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Original Research Article

The role of color Doppler and multidetector CT angiography in evaluation of peripheral arterial diseases of lower limb

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ABSTRACT

Background: Characterized by atheromatous narrowing and hardening of arteries supplying blood to the legs and feet. Diabetes, along with other risk factors such as hypertension and smoking, exacerbates the prevalence and severity of PAD, leading to decreased blood flow and subsequent tissue injury. The prevalence of PAD in diabetics rises with age, underscoring the importance of early detection and management strategies.
Methods: This study aims to evaluate the efficacy of color Doppler and MDCT Angiography in assessing lower limb peripheral arterial diseases. Conducted over twenty-four months, the cross-sectional study involved clinically suspected symptomatic cases aged 30 years and above, presenting at a tertiary care center. Patients underwent thorough clinical examination and demographic assessment before undergoing Color Doppler flowmetric studies and MDCT angiography.
Results: Results revealed that color Doppler, with its ability to measure wall thickness and vascular flow, demonstrated promising diagnostic efficacy compared to MDCT angiography. Additionally, follow-up records of patients undergoing medical or surgical interventions provided valuable insights into the practical utility of these imaging modalities in guiding clinical management decisions.
Conclusions: Overall, this study underscores the importance of non-invasive imaging techniques in diagnosing and evaluating the progression of peripheral arterial diseases. It suggests that Color Doppler Ultrasound, with its accessibility, low cost, and radiation-free nature, could serve as a suitable alternative to MDCT Angiography for assessing arterial characteristics in patients with PAD.

Keywords: Color Doppler ultrasound, Diagnostic efficacy, Lower limb arterial diseases, MDCT angiography, Non-invasive imaging modalities, Peripheral artery disease

INTRODUCTION

Peripheral artery disease manifests as age-related arterial narrowing in the legs and feet, posing a significant risk of cardiovascular and cerebrovascular events, particularly among older adults.[1] Symptoms vary, including intermittent claudication, rest pain, ulcers, and gangrene; however, diabetic patients often experience asymptomatic conditions due to neuropathy.[2] Management ranges from conservative approaches for intermittent claudication to angioplasty or surgical intervention for severe ischemia.[3] The prevalence of PAD among diabetics aged over 40 is approximately 20%, escalating to 29% in those over 50 years.[4-7] This condition reduces blood flow, potentially damaging nerves and tissues, with diabetes being the primary risk factor alongside hypertension, heart disease, and smoking.[8] PAD significantly elevates the risk of heart attack, stroke, mortality, and long-term disability, often affecting more distal calf vessels in this demographic.[9-13]

To mitigate cardiac mortality, aggressive modification of risk factors is imperative, encompassing smoking cessation, blood pressure control, LDL reduction, weight management, diabetes regulation, and antiplatelet therapy like aspirin or aspirin clopidogrel.[14]

Management strategies diverge for lower limb arterial disease, marked by progressive plaque formation within vessel walls.[15,16] Methods detecting this plaque are valuable for evaluating disease progression and prognosis. Early phases entail medial cell hypertrophy, assessable through wall thickness evaluation, while later stages manifest as carotid plaques due to inflammation, oxidation, and smooth muscle proliferation.[17,18] Lower extremity wall assessments, including thickness, diameter, and stiffness, correlate significantly with ankle-brachial index and symptomatic presentation, offering insights into atherosclerosis.[19,20]

Various diagnostic modalities for peripheral arterial disease (PAD) exist, each with distinct strengths and limitations. The ankle-brachial index serves as a simple office-based screening tool, while segmental limb pressure exams and pulse volume recordings pinpoint disease location. Imaging techniques like duplex ultrasonography, magnetic resonance angiography, and computed tomographic angiography provide anatomical detail for interventional planning.[21] CT angiography, increasingly favored for its non-invasive nature and high accuracy, now rivals conventional angiography as the gold standard.[22,23]

Among non-invasive imaging methods, Color Doppler ultrasound and CT are prevalent. Color Doppler Ultrasound offers advantages in accessibility, cost-effectiveness, radiation protection, and avoidance of contrast administration.[24] It excels in evaluating upper and lower extremity arteries due to their shallower depth, ensuring more consistent imaging compared to deeper vessels.[25] Assessing vascular function and artery wall thickness in the lower extremities demonstrates high diagnostic efficacy for PAD.[26]

The objective of this study was to evaluate and compare the efficacy of Color Doppler ultrasound and MDCT Angiography in assessing lower limb peripheral arterial diseases, specifically focusing on their diagnostic accuracy, ability to measure arterial characteristics, and practical utility in guiding clinical management decisions.

METHODS

The present study was a cross-sectional study carried out over the duration of twenty-four months from 24th March 2020 to 23rd March 2022 in the Department of Radiodiagnosis in collaboration with the Department of Surgery, Era's Medical College and Hospital, Lucknow. Clinically suspected symptomatic cases of age 30 years or above, with peripheral artery disease, presenting to the surgical OPD and IPD of Era‘s Lucknow Medical College & Hospital, Lucknow were included in the study, while the patients with deranged kidney function tests were excluded. Necessary ethical clearance for carrying out the study was obtained from the Institutional Ethical Committee, Era's Lucknow Medical College & Hospital, Lucknow.

Sample size was calculated on the basis of minimum agreement of CT with by using the formula:

$$n = d\left[\left(\frac{z_\alpha + z_\beta}{C(r)}\right)^2 + 3\right]$$

where,

$$C(r) = \frac{1}{2}\log_e \frac{1+r}{1-r}$$

r = 0.581, the minimum agreement of CT with Color Doppler.

d = 1.5, the design effect for considering several parameters (according to the reference paper by Shirol et al).

type I error α = 5% corresponding to 95% confidence level.

type II error β = 10% for detecting results with 90% power of study. Then the calculated sample size was 49, and by adding 10% loss to follow-up, the required minimum sample size was 54.

The study encompassed comprehensive clinical and imaging evaluations for patients meeting eligibility criteria. Initial assessments included demographic data, medical history, and oxygen saturation measurements using a pulse oximeter. Color Doppler flowmetric studies were conducted using a LOGIC P-9 system with a 7-12MHz transducer.

The Doppler procedure involved locating and examining various arterial segments, from the common femoral artery to the popliteal artery, and further to the anterior tibial, posterior tibial, peroneal, and dorsalis pedis arteries in both lower limbs. Doppler parameters such as vessel diameter, wall thickness, and flow spectrum were recorded, with abnormal findings noted. MDCT angiography was performed using a Siemens SOMATOM-force system after contrast material administration. Scanning parameters were standardized, and images were analyzed for atheromatous changes and luminal narrowing. Bilateral evaluations were conducted for abnormalities in multiple arterial segments. The study compared the efficacy of Color Doppler against MDCT, with follow-up records of diagnosed patients obtained and compared with imaging results from both modalities. Data analysis was carried out using IBM SPSS 21.0 software, presenting results as numbers/percentages or mean±SD. Statistical tests such as chi-square and ANOVA were utilized for comparison. Diagnostic efficacy of Color Doppler was assessed against MDCT using sensitivity, specificity, positive predictive value, negative predictive value, and accuracy calculations.

RESULTS

The present study was carried out to evaluate the efficacy of Color Doppler and MDCT Angiography in assessment of peripheral artery disease of lower limb. Along with this major objective, a comparison of pulse oximetry as a possible measure for early and accurate assessment of the disease. For this purpose, a total of 54 patients fulfilling the eligibility criteria were enrolled in the study.

Age of the patients ranged from 30 to 77 years. Almost half the patients (n=28; 51.9%) were aged between 30 and 49 years and remaining 26 (48.1%) were aged between 50 and 79 years. Mean age of patients was 48.33±13.67 years. Majority of patients were males (n=37; 68.5%). There were 17 (31.5%) females. Sex ratio (M:F) of the study population was 2.18 (Table 1).

Table 1: Age and sex profile of the patients (n=54).

Variable		Frequency	Percentage
Age in years	30-39	19	35.2
	40-49	9	16.7
	50-59	15	27.8
	60-69	6	11.1
	70-79	5	9.3
	Mean age±SD (range) in years	48.33±13.67 (30-77)	
Sex	Male	37	68.5
	Female	17	31.5

Table 2: Clinical profile of the patients (n=54).

Variable		Frequency	Percentage
BMI in kg/m^2	18.5-24.9	2	3.7
	25.0-29.9	46	85.2
	$\geq$30	6	11.1
	Mean±SD (range)	27.87±1.62 (24.3-31.2)	
Complaints	Pain in legs	48	88.9
	Cramps	12	22.2
	Ulcers	10	18.5
	Hair loss	6	11.1
	Cool skin	4	7.4
	Thinning skin	4	7.4
Medical history	Diabetes mellitus	36	66.7
	Hypertension	21	38.9
	Heart disease	17	31.5
	Respiratory disease	15	27.8
Oxygen saturation at presentation	Mean±SD (range)	97.31±0.89 (94-98)	

Body mass index of patients ranged from 24.3 to 31.2 kg/m^2. Only 2 (3.7%) patients were in BMI category 18.5-24.9 kg/m² and 6 (11.1%) had BMI $\geq$30 kg/m². Majority of cases had BMI in 25.0-29.9 kg/m^2 range. Mean BMI of patients was 27.87±1.62 kg/m².

Pain in legs (88.9%) was the leading presenting complaint. All the other complaints were seen in 7.4% to 22.2% of patients and included cramps (22.2%), ulcers (18.5%), hair loss (11.1%), thinning skin and cool skin (7.4% each).

The majority of patients had history of diabetes mellitus (66.7%) followed by hypertension (38.9%), heart disease (31.5%) and respiratory disease (27.8%). No any history of any significant medical illness was reported. Oxygen saturation ranged from 94 to 98% with a mean of 97.31±0.89%.

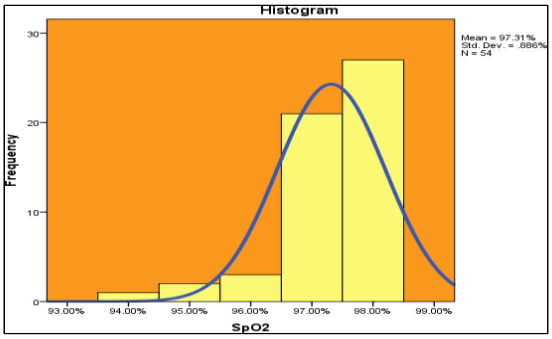


Figure 1: Pulse oximetry measured oxygen saturation profile of patients.

Doppler assessment revealed varying proportions of abnormal findings across different arterial locations, with PAD diagnosed in 66.7% of cases. The number of involved arteries ranged from 1 to 16, with a mean of 5.91±6.42. MDCT angiography identified abnormal findings in 77.8% of cases, with varying numbers of involved arteries. The mean number of involved arteries was 6.94±6.07.

Overall, both methods detected PAD, with MDCT angiography showing a slightly higher detection rate and a marginally higher mean number of involved arteries compared to Doppler assessment.

For CFA abnormalities, Color Doppler underdiagnosed 7 abnormalities and over diagnosed 3, with strong agreement rates and high sensitivity and specificity. SFA abnormalities showed similar trends, with Color Doppler demonstrating good agreement rates and high sensitivity and specificity. PFA, ATA, Peroneal artery, PTA, DPA, and Popliteal artery evaluations followed similar patterns of underdiagnoses and overdiagnoses, with varying degrees of agreement rates and diagnostic values. For overall evaluation (n=864 arteries), as compared to MDCT, Color Doppler had an over diagnosis in 25 cases and an under diagnosis in 77 cases. As compared to MDCT, Doppler assessment was 79.2% sensitive and 94.9% specific.

Table 3: Findings of Color Doppler and MDCT angiography.

Variables	Color Doppler examination (%)		MDCT angiography (%)	
Abnormal arteries detected (n=864)				
Number of abnormal arteries	318 (36.8)		370 (42.8)	
Number of normal arteries	546 (63.2)		494 (57.2)	
Prevalence and type of PAD (n=54)				
No PAD	18 (33.3)		12 (22.2)	
PAD	36 (66.7)		42 (77.8)	
Mono	01 (1.9)		03 (5.6)	
Poly	35 (64.8)		39 (72.2)	
Number of arteries involved (n=54)				
No	18 (33.3)		12 (22.2)	
One	01 (1.9)		3 (5.6)	
Two	01 (1.9)		0 (0.0)	
Three	05 (9.3)		3 (5.6)	
Four	09 (16.7)		04 (7.4)	
Five	0 (0.0)		04 (7.4)	
Six	04 (7.4)		05 (9.3)	
Seven	0 (0.0)		01 (1.9)	
Eight	01 (1.9)		7 (13.0)	
Nine	01 (1.9)		0 (0.0)	
Ten	0 (0.0)		01 (1.9)	
Sixteen	14 (25.9)		14 (25.9)	
Mean±SD	5.91±6.42		6.94±6.07	
Location (N=54)	**Left**	**Right**	**Left**	**Right**
Common femoral artery (CFA)	26 (48.1)	24 (44.4)	27 (50.0)	27 (50.0)
Superficial femoral artery (SFA)	26 (48.1)	24 (44.4)	26 (48.1)	26 (48.1)
Profunda femoris artery (PFA)	25 (46.3)	23 (42.6)	26 (48.1)	26 (48.1)
Anterior tibial artery (ATA)	15 (27.8)	18 (33.3)	24 (44.4)	21 (38.9)
Peroneal artery (PA)	14 (25.9)	17 (31.5)	22 (40.7)	18 (33.3)
Posterior tibial artery (PTA)	15 (27.8)	18 (33.3)	18 (33.3)	18 (33.3)
Dorsalis pedis artery (DPA)	16 (29.6)	16 (29.6)	23 (42.6)	21 (38.9)
Popliteal artery (Pop A)	21 (38.9)	20 (37.0)	23 (42.6)	24 (44.4)

The positive and negative predictive values were 92.1% and 94.9% respectively. There was an agreement on 88.2% findings between MDCT and Color Doppler. The measure of agreement was strong (κ=0.755; p<0.001).

Clinical follow-up and correlation with imaging outcomes

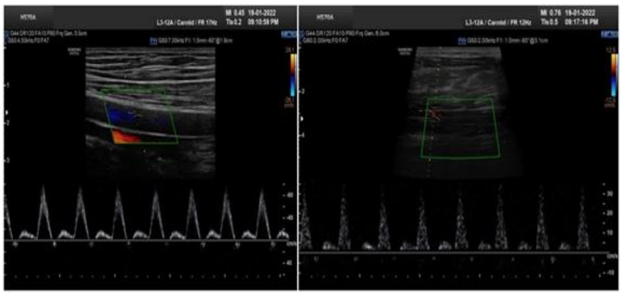
There were 54 patients in the present study, out of which 18 patients were prescribed medical treatment and other 14 underwent surgical intervention could be followed up. In the 14 patients undergoing surgical intervention, the findings of both the imaging modalities were confirmed in 12. In remaining 2 patients, Color Doppler was not upto the mark as it showed no obvious findings, however, both these patients had abnormal findings on MDCT angiography. Thus the surgical findings correlated with MDCT in 14/14 (100%) as compared to 12/14 (85.7%) of Color Doppler. Remaining 18 patients who underwent medical intervention showed improvement from their previous state. All these patients had abnormal findings on MDCT as well as Doppler.

Table 4: Agreement between Doppler and MDCT diagnosis for PAD abnormalities and sensitivity, specificity, PPV, NPV and % agreement of Doppler against MDCT.

Artery	Site	Doppler		MDCT		p-value
		Abnormal %	Normal %	Abnormal %	Normal %	% Agreement
CFA	Left	26	28	27	27	p<0.001
		Sens 92.6	Spec 96.3	PPV 96.2	NPV 92.9	Agreement 94.4
	Right	24	30	27	27	p<0.001
		Sens 81.5	Spec 92.6	PPV 91.7	NPV 83.3	Agreement 87.0
	Total	50	58	54	54	p<0.001
		Sens 87.0	Spec 94.4	PPV 94.0	NPV 87.9	Agreement 90.7
SFA	Left	26	28	26	28	p<0.001
		Sens 92.3	Spec 92.9	PPV 92.3	NPV 92.9	Agreement 92.6
	Right	24	30	26	28	p<0.001
		Sens 84.6	Spec 92.9	PPV 91.7	NPV 86.7	Agreement 88.9
	Total	50	58	52	56	p<0.001
		Sens 88.5	Spec 92.9	PPV 92.0	NPV 89.7	Agreement 90.7
PFA	Left	25	29	26	28	p<0.001
		Sens 88.5	Spec 92.9	PPV 92.0	NPV 89.7	Agreement 90.7
	Right	23	31	26	28	p<0.001
		Sens 80.8	Spec 92.9	PPV 91.3	NPV 83.9	Agreement 87.0
	Total	52	56	48	60	p<0.001
		Sens 84.6	Spec 92.9	PPV 91.7	NPV 86.7	Agreement 88.9
ATA	Left	15	39	24	30	p<0.001
		Sens 62.5	Spec 100.0	PPV 100.0	NPV 76.9	Agreement 83.3
	Right	21	33	18	36	p<0.001
		Sens 76.2	Spec 93.9	PPV 88.9	NPV 86.1	Agreement 87.0
	Total	45	63	33	75	p<0.001
		Sens 68.9	Spec 96.8	PPV 93.9	NPV 81.3	Agreement 85.2
PrA	Left	22	32	14	40	p<0.001
		Sens 63.6	Spec 100.0	PPV 100.0	NPV 80.0	Agreement 85.2
	Right	17	37	18	36	p<0.001
		Sens 88.9	Spec 97.2	PPV 94.1	NPV 94.6	Agreement 94.4
	Total	40	68	31	77	p<0.001
		Sens 75.0	Spec 98.5	PPV 96.8	NPV 87.0	Agreement 89.8
PTA	Left	15	39	18	36	p<0.001
		Sens 61.1	Spec 88.9	PPV 73.3	NPV 82.1	Agreement 79.6
	Right	18	36	18	36	p<0.001
		Sens 88.9	Spec 94.4	PPV 88.9	NPV 94.4	Agreement 92.6
	Total	33	75	36	72	p<0.001
		Sens 75.0	Spec 91.7	PPV 81.8	NPV 88.0	Agreement 86.1
DPA	Left	16	38	23	31	p<0.001
		Sens 69.6	Spec 100.0	PPV 100.0	NPV 81.6	Agreement 87.0
	Right	16	38	21	33	p<0.001
		Sens 71.4	Spec 97.0	PPV 93.8	NPV 84.2	Agreement 87.0
	Total	32	76	44	64	p<0.001
		Sens 70.5	Spec 98.4	PPV 96.9	NPV 82.9	Agreement 87.0
PA	Left	21	33	23	31	p<0.001
		Sens 82.6	Spec 93.5	PPV 90.5	NPV 87.9	Agreement 88.9
	Right	20	34	24	30	p<0.001

Continued.

Artery	Site	Doppler		MDCT		p-value
		Abnormal %	Normal %	Abnormal %	Normal %	% Agreement
		Sens 75.0	Spec 93.3	PPV 90.0	NPV 82.4	Agreement 85.2
	Total	41	67	47	61	p<0.001
		Sens 78.7	Spec 93.4	PPV 90.9	NPV 85.1	Agreement 87.0
Overall arteries (N=864)		318	545	370	494	p<0.001
		Sens 79.2	Spec 94.9	PPV 92.1	NPV 86.1	Agreement 88.2



Figures 1: Normal color flow with a triphasic waveform pattern in the femoral and posterior tibial artery.

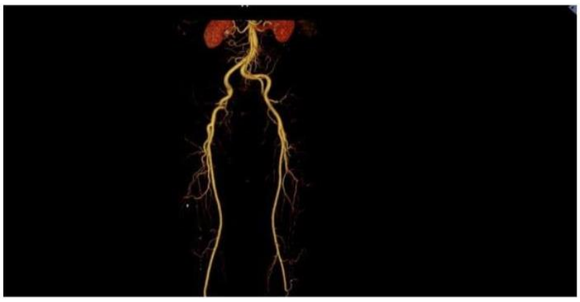


Figure 2: 3D volume rendering with bone removal MDCT image of lower limb vasculature showing normal femoral arteries.

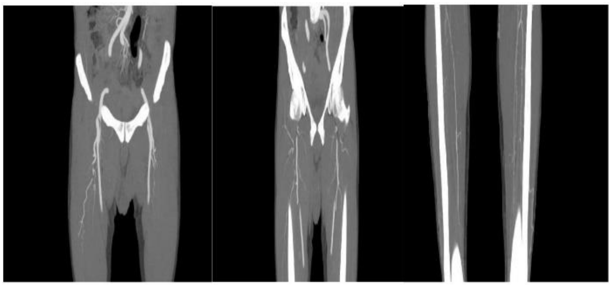


Figure 3: MIP images of a CT angiogram showing normal femoral and anterior tibial.

DISCUSSION

Peripheral arterial disease (PAD) develops gradually due to the accumulation of atherogenic material in blood vessels, leading to arterial narrowing and blockages. Detecting PAD early allows for effective treatment strategies to slow or reverse progression. Color Doppler ultrasound, alongside B-mode ultrasound, has long served as a non-invasive method for assessing vascular changes.[26,27] However, MDCT angiography has emerged as a valuable alternative in recent years, offering 3-D imaging and post-processing capabilities.[28]

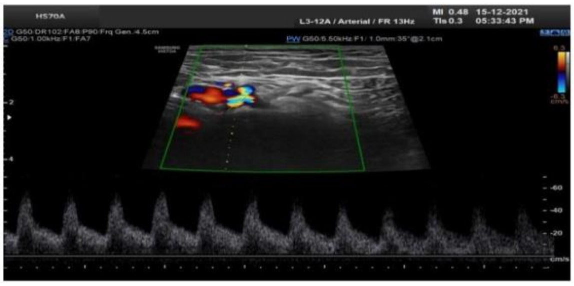


Figure 4: Monophasic flow with thrombus and collateral formation in the left femoral artery and monophasic flow with intimal thickening causing stenosis in the left popliteal artery.

Figure 5: 3D volume rendering with bone removal MDCT image of lower limb vasculature showing thrombotic occlusion of left common femoral artery, the proximal and mid one-third portion of left superficial femoral artery, and proximal portion of the left popliteal artery. Atherosclerotic changes were seen in the right femoral artery.

While MDCT angiography has become the gold standard for PAD evaluation, its accessibility is lower compared to Color Doppler. The accuracy of Color Doppler relative to MDCT remains debated, with various studies attempting comparisons. Given resource constraints in many settings, especially in economically limited areas focusing on affordable healthcare, evaluating cost-effective techniques like Color Doppler is crucial for clinical utility. Hence, our study aimed to compare Color

Doppler flowmetry and MDCT angiography for PAD evaluation.

We assessed 54 patients for lower limb arterial abnormalities, evaluating a total of 864 arteries using both techniques. Overall, Color Doppler showed sensitivity, specificity, PPV, and NPV values of 79.2%, 94.9%, 92.1%, and 86.1% respectively, with an 88.2% agreement with MDCT. Comparisons with previous studies showed varying results in sensitivity, specificity, and accuracy rates, with Doppler generally exhibiting accuracy within the 80-90% range. Studies referenced as Ali et al, Dev et al and Yadav and Khanduri.[29-31]

The present study included patients with clinical suspicion of PAD, primarily in early clinical stages. Unlike studies showing high Doppler sensitivity, our focus on early-stage patients might have influenced our results. In high-risk patients, such as diabetics, Doppler may exhibit higher sensitivity.

MDCT angiography, known for its high sensitivity and specificity, remains the preferred non-invasive diagnostic modality for PAD diagnosis. However, Color Doppler, with its accessibility and lower cost, offers a viable alternative in low-resource settings where MDCT angiography is unavailable. Further studies are warranted to validate our findings.

This study has few limitations. Limited sample size and focus on early-stage patients may not fully represent diverse PAD cases. Comparison with MDCT angiography may be influenced by varying disease severity. Generalizability may be limited to settings with similar resource constraints. Further validation studies are needed for broader applicability.

CONCLUSION

In the present study, a total of 54 patients were evaluated for 8 lower limb artery abnormalities for peripheral vascular disease on each limb, thus contributing to the evaluation of a total of 864 arteries using Color Doppler flowmetry and MDCT angiography. Based on the present study, we concluded that Color Doppler assessed abnormalities in a comparatively less proportion of cases than MDCT Angiography, and Color Doppler had a higher number of under-diagnosis cases as compared to over-diagnosis. As compared to MDCT angiography, Color Doppler had higher sensitivity, specificity, PPV and NPV values. An agreement between MDCT and Color Doppler was seen on 88.2%. The measure of agreement between the two methods was strong.

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Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee of Era's Lucknow Medical College & Hospital, Lucknow, India

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