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Lower Limb Arteries Assessed With Doppler Angiography–A Prospective Comparative Study With Multidetector Angiography

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Abstract

Background: Lower limb arterial disease is an important cause of morbidity in middle-aged and the elderly. It is commonly caused by atheromatous narrowing or occlusion of an artery or arteries of the leg. It may be symptomatic causing intermittent claudication, ischemic rest pain, ulceration, and gangrene. Management strategies differ for patients with lower limb arterial Disease. Patients with intermittent claudication are often managed conservatively, While patients with limb-threatening ischemia are treated with angioplasty, surgical revascularization, or amputation. the choice of intervention is governed by the severity of the disease and may involve combined treatments.

Aim Of The Study: This prospective study aims to determine the accuracy of Duplex Ultrasonography compared with MDCT angiography in identifying and estimating the degree of obstructive arterial lesions in lower limbs**.**

Methods: The study group includes 34 patients with unilateral or bilateral lower limb ischemic disease, from September 2022 To August 2023 At Padmashree Diagnostics Centre, Vijayanagar, Bangalore, Karnataka, India. Duplex ultrasound was done with a GE Voluson Ultrasound machine, bandwidth frequency transducer with a range of 5-13MHz for lower limb artery and 3.5MHz probe for infrarenal aorta and iliac vessels. Patients were kept fasting for at least 6 hours to improve visualization of the aorto-iliac region. Color flow-assisted B-mode was used to rapidly map the vessels of interest and locate lesions. Pulse Doppler was used to analyze spectral waveform and to measure peak systolic velocity.CT angiography was done with GE Aspire 16 slice Multidetector CT. Patients were placed in a supine position with feet entering the gantry first. Scanogram and plain study are taken. Spiral acquisitions were performed in a single scanning pass from the level of the diaphragm down to the ankles. The average length of scanning for a patient is about 1500mm. Patients were asked to hold their breath during the first part of the scanning pass. After saline check, 100mL volume of iodinated contrast material (320 mg of iodine per milliliter), was administered through a 20-gauge cannula in an antecubital vein at a rate of 4.5mL/sec. through pressure injector followed by the saline chase.

Results: Though 68 limbs, and 835 individual arterial segments were evaluated using each modality but only 807 segments for available for comparison.25 patients had atherosclerosis, 7 had TAO, while 1 had acute thrombosis due to trauma and 1 had cystic adventitial disease of popliteal artery.2 had intermittent claudication (Fontaine’s stage II), 7 had rest pain(Fontaine’s stage III), trophic changes, ulcers and gangrene were seen in 25 persons(Fontaine’s stage IV).18 were chronic smokers, 16 had diabetes and 25 had hypertension.

Conclusion: It may also determine the significance of equivocal lesions identified by MDCT angiography. A combination of Duplex Ultrasound with MDCT angiography has better diagnostic accuracy. Thus, Duplex

Ultrasound is a safe, inexpensive, non-invasive, easily available diagnostic tool with high diagnostic accuracy and is indispensable in the investigation of peripheral arterial disease.

Keywords: Non-invasive imaging, Peripheral arterial disease, Stenosis grading

Introduction

Lower limb arterial disease is an important cause of morbidity in the middle-aged and the elderly. It is commonly caused by the atheromatous narrowing or occlusion of an artery or arteries of the leg. It may be symptomatic causing intermittent claudication, ischaemic rest pain, ulceration, and gangrene[1]. Management strategies differ for patients with lower limb arterial disease. Patients with intermittent claudication are often managed conservatively, while patients with limb-threatening ischemia are treated with angioplasty, surgical revascularization, or amputation[2]. The choice of intervention is governed by the severity of the disease and may involve combined treatments. Thus patients with limb-threatening ischemia require a detailed assessment for a suitable treatment plan to be developed. Intra-arterial contrast angiography is regarded as the reference standard for investigating lower limb arterial disease. Its drawbacks are those associated with an arterial puncture, ionizing radiation, and potential nephrotoxicity of iodinated contrast agents. Several alternative imaging techniques are available, including Magnetic Resonance Angiography, Computed Tomography Angiography, and Duplex Ultrasonography. While Computed Tomography Angiography carries risks relating to ionizing radiation and both contrast-enhanced Magnetic Resonance Angiography and Computed Tomography Angiography carry risks associated with the use of contrast agents,[3]DuplexUltrasonography is unassociated with any risk. Recent advances in Duplex Ultrasound like better post-processing capability, transducer technology, image resolution, signal strength, and spectral analysis capabilities have improved its ability to visualize and grade abnormalities, thus extending the scope for non-invasive assessment of peripheral arterial disease. Several studies validate contrast material-enhanced MultiDetector CT Angiography as a noninvasive alternative to conventional Digital Subtraction Angiography for imaging the vascular tree. [4]

Unfortunately there is a paucity of high-quality trials to determine the accuracy of Magnetic Resonance Angiography (MRA), Duplex ultrasound, and Computed Tomography Angiography (CTA) in the investigation of peripheral arterial disease.[5]

Methods

The study group includes 34 patients with unilateral or bilateral lower limb ischemic disease, from September 2022 To August 2023 At Padmashree Diagnostics Centre, Vijayanagar, Bangalore, Karnataka, India.

Inclusion Criteria

1. Age group–any age group
2. Unilateral or Bilateral lower limb arterial disease
3. Acute or Chronic lower limb arterial disease

Exclusion Criteria

1. Patients with extensive ulcerations and gangrene
2. Immediateunstablepostoperativepatientswithsteriledressingsinlower limb
3. Patientswithcontrastreaction
4. Patientswhoextremepaininthelowerlimbduetoischemia
5. PatientswithrenalfailureandcontrasthypersensitivitydidnotundergoCTangiography

Data Acquisition Duplexultrasonography

Duplex ultrasound was done with GE Voluson Ultrasound machine bandwidth frequency transducer with a range of 5-13MHz forlowerlimbarteryand3.5MHzprobeforinfrarenalaortaandiliacvessels.Patientswerekeptfastingforatleast6hours,toimprovevisualizationoftheaorto-iliac region

Color flow-assisted B-mode was used to rapidly map the vessel of interest and locate lesions

Pulse Doppler was used to analyze spectral waveform and to measure peak systolic velocity.

Gray scale sonography to identify plaque morphological features and calcification.

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Following scanner control adjustments were followed

The color box was not too large as the image frame rate may become too low.

The color pulse repetition frequency was optimized so that the peak systolic velocity was in the upper region of the color scale. Stenoses will be rapidly identified as areas of aliasing.

The color wall filter was set correctly.

The angle of insonation was kept close to 60 degrees to the vessel axis.

Duplexultrasound criteria for assessment of peripheral arterial disease

Patency of the vessel was determined by normal triphasic waveform pattern and color saturation,demonstratedthroughoutthelumenofthearter y

Occlusion was diagnosed when no color saturation and no Doppler waveformwasseenintheartery

Nonocclusive lesions - Arterial lesions were located by a change in the color flow pattern, change in vessel diameter, and broadening of the Doppler spectrum. Grading of the arterial segment with color Doppler was based on the ratio and spectral pattern analysis. A hemodynamically significant stenosis(>50%)wasinferredwhenthewaveformchange dfromtriphasictomonophasic, with the appearance of spectral broadening and PSV ratio >2. The peaksystolic velocity ratio is measured concerning a point with normal flowpatterninthelumenatleast4cmproximally.Althoug hanumberofparametersintheDopplerwaveformareaffe ctedbystenoses,thepeaksystolicvelocityratioisthemost widelyadoptedmeasurement.Apeaksystolicvelocityrat ioofgreaterthantwoindicatesastenosisofgreaterthan50 %.

To eliminate interobserver variation, all Doppler studies were done bythesameradiologist.

Ct Angiography

CT angiography was done with GE Aspire 16 slice Multidetector CT Patients were placed in a supine position with feet entering the gantry firstScanogram and plain study are taken. Spiral acquisitions were performed in a single scanning pass from the level of thehediaphragmowntotheankles. Theaveragelengthof scanning for a patient is about 1500mm. Patients were asked to hold their breath during the first part of the scanning pass. After the saline check, a 100mL volume ofiodinatedcontrastmaterial(320mgofiodinepermillilit er), was administered through a 20-gauge cannula in an antecubital vein at a rate of 4.5mL/sec. through pressure injector followed by salinechase. Scanning was begun when the contrast opacification of the descending thoracic aorta reached 100 HU – determined by the Automated bolus tracking technique. Imageswerereconstructedwithaneffectivesectionthick nessof2mmandanincrementof1mm by using the smooth algorithm. All transverse source images were transferred to workstations for the preparation reconstruction. Sliding maximum intensity projections were obtained with coronal and sagittal projections of each dataset. Whole-volume maximum intensity projections with the segmentation of bone andvesselwallcalcificationsandVolumerenderedimage swereobtained Allmulti–detectorrowCTangiographyexaminationswereperform edbydedicatedCTtechnologists.Postprocessingreconst ructionswereperformedbydedicatedCTtechnologistsi magesinterpretedbyexperiencedradiologists.The images were analyzed based on transverse images, MIP & VR images–for stenosis, occlusion, calcification,plaquemorphologyandcollaterals. Thus, for a patient with unilateral limb involvement,13segmentswereexaminedandincaseofbi laterallimbdisease, and 25 segments were examined.

Results

Thestudyinvolved34patients(32men,2women).Of these patients,

28wereabove40and60yearsofage.3patientshadbelowk neeamputation.Though68limbs,835individualarterials egmentswereevaluatedusingeachmodalitybutonly807 segmentsforavailableforcomparison.25 patients had atherosclerosis,7hadTAO,while1hadacutethrombosis due to trauma and 1 had cystic adventitial disease of poplitealartery. 2hadintermittentclaudication(Fontaine’sstageII),7had restpain(Fontaine’sstageIII),trophicchanges,ulcersand gangrenewereseenin25 persons(Fontaine’sstage IV).

18werechronicsmokers,16haddiabetesand25hadhyper tension

Statistical Analysis

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Results were tabulated and analyzed by two contingency tables and Kappa statistics. Sensitivity, Specificity, Positive Predictive ValueandNegativePredicitiveValuewere obtained.

TABLE :1 AORTOILIACREGION INFRARENALAORTA

	CTpositive	**CTnegative**	**Total**
Dopplerpositive	1	0	1
Dopplernegative	0	26	26
	1	26	27

COMMON ILIAC ARTERY

	CTpositive	**CTnegative**	**Total**
Dopplerpositive	7	0	7
Dopplernegative	1	48	49
	8	48	56

EXTERNALILIACARTERY

	CTpositive	**CTnegative**	**Total**
Dopplerpositive	7	0	7
Dopplernegative	1	54	55
	8	54	62

TABLE:2 FEMOROPOPLITEAL REGIONCOMMONFEMORALARTERY

	CTpositive	**CTnegative**	**Total**
Dopplerpositive	9	0	9
Dopplernegative	0	59	59
	9	59	68

PROXIMALPART OFPROFUNDAFEMORIS

	CTpositive	**CTnegative**	**Total**
Dopplerpositive	9	6	15
Dopplernegative	0	53	53
	9	59	68

PROXIMALSUPERFICIALFEMORALARTERY

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	CTpositive	CTnegative	Total
Dopplerpositive	26	0	26
Dopplernegative	0	42	42
	26	42	68

MIDDLESUPERFICIALFEMORALARTERY

	CTpositive	CTnegative	Total
Dopplerpositive	29	0	29
Dopplernegative	0	39	39
	29	39	68

DISTALSUPERFICIALFEMORALARTERY

	CTpositive	CTnegative	Total
Dopplerpositive	35	2	37
Dopplernegative	0	25	25
	35	27	62

POPLITEAL ARTERY

	CTpositive	CTnegative	Total
Dopplerpositive	43	2	45
Dopplernegative	0	23	23
	43	25	68

TABLE :3 INFRAPOPLITEAL REGIONANTERIORTIBIALARTERY

	CTpositive	CTnegative	Total
Dopplerpositive	9	7	16
Dopplernegative	3	46	49
	12	50	65

POSTERIOR TIBIAL ARTERY

	CTpositive	CTnegative	Total

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Dopplerpositive	14	6	20
Dopplernegative	4	41	45
	18	47	65

PERONEAL ARTERY

	CTpositive	CTnegative	Total
Dopplerpositive	15	13	28
Dopplernegative	5	32	37
	20	45	65

DORSALISPEDIS

	CTpositive	CTnegative	Total
Dopplerpositive	20	5	25
Dopplernegative	7	33	40
	27	38	65

TABLE :4 AORTOILIACREGION	
Totalnumberofsegments :	170
Noofsegmentsobscuredbybowelgas :	25
noofsegmentsavailableforcomparison:	145

	CTpositive	CTnegative	
Dopplerpositive	14	0	14
Dopplernegative	2	129	131
	16	129	145

FEMOROPOPLITEALREGION

Totalnumberofsegments=402

	CTpositive	CTnegative	Total
Dopplerpositive	151	10	161
Dopplernegative	0	241	241

	151	251	402

INFRAPOPLITEALREGION

Totalnumberofsegments=260

	CTpositive	**CTnegative**	**Total**
Dopplerpositive	58	31	174
Dopplernegative	19	152	86
	186	74	260

TABLE :5 LIMBARTERIALSYSTEM

TOTALNUMBEROFSEGMENTSANALYSED:807

	CTpositive	**CTnegative**	
Dopplerpositive	223	41	264
Dopplernegative	21	522	543
	244	563	807

Table6showingsensitivity, specificity, PPV, and NPVof Duplexultrasoundinthe evaluationoflowerlimbarterialsystem

	SENSITIVITY%	**SPECIFICITY%**	**PPV%**	**NPV%**
Aortoiliacregion	87.5	100	100	98.46
Femoropoplitealregion	100	96.01	93.79	100
Infrapoplitealregion	75.32	83.06	65.16	88.88
OVERALLSEGMENTS	91.39	92.71	84.47	96.13

Table7showingagreementbetweenthetwomodalities–analysedwithKAPPASTATISTICS

SEGMENTANALYSED	**AGREEMENTOFDUPLEXWITHCTANGIOGRAPHY**
Infrarenalaorta	Perfect(1.000)

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Common iliac artery	Very good(0.923)
Externaliliacartery	Very good(0.924)
Commonfemoralartery	Perfect(1.000)
Superficialfemoralartery-prox	Perfect(1.000)
Superficialfemoralartery-mid	Perfect(1.000)
Superficialfemoralartery-distal	Very good(0.934)
Proximalprofundafemoris	Good(0.700)
Popliteal artery	Very good(0.936)
Anterior tibial artery	Moderate(0.547)
Posterior tibial artery	Good(0.629)
Peronealartery	Moderate(0.415)
Dorsalispedis	Good(0.616)

Discussion

The study involved 34 patients out of whom 3 patients had below knee amputation.Out of 34 patients, the infrarenal aorta was obscured by bowel gas in 7 patients.Out of those 27 segments assessed,1patienthadsignificantstenosis and the rest had normal or hemodynamically insignificant stenosis.CT angiography confirmed the findings. The sensitivity, specificity, positivepredictivevalueandnegativepredictivevalueof Dopplerwas100%inevaluating the infra renal aorta. The strength of agreement was perfect betweenDopplerandCTangiographywhenanalysedwithkappastatistics.Incommoniliacarterialsegment, out of 68 segments, 12segments were not evaluated due to bowel gas. Of the evaluated 56 segments, Doppler was able to pick up 7 of the 8 hemodynamically significant stenosis. It missed significant stenosis in 1 patient who had a calcific plaque. False negativity in this patient could be due to overestimation of stenosis by CT angiography in arteries with calcific plaques. Because of this, the sensitivity of Doppler was reduced to 87.5%. However, the strength of agreement was considered to be very good between Doppler and CT angiography when analyzed with kappa statistics.In the external iliac arterial segment, out of 68 segments, 6 segments were obscured by bowel gas.In intheremaining62 segments, Doppler failed to detect hemodynamically significant stenosis in the same patient as that common iliac artery, probably due to overestimation of the stenosis caused bycalcificplaquebyCTangiography.Thesensitivityfellto87.5%andthespecificity was 100%.[7]The strength of the agreement was considered to be verygoodbetweenDopplerandCTangiographywhenanalysedwithkappastatistics.In the common femoral artery, Doppler was able to detect all the 9hemodynamically significant stenosis with the resulting sensitivity and specificity of 100%.[8]The strength of agreement was perfect between DopplerandCTangiographywhenanalysedwithkappastatistics.In the proximal and middle superficial femoral artery, Doppler was able to detect all the 26 and 29 hemodynamically significant stenosis respectively, with the resulting sensitivity and specificity of 100%.In the distal superficial femoral artery, out of 68 segments, only 62 segments were available for comparison since in 6 patients distal SFA was not visualized – which is a blind spot for sonographers. In the evaluated patients,[9]Doppler did not miss any hemodynamically significant stenosis – instead overestimated 2 segments with hemodynamically insignificant stenosis resulting in false positivity.These Thesepatientshadlongsegmentdiseaseintheproximalandmidpart of SFAwhichresultedinmonophasic flowinthedistalSFAwhichwasmistakenforhemodynamicallysignificantstenosisinthedistalpart. the distal part and its branches were not accessible. Out of 68 segments evaluated, Doppler detected all hemodynamically significant stenosis. It also increased 6 segments with hemodynamically insignificant stenosis, resulting in false positivity.[10] These segments showed elevated peak systolic velocity due to compensatory increased flow through them to the distal leg when there is occlusion of SFA. As a result, the specificity of Doppler in evaluating proximalprofundafemoris was only 89.83%, while the sensitivity was 100%.In the Inthepoplitealartery, Significant flow in the distal SFA was mistaken for hemodynamically significant stenosis In. The sensitivity and specificity of Doppler in evaluating popliteal artery were 100% and 92% respectively.The popliteal vessels were evaluated only for the presence orabsenceofflowwithDopplerwhichwascomparedtothepresenceofopacificationornonopacificationofthosevesselswithcontrastinCTangiography.[11]Doppler was not able to find flow in 7 anterior tibial arterial segments, 6posterior tibial arterial segments, 13 peroneal arterial segments and 5 dorsalispedis which opacified with contrast in CT angiography. These patients hadocclusionoffemoropoplitealregionwithreformation oftheinfrapoplitealvessels at their mid or distal part and it was difficult to find the reformation of these vessels as there were many collateral vessels seen in the leg. Although major arteries are accompanied by venue commitants and not the collaterals it was stilldifficulttotraceoutthemajorvessels.Interestingly, Doppler was able to pick up the flow in those infrapopliteal vessels that were not opacified with contrast.[12] In three patients with proximally significant stenosis,therewasnoopacificationintheinfrapoplitealvesselswith the contrast, but Doppler was able to pick up monophasic flow. Thiscouldbebecauseofdifferentratesofcruralvesselopacification,orinadequateopacificationdistaltoanocclusioninCTangiography. Implies that when Doppler is used in conjunction with CT angiography, thefalsepositiveocclusionsof CTangiographycouldbeminimized. This [13]Thus, the sensitivity of Dopplerinevaluatingaortoiliacsegments, femoropopliteal segments, and infrapopliteal segments were 87.5%, 100% and75.32%respectivelyandspecificityinevaluatingaortoiliacsegments, femoropopliteal segments and infrapopliteal segments were 100%, 96.01%and 83.06% respectively if CT angiography was taken as gold standard. The agreement between the two modalities in the evaluation of the aortoiliac region and femoropopliteal region was very good, and ofinfrapoplitealvesselsisonlymoderate[14].Doppler can demonstrate flow in those infrapopliteal vessels where CT shows no opacification with contrast due to proximalsignificantstenosis.It is also able to demonstrate the nature of plaque – whether calcific or soft plaque.Softplaqueswerebetterdemonstratedwithultrasoundthanwith CT.It can show the duration of occlusion– as acute thrombus distends the vessels while chronic occlusion narrows the vessel caliber. 1 patient had traumatic injury of right SFA and Doppler showed complete occlusion of the proximal and midSFAwiththrombuswithdistalmonophasicflow.[15] Although the occlusion was demonstrated in CT angiography the distension of the vessel with thrombus was notdemonstrableinCTbecauseofitslackofsoft tissueresolution.There is no hazard of radiation with Doppler, while the mean effective dose ofradiationdeliveredtoapatientinasinglestudywithCTangiographyis12-14Ms. Since no iodinated contrast is required, it is safely performed in patients with with renal failure (these patients were excluded from the study in whom Doppler alone wasdonetoevaluatethelowerlimbarteries)Doppler could be performed in cases of emergencies like traumatic/iatrogenic injuries to rule out arterial obstruction at any time, while CT angiography is not easilyavailableatallthetimeand isavailableonlyatapexinstitutions.DopplerisalsocosteffectivewhencomparedtoCTangiography.[16,17,18].

Conclusion

DuplexUltrasoundprovideshigh-resolution, precise anatomical and physiological information of the peripheral arteries. It is unlikely to misclassify a whole limb as “normal” and thus inappropriately screen out a patient from further investigation. Duplex Ultrasound was found to have a high negative predictive value and could exclude a significant lesion, thus helping to avoid other costly diagnostic modalities in a mildly symptomatic patient. It could determine the thenatureandextentofarterialdiseasebasedonwhichtreatmentcanbeplanned,eitherendovascularorsurgical.Itm

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ayalsodeterminethesignificanceofequivocallesionsidentifiedbyMDCTangiography. Combination of Duplex Ultrasound with MDCT angiography has better diagnostic accuracy. Thus, Duplex Ultrasound is a safe, inexpensive, non-invasive, easily available diagnostic tool with high diagnostic accuracy and is indispensable in the investigation of peripheral arterialdisease.

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