

Role of Doppler Ultrasound in Assessing the Severity of Peripheral Arterial Diseases of the Lower Limb

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Abstract

Background: Peripheral arterial disease is defined as a clinical disorder in which there is a stenosis or occlusion of the arteries of the limbs. The most common etiology is ischemia due to occlusive disease. The objective of this study is to assess the severity of lower-limb peripheral arterial diseases based on various Doppler parameters. **Methods:** This descriptive cross-sectional study comprised 55 patients with clinical signs and symptoms of lower-limb peripheral arterial disease. Both inpatients and outpatients attending the authors' institute were taken up for the study. In this study, Doppler sonography was performed using 3–12 MHz linear array and 1–7 MHz curvilinear array transducers (SAMSUNG RS80A Ultrasound System). **Results:** Out of 55 patients, Doppler sonography demonstrated echogenic plaques in 32 patients and corkscrew collaterals in 15 patients. Monophasic waveform with peak systolic velocity ratio of $>2:1$ was found in 42 patients, which is consistent with significant stenoses. **Conclusion:** Our study shows that Duplex Doppler sonography aided by color Doppler sonography can accurately locate the site and severity of stenosis/occlusion. It is safe, cost-effective, repeatable, and noninvasive.

Keywords: Corkscrew collaterals, Doppler sonography, ischemia, monophasic waveform, peak systolic velocity ratio

INTRODUCTION

Peripheral arterial disease is defined as a clinical disorder in which there is a stenosis or occlusion of the arteries of the limbs.^[1] The most common cause of occlusion is atherosclerosis.^[2] Lifestyle diseases such as diabetes mellitus and hypertension predispose the individual to peripheral arterial diseases of the lower limb.^[3] These patients have increased risk of mortality, myocardial infarction, and stroke. It adversely affects the functional status of the limb and is associated with poor quality of life.

The disease may manifest as claudication, rest pain, local tissue loss (ulceration), or gangrene, color change, paresthesia, and potentially, amputation. However, the disease can also be asymptomatic.^[3]

Ultrasound imaging provides a noninvasive assessment of the arterial system of the lower limb and is considered as a valuable diagnostic technique. Grayscale images identify plaque and thrombus, duplex assessment provides a measurement of blood velocity through a vessel, and color Doppler assessment

enables the rapid localization of arterial stenoses and occlusions.^[2] Recent advances in duplex ultrasound such as better postprocessing 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 noninvasive assessment of peripheral arterial disease.^[4]

Our study was conducted with the objective of assessing the severity of lower-limb peripheral arterial diseases based on various Doppler parameters.

MATERIALS AND METHODS

This descriptive cross-sectional study was conducted in the department of radiodiagnosis of a tertiary care center in North-East India over a 12-month period from November 2018 to October 2019. The study was approved by the “Institutional

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Received: 10-09-2020 Revised: 08-12-2020 Accepted: 19-01-2021 Available Online: 13-04-2021

Access this article online

Quick Response Code:



Website:
www.jmuonline.org

DOI:
10.4103/JMU.JMU_137_20

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How to cite this article: Islam SN, Deka N, Hussain Z. Role of doppler ultrasound in assessing the severity of peripheral arterial diseases of the lower limb. *J Med Ultrasound* 2021;29:277-80.

Ethics Committee of Gauhati Medical College and Hospital, Guwahati” (approval no.: MC/190/2007/Pt-1/EC/52; approval date: 05/04/2018) and the protocol complied with the Declaration of Helsinki. Fifty-five patients of either gender presenting with clinical signs and symptoms of lower-limb peripheral arterial disease were selected for the study. Both inpatients and outpatients attending the hospital were taken up for the study. However, patients with sterile dressings in the lower limb, those in extreme pain in the lower limb due to ischemia, and patients with extensive ulceration were excluded from the study.

Data collection

A detailed history of all the patients was taken and clinically obvious signs and symptoms and risk factors documented on a pretyped pro forma. The duration of complaints was noted in each patient. All the patients were subjected to Doppler sonographic examination after taking informed consent for the same.

Equipment

Doppler sonography was performed using 3–12 MHz linear array and 1–7 MHz curvilinear array transducers (SAMSUNG RS80A Ultrasound System).

Study procedures

With the patient in the supine position, the following vascular segments were analyzed independently for the presence of hemodynamically significant stenosis or occlusion, plaque morphology, and collaterals – external iliac artery, common femoral artery, proximal superficial femoral artery, mid superficial femoral artery, distal superficial femoral artery, popliteo-femoral artery, popliteal artery, anterior tibial artery, posterior tibial artery, peroneal artery, and dorsalis pedis artery. Curved array transducer was used for assessing the external iliac artery. Thus, for a patient with unilateral limb involvement, 11 segments were examined, and in case of bilateral limb disease, 22 segments were examined.

Grayscale sonography was performed to identify atherosclerotic plaques [Figure 1a and b]. Color Doppler was used to rapidly map the vessel of interest, to locate sites of stenoses by color aliasing, and to identify corkscrew collaterals [Figure 2a and b].

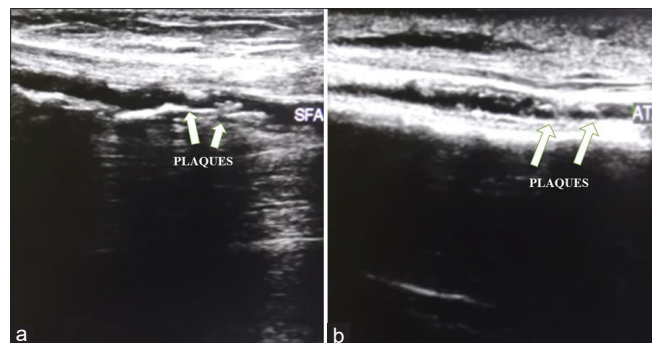


Figure 1: (a) Atherosclerotic plaques in the superficial femoral artery causing luminal narrowing. (b) Atherosclerotic plaques in the anterior tibial artery causing luminal narrowing

Pulse Doppler was then used to analyze type of spectral waveform [Figure 3a-c] and to measure peak systolic velocity [Figure 4a and b]. Peak systolic velocity ratio (PSVR) was calculated by dividing the peak systolic velocity at the stenotic site by peak systolic velocity 4 cm proximal to the stenotic site.

Statistical analysis

Descriptive statistical analysis was carried out for the study. SPSS 15.0 software (IBM, Armonk, New York, USA) was used for the analysis of the data, and Microsoft Excel was used to generate tables. Results on categorical measurements were presented in numbers and percentages. Two-sided Fisher's test was used to show the significance of corkscrew collaterals.

RESULTS

In our study, the most commonly involved lower-limb artery was found to be superficial femoral artery followed by the popliteal artery [Table 1]. Majority of the patients were found to have echogenic atherosclerotic plaques with resultant luminal narrowing [Table 2]. Color Doppler ultrasound showed corkscrew collaterals which represent dilated vasa vasorum of the occluded arteries and serve to provide distal perfusion. However, corkscrew collaterals were absent in most patients [Table 3]. All patients with type III and IV corkscrew

Table 1: Anatomic segment-wise distribution of peripheral arterial disease

| Arteries involved | Number of patients (%) |
|-------------------|------------------------|
| EIA | 1 (1.82) |
| CFA | 9 (16.36) |
| SFA | 25 (45.45) |
| PFA | 5 (9.1) |
| PA | 20 (36.36) |
| PTA | 9 (16.36) |
| ATA | 12 (21.81) |
| DPA | 10 (18.18) |

EIA: External iliac artery, CFA: Common femoral artery, SFA: Superficial femoral artery, PFA: Popliteo-femoral artery, PA: Popliteal artery, PTA: Posterior tibial artery, ATA: Anterior tibial artery, DPA: Dorsalis pedis artery

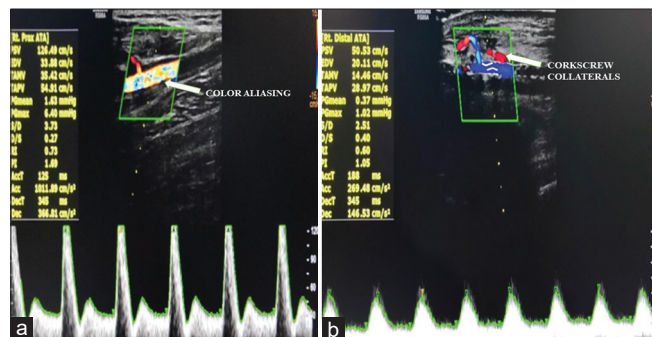


Figure 2: (a) Increased peak systolic velocity and color aliasing at stenotic site of the anterior tibial artery. (b) Corkscrew collaterals and monophasic waveform in the anterior tibial artery

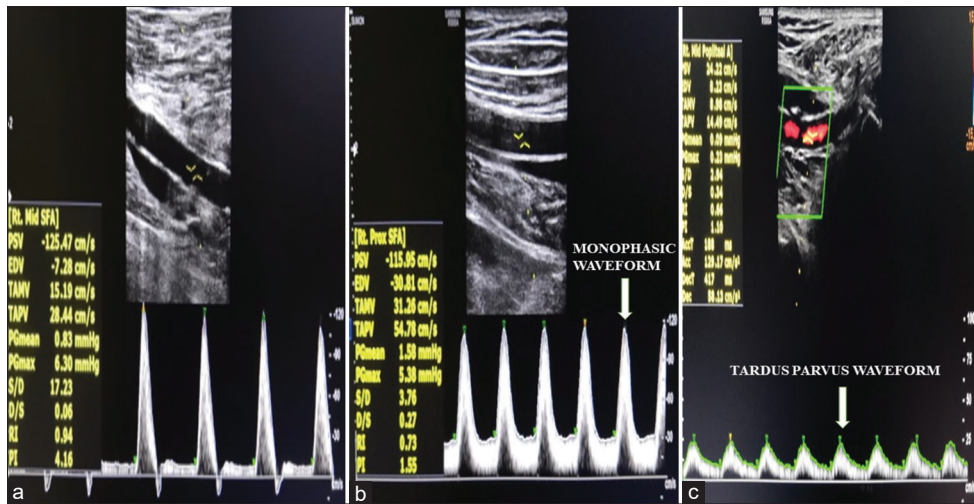


Figure 3: (a) Triphasic waveform with reduced diastolic flow reversal and spectral broadening in the superficial femoral artery. (b) Monophasic waveform with spectral broadening of the superficial femoral artery. (c) Tardus-parvus waveform distal to stenotic site in the popliteal artery

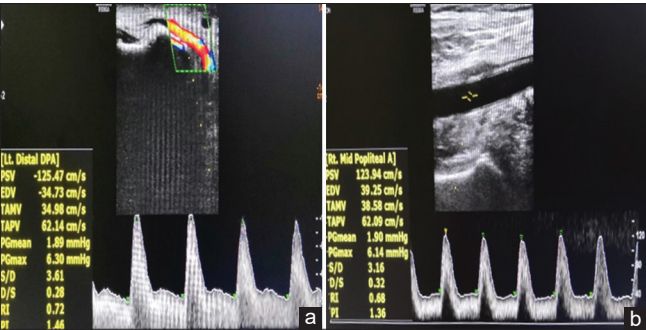


Figure 4: (a) Increased peak systolic velocity at the stenotic site in the dorsalis pedis artery. (b) Increased peak systolic velocity at the stenotic site in the popliteal artery

collaterals were found to have ischemic ulceration. The *P* value by two-sided Fisher's exact test is <0.0001 which indicates that the presence of type III and IV collaterals is statistically significant.

On spectral Doppler sonography, most patients were found to have monophasic waveform [Table 4]. Patients with triphasic waveforms were found to have minimal or prominent spectral broadening whereas the patients with monophasic waveform were found to have extensive spectral broadening. Majority of the patients were found to have hemodynamically significant stenoses with PSVR >2:1 [Table 5] and [Bar Diagram 1].

DISCUSSION

Peripheral arterial disease is the most common condition affecting the arteries of the lower extremity, and Doppler ultrasound is a valuable diagnostic technique to assess the severity of stenoses, thereby helping in early management.

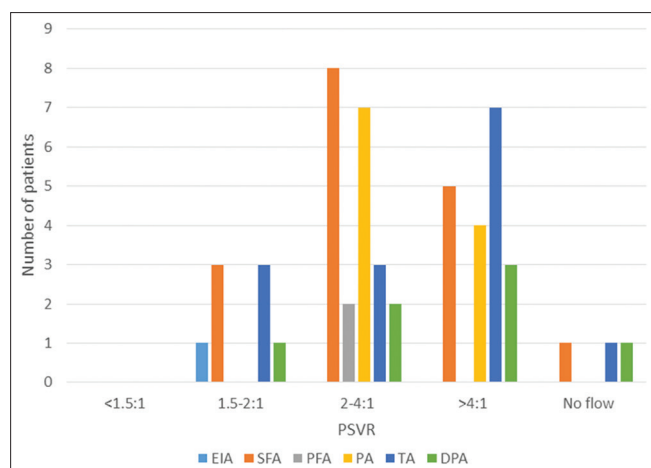
In our study, 55 patients presenting with clinical features of peripheral arterial disease underwent duplex Doppler sonography aided by color Doppler and spectral Doppler sonography of the lower-limb arteries. During the scan, the

| Table 2: Plaque distribution in patients | |
|--|------------------------|
| Echogenic plaque | Number of patients (%) |
| Present | 32 (58.18) |
| Absent | 23 (41.82) |
| Total | 55 (100) |

| Table 3: Corkscrew collateral distribution in patients | | |
|--|--------------------|--|
| Corkscrew collaterals | Number of patients | Number of patients with ulceration (%) |
| Absent | 33 | 2 (60) |
| Type I | 3 | 0 (5.45) |
| Type II | 7 | 0 (12.73) |
| Type III | 7 | 7 (12.73) |
| Type IV | 5 | 5 (9.1) |
| Total | 55 | 14 (100) |

| Table 4: Waveform-wise distribution of patients | |
|---|------------------------|
| Type of waveform | Number of patients (%) |
| Triphasic waveform with minimal spectral broadening | 2 (3.6) |
| Triphasic with prominent spectral broadening | 8 (14.54) |
| Monophasic with extensive spectral broadening | 42 (76.36) |
| No flow/waveform | 3 (5.46) |
| Total | 55 (100) |

| Table 5: Peak systolic velocity ratio of occluded arteries | | |
|--|-------------------------|------------------------|
| PSVR of occluded arteries | Percentage stenosis (%) | Number of patients (%) |
| 1.5-2:1 | 25-50 | 10 (18.18) |
| 2-4:1 | 50-75 | 23 (41.82) |
| >4:1 | >75 | 19 (34.55) |
| No flow | Occluded | 3 (5.45) |
| PSVR: Peak systolic velocity ratio | | |



Bar Diagram 1: PSVR of occluded arteries. Abbreviations: EIA: External iliac artery, SFA: Superficial femoral artery, PFA: Popliteo-femoral artery, PA: Popliteal artery, TA: Tibial artery, DPA: Dorsalis pedis artery, PSVR: Peak systolic velocity ratio

external iliac artery to the dorsalis pedis artery of bilateral lower limbs was examined. Most of the patients were found to have atherosclerotic plaques with resultant luminal narrowing. The presence or absence of corkscrew collaterals was also assessed by color Doppler sonography. They were classified into four types by size and pattern by Fujii *et al.* in 2010 as follows:^[5]

- Type I – Artery diameter >2 mm, large helical sign
- Type II – Diameter 1.5–2 mm, medium helical sign
- Type III – Diameter 1–1.5 mm, small helical sign
- Type IV – Diameter <1 mm, tiny helical sign.

Patients who presented with more severe clinical symptoms like ulceration were found to have type III and IV collaterals or no collaterals, which correlated with the study done by Fujii *et al.*^[5] Other parameters noted were peak systolic velocity, peak systolic velocity ratio, and spectral waveform changes. Normal arterial waveform is triphasic with early diastolic reversal. A hemodynamically significant stenosis (>50%) was inferred when the waveform changed from triphasic to monophasic, with appearance of spectral broadening and peak systolic velocity ratio >2:1.^[6] Although a number of parameters in the Doppler waveform are affected by stenoses, the PSVR is the most widely adopted measurement.^[7,8] A PSVR of >2:1 indicates a stenosis of >50%.^[9] It was observed in our study that 76.3% of the patients had hemodynamically significant stenosis (>50% lumen diameter reduction) with PSVR >2:1 and monophasic waveforms with varying degrees of spectral broadening.

Thus, Doppler ultrasound helps in assessing the severity of peripheral artery disease, which helps in their management. Patients with intermittent claudication are often managed conservatively, while patients with limb threatening ischemia

are treated with angioplasty, surgical re-vascularization, or amputation.^[10,11] The advantages of Doppler ultrasound are the noninvasive nature of the examination, its relatively low cost, easy repeatability with no radiation exposure, and its unique ability to provide both morphologic and hemodynamic information.

CONCLUSION

Doppler sonography can accurately locate the site and severity of stenosis/occlusion. It can be used to classify peripheral arterial disease into hemodynamically nonsignificant and significant using various parameters.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Collins R, Burch J, Cranney G, Aguiar-Ibanez R, Craig D, Wright K, *et al.* Duplex ultrasonography, magnetic resonance angiography, and computed tomography angiography for diagnosis and assessment of symptomatic, lower limb peripheral arterial disease: Systematic review. *BMJ* 2007;334:1257.
- Allan PL, Baxter GM, Weston MJ. Clinical ultrasound. In: Set E-Book: Expert Consult: Online and Print. Vol. 2. London, United Kingdom: Elsevier Health Sciences; 2011.
- Criqui MH, Langer RD, Fronek A, Feigelson HS, Klauber MR, McCann TJ, *et al.* Mortality over a period of 10 years in patients with peripheral arterial disease. *N Engl J Med* 1992;326:381-6.
- Favaretto E, Pili C, Amato A, Conti E, Losinno F, Rossi C, *et al.* Analysis of agreement between Duplex ultrasound scanning and arteriography in patients with lower limb artery disease. *J Cardiovasc Med (Hagerstown)* 2007;8:337-41.
- Fujii Y, Soga J, Nakamura S, Hidaka T, Hata T, Idei N, *et al.* Classification of corkscrew collaterals in thromboangiitis obliterans (Buerger's disease). *Circ J* 2010;74:1684-8.
- Zierler RE, Zierler BK. Duplex sonography of lower extremity arteries. *Semin Ultrasound CT MR* 1997;18:39-56.
- Collins R, Burch J, Cranney G, Aguiar-Ibáñez R, Craig D, Wright K, *et al.* Duplex ultrasonography, magnetic resonance angiography, and computed tomography angiography for diagnosis and assessment of symptomatic, lower limb peripheral arterial disease: Systematic review. *BMJ* 2007;334:1257.
- Sensier Y, Hartshorne T, Thrush A, Nydahl S, Bolia A, London NJ. A prospective comparison of lower limb colour-coded duplex scanning with arteriography. *Eur J Vasc Endovasc Surg* 1996;11:170-5.
- Cossmann DV, Ellison JE, Wagner WH, Carroll RM, Treiman RL, Foran RF, *et al.* Comparison of contrast arteriography to arterial mapping with color-flow duplex imaging in the lower extremities. *J Vasc Surg* 1989;10:522-8.
- Burke BJ. Ultrasound in the assessment and management of arterial emergencies. In: Introduction to Vascular Ultrasonography. 6th ed. Philadelphia, PA: Elsevier; 2012. p. 324-39.
- Rooke TW, Hirsch AT, Misra S, Sidawy AN, Beckman JA, Findeiss LK, *et al.* 2011 ACCF/AHA focused update of the guideline for the management of patients with peripheral artery disease (updating the 2005 guideline): A report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol* 2011;58:2020-45.