY	**92.25**	**87.75**	-	-	**N=50,128 MDCT**

The above comparison table shows that our study is in agreement studies mentioned above with high correlation between CDUS and CTA in evaluating stenosis in PADs in lower limb arteries.

B. Collaterals - In our study we found that overall sensitivity and specificity for detecting collaterals was 90% and 88% respectively. PPV and NPV was 46% and 99% respectively. Hence, statistically CDUS is comparable to CTA in detection of collaterals. However origin and their morphological features of full length of collaterals could not be properly evaluated nor was it reproducible on CDUS. CTA accurately overcame both these limitation. Hence MDCT is needed before vascular intervention.

Rahul J. Shirol et al. 2015 [13] studied the collaterals status in PADs evaluation between CDUS and CTA and found it to be 58.1 %(moderately significant) with P value <0.05. However in our study we found very high sensitivity (90%) and specificity (88%) of CDUS in detecting collaterals compared to CTA except in deep femoral (DFA) arterial segment where USG sensitivity is not good due to its deep location. This discordance may be due to quality of machines and experience of radiologist. Studies done by **Larch Eet al. 1997[14], A Joshi et al 2014 and Prem kumar et al in 2016**[7]showed that CTA is much better for depiction of arterial reformations and extent of collaterals but poor for direction of flow. These all studies are in concordance with our study.

C. **Length of involved segment-Doppler** USG is excellent modality in evaluating the extent of disease with overall sensitivity and specificity of 94% and 98.5% respectively. PPV and NPV were 99% and 92.5%.

D. **Thrombus –** In our study overall sensitivity and specificity of Doppler USG compared to CTA was found to be 57.25% and 96%. PPV and NPV were found to be 72.5% and 91.25.

E. Plaque detection - Overall Sensitivity and specificity of Doppler USG was found to be 89% and 96% compared to CTA. PPV and NPV were found out to be 89% and 93% respectively.

Detection and characterisation of atherosclerotic plaques and the presence or absence of calcification within it is significant. Some are more prone to calcify, while soft plaques have propensity to rupture and throw life-threatening emboli. The presence of heavy calcification is a disadvantage for CTA, as the vessels are then not adequately evaluated due to volume averaging artefacts, especially in smaller caliber vessels, beyond the level of the inguinal ligament. However with the development of newer software logarithms, this drawback would be very soon overcome.

F. Wall calcification: Overall Sensitivity and specificity of Doppler USG compared to CTA was found to be 92% and 93.75%. PPV and NPV were found to be 87.75% and 92.5% respectively. Rahul J. Shirol et al in 2015[13] found the agreement between two modalities in assessing wall calcification to be 82.3% (P value <0.05). In our study also we found high correlation between CDUS and CTA with P value <0.05.This is in concordance with our study.

V. CONCLUSION

In the current study segmental comparison of lower limb arteries (i.e., Common femoral artery, Superficial Femoral Artery, Deep Femoral Artery, Popliteal Artery) on the basis of CDUS and CTA was done.

- Overall sensitivity, specificity, PPV and NPV of CDUS compared to CTA in femoro popliteal segments for percentage stenosis was found to be 92.25%, 87.75%, 91% and 89.5% respectively.
- Overall sensitivity, specificity, PPV and NPV for detecting collaterals was 90%, 88%, 46% and 99% respectively.
- Doppler USG is excellent modality in evaluating the extent of disease with overall sensitivity, specificity, PPV and NPV of 94% and 98.5%, 99% and 92.5% respectively.
- Overall sensitivity, specificity, PPV and NPV of Doppler USG compared to CTA for detecting thrombus was found to be 57.25%, 96%, 72.5% and 91.25 respectively.
- Overall Sensitivity, specificity, PPV and NPV of Doppler USG for plaque detection was found to be 89%, 96%, 89% and 93% respectively.
- Overall Sensitivity, specificity, PPV and NPV of Doppler USG compared to CTA for wall calcification was found to be 92%, 93.75%, 87.75% and 92.5% respectively.

In our study we found CDUS to have good correlation with CTA in evaluation of PADs in lower limb vessels. Thus CDUS favors to be the 1st line investigation for evaluation of PADs followed by CT before planning any interventional treatment.

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