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Ultrasound Evaluation of Peripheral Arterial Disease with Clinical Correlation

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Abstract

Background: Peripheral arterial disease (PAD) is a common manifestation of systemic atherosclerosis resulting in reduced blood flow to the extremities. Colour Doppler Ultrasonography is a non-invasive, readily available imaging modality that provides both anatomical and hemodynamic information for the diagnosis and assessment of PAD.

Aim: To evaluate the role of Colour Doppler Ultrasonography in the diagnosis of peripheral arterial disease and to correlate Doppler findings with clinical severity.

Materials and Methods: This hospital - based observational study was conducted in the Department of Radio diagnosis and Imaging at Muzaffarnagar Medical College, Uttar Pradesh, over a period of 18 months. Thirty patients clinically suspected of peripheral arterial disease and referred for Colour Doppler Ultrasonography were included using consecutive sampling. Patients underwent a detailed clinical

evaluation, followed by a Colour Doppler examination of the affected upper or lower limb arteries, using a standardised protocol.

Doppler findings were graded according to waveform characteristics and correlated with Rutherford clinical staging. Statistical analysis was performed using SPSS version 22.0, and a *p*-value <0.05 was considered statistically significant.

Results: Of the 30 patients, 22 (73.3%) were aged 41–60 years and 19 (63.3%) were males. Lower limb involvement was observed in 27 (90%) patients, while upper limb involvement was present in 3 (10%). Diabetes mellitus (63.3%) was the most common co morbidity, followed by hyperlipidemia (56.7%) and hypertension (23.3%).

Colour Doppler Ultrasonography demonstrated arterial stenos is in 20 (66.7%) patients, near-total occlusion in 7 (23.3%), and normal arterial flow in 3 (10%). Grade 1 Doppler severity was observed in 66.7% of patients, whereas Grade 2 disease was present in 23.3%. A statistically significant moderate positive correlation was found between Rutherford clinical stage and Doppler severity grading (Spearman's $\rho = 0.437$, $p = 0.016$).

Conclusion: Colour Doppler Ultrasonography is a reliable, non-invasive, and cost-effective modality for the diagnosis and severity assessment of peripheral arterial disease. It accurately detects arterial stenos is and occlusion and demonstrates good correlation with clinical severity, making it an excellent first-line imaging investigation in patients with suspected PAD.

Keywords: Peripheral Arterial Disease, Colour Doppler Ultrasonography, Duplex Doppler, Arterial Stenos Is, Rutherford Classification, Peripheral Vascular Disease.

Introduction

Peripheral arterial disease (PAD) is a common manifestation of systemic atherosclerosis characterised by progressive narrowing or occlusion of the peripheral arteries, leading to reduced blood flow to the extremities. The lower limb arteries are affected more frequently than the upper limb arteries, and the disease is associated with considerable morbidity, reduced quality of life, and an increased risk of cardiovascular and cerebrovascular events [1,2].

PAD is a major public health problem affecting more than 200 million people worldwide, with its prevalence increasing due to ageing populations and the rising incidence of diabetes mellitus, hyper tension, dyslipidemia, obesity, and smoking [2,3].

In India, the burden of peripheral arterial disease is increasing rapidly owing to the growing prevalence of metabolic disorders and lifestyle-related risk factors [4].

The pathophysiology of PAD primarily involves atherosclerotic plaque formation within the arterial wall, resulting in luminal narrowing, decreased tissue perfusion, and progressive ischemia. Diabetes mellitus accelerates atherosclerosis by causing endothelial dysfunction, vascular inflammation, and diffuse involvement of distal arteries, thereby increasing the risk of limb-threatening ischemia and amputation [3,5].

Clinically, patients with PAD may remain asymptomatic or present with intermittent claudication, rest pain, non-healing ulcers, gangrene, or critical limb ischemia depending on the severity of arterial obstruction [6]. Intermittent claudication is the classical presenting symptom and is characterized by reproducible muscular pain during walking that is relieved by rest. Physical examination may reveal diminished peripheral pulses, arterial bruits, cool extremities, trophic skin changes,

delayed capillary refill, and ischemic ulcers [7]. The Rutherford classification is commonly used for grading the clinical severity of peripheral arterial disease and assists in determining appropriate treatment strategies [8].

Various imaging modalities are available for the evaluation of PAD, including ankle-brachial index (ABI), Colour Doppler Ultrasonography, computed tomography angiography (CTA), magnetic resonance angiography (MRA), and digital subtraction angiography (DSA). Although DSA remains the reference standard for vascular imaging, its invasive nature, requirement for iodinated contrast media, radiation exposure, and procedural risks limit its routine use [6,9].

Colour Doppler Ultrasonography has become the first-line imaging modality in the evaluation of peripheral arterial disease because it is non-invasive, inexpensive, readily available, free of ionizing radiation, and capable of providing both anatomical and hemodynamic information [10]. It combines B-mode imaging with colour flow mapping and spectral Doppler analysis to assess arterial wall morphology, plaque characteristics, blood flow direction, peak systolic velocity (PSV), velocity ratios, and waveform patterns [10,11].

Normal peripheral arteries exhibit a triphasic waveform with a sharp systolic upstroke, early diastolic flow reversal, and late diastolic forward flow. Progressive arterial stenos is produces increased peak systolic velocity, spectral broadening, post-stenotic turbulence, and conversion of triphasic waveforms to biphasic and monophasic patterns. Complete arterial occlusion is characterized by absent or markedly diminished distal flow signals[10,12]. These Doppler findings allow accurate grading of arterial stenos is and help determine the hemodynamic significance of vascular lesions.

Several studies have demonstrated excellent diagnostic accuracy of Colour Doppler Ultrasonography in detecting significant arterial stenos is and occlusion, with sensitivity and specificity exceeding 90% when compared with digital subtraction angiography [11,13]. Owing to its diagnostic reliability, safety, and cost-effectiveness, Colour Doppler Ultrasonography is widely accepted as the preferred initial investigation for patients with suspected PAD.

Despite its increasing use, there is limited hospital-based data regarding the clinico-radiological profile of peripheral arterial disease in the Indian population. The present study was therefore undertaken to evaluate the role of Colour Doppler Ultrasonography in the diagnosis of peripheral arterial disease, assess the spectrum of Doppler findings, identify associated risk factors, and correlate Doppler severity grading with Rutherford clinical staging.

Materials and Methods

Study Design and Setting

This hospital-based observational study was conducted in the Department of Radio-diagnosis and Imaging, Muzaffarnagar Medical College, Muzaffarnagar, Uttar Pradesh, India. The study was carried out over a period of 18 months, comprising 12 months of patient recruitment and data collection followed by 6 months of data compilation, statistical analysis, and interpretation.

Study Population

The study included all outpatient (OPD) and inpatient (IPD) patients who were clinically suspected to have peripheral arterial disease (PAD) and were referred to the Department of Radio-diagnosis for Colour Doppler Ultrasonography during the study period.

Sample Size and Sampling Technique

A total of 30 patients were enrolled in the study. The sample size was based on the total number of clinically suspected PAD cases referred for Doppler Ultra sonography during the study period. Consecutive sampling was employed, and all eligible patients fulfilling the inclusion criteria were included.

Inclusion Criteria

- Patients clinically suspected to have peripheral arterial disease (PAD).

Exclusion Criteria

- Patients who did not provide written informed consent.
- Patients with limb amputation proximal to the head of the metatarsals in one or both lower limbs or proximal to the wrist in one or both upper limbs.
- Patients with a history of previous lower limb arterial bypass surgery.
- Patients presenting with acute limb ischemia during cuff inflation.

Study Methodology

All eligible patients were enrolled after obtaining written informed consent. Demographic details including age, gender, relevant medical history, and presenting clinical symptoms were recorded using a structured proforma.

A detailed clinical examination was performed with particular emphasis on symptoms and signs suggestive of peripheral arterial disease.

Patients were questioned regarding exertional pain in the upper or lower limbs, distance of onset of claudication, and the presence of rest pain. Both upper and lower extremities were examined for non-healing ulcers, trophic skin changes, peripheral pulses, and arterial bruits.

Doppler Ultrasonography Protocol

Color Doppler Ultrasonography was performed with the patient in the supine position using an appropriate ultrasound system equipped with high-frequency linear transducers. Ultrasound gel was applied over the region of interest, and arterial duplex imaging was carried out following standard vascular imaging protocols. Spectral Doppler waveforms were obtained from each artery to evaluate the direction of blood flow, peak systolic velocity (PSV), waveform characteristics, and blood flow velocities.

The Doppler insonation angle was maintained between 45° and 60°, with 60° used whenever feasible. Angles greater than 60° were avoided to ensure accurate velocity measurements. All examinations were performed independently by a single experienced sonographer.

Upper Limb Arterial Doppler Examination

The upper limb arterial evaluation extended from the subclavian artery to the wrist. During examination, the patient's head was slightly elevated, and the arm was externally rotated. For evaluation of the axillary artery, the arm was positioned comfortably on a pillow while maintaining the appropriate patient posture.

The following arteries were systematically examined:

- Subclavian artery
- Axillary artery
- Brachial artery
- Radial artery
- Ulnar artery

Real-time B-mode imaging, Color Doppler, and spectral Doppler analysis were performed for each arterial segment. In suspected arterial stenos is, peak systolic velocity (PSV) measurements were obtained proximal to, within, and distal to the lesion. The PSV ratio was

calculated by dividing the PSV at the steno tic segment by the PSV in the adjacent normal proximal artery. Post-steno tic turbulence was also assessed to determine the hemodynamic significance of the lesion.

For aneurysmal lesions, vessel diameter was measured from outer wall to outer wall. Spectral Doppler velocities were recorded proximal to, within, and distal to the aneurysm. The presence of mural thrombus was documented whenever identified. Imaging of the subclavian artery was occasionally limited because of acoustic shadowing from the clavicle.

Lower Limb Arterial Doppler Examination

Lower extremity arterial duplex examination commenced at the level of the abdominal aortic bifurcation using a low frequency (2.0–3.5 MHz) transducer for evaluation of proximal vessels.

The arterial system was evaluated sequentially in the following order:

- Distal abdominal aorta
- Common iliac arteries
- Internal iliac arteries
- External iliac arteries
- Common femoral artery
- Superficial femoral artery
- Profundafemoris artery
- Popliteal artery
- Anterior tibial artery
- Posterior tibial artery
- Peroneal artery

The distal abdominal aorta and common iliac arteries were visualized with the patient turned slightly to the left, whereas evaluation of the iliac arteries was performed in the lateral decubitus position. Longitudinal B-mode imaging and spectral Doppler interrogation were performed at each arterial segment. The common femoral artery was traced distally to its bifurcation into the superficial femoral and profundafemoris arteries. The superficial femoral artery was followed along the medial thigh into the popliteal artery. The popliteal artery was assessed through the popliteal fossa and traced distally to the tibial vessels.

The anterior tibial artery was examined along the lateral aspect of the leg to the ankle. The posterior tibial and peroneal arteries were evaluated through the medial aspect of the calf and followed to the level above the medial malleolus.

After each examination, ultrasound gel was removed from the patient's skin, and the transducer was cleaned using an approved disinfectant according to institutional infection-control protocols.

Equipment

All Doppler examinations were performed using a Samsung HS50 ultrasound system equipped with high-frequency linear and low-frequency convex transducers as appropriate for vascular imaging.

Statistical Analysis

The collected data were entered into Microsoft Excel and subsequently analyzed using Statistical Package for the Social Sciences (SPSS) version 22.0 under the guidance of a statistician. Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. Appropriate statistical tests were applied wherever necessary, and a *p*-value <0.05 was considered statistically significant.

Results and Observations

Demographic Profile of the Study Population

A total of 30 patients clinically suspected of peripheral arterial disease (PAD) were evaluated using Colour Doppler Ultrasonography.

Table 1: Age-wise Distribution of the Study Population (n = 30)

Age group (years)	Number of patients	Percentage (%)
≤40 years	1	3.3
41–60 years	22	73.3
>60 years	7	23.3
Total	30	100

Observation: The majority of patients (73.3%) belonged to the 41–60 years age group, followed by patients aged > 60 years (23.3%). Only one patient (3.3%) was aged 40 years or younger, indicating that PAD was predominantly observed in middle-aged and elderly individuals.

Table 2: Sex-wise Distribution of the Study Population (n = 30)

Sex	Number of patients	Percentage (%)
Male	19	63.3
Female	11	36.7
Total	30	100

Observation: Male patients constituted 63.3% of the study population, whereas females accounted for 36.7%, demonstrating a clear male predominance among patients with suspected PAD.

Table 3: Distribution According to Limb Involvement (n = 30)

Limb involved	Number of cases	Percentage (%)
Lower limb	27	90.0
Upper limb	3	10.0
Total	30	100

Observation: Lower limb arterial disease was observed in 90% of patients, while only 10% had upper limb arterial involvement, indicating that lower extremity PAD was considerably more common.

Distribution of Comorbidities

Table 4: Distribution of Comorbidities among the Study Population (n = 30)

Comorbidity	Number of patients	Percentage (%)
Diabetes mellitus	19	63.3
Hypertension	7	23.3
Hyperlipidemia	17	56.7

Observation: Diabetes mellitus was the most frequently encountered comorbidity, affecting 63.3% of patients, followed by hyperlipidemia (56.7%) and hypertension (23.3%). These findings suggest that metabolic risk factors were highly prevalent among patients with PAD.

Colour Doppler Ultrasound Findings

Table 5: Spectrum of Doppler Findings (n = 30)

Doppler finding	Number of cases	Percentage (%)
Normal study	3	10.0
Stenosis	20	66.7
Near-total occlusion	7	23.3
Total	30	100

Observation: Arterial stenosis was the most common Doppler finding, observed in 66.7% of patients. Near-total arterial occlusion was identified in 23.3%, whereas only 10% of patients demonstrated normal arterial flow.

Table 6: Doppler Severity Grading (n = 30)

Doppler Severity Grade	Description	Number of cases	Percentage (%)
Grade 0	Normal triphasic flow	3	10.0
Grade 1	Stenosis with biphasic waveform	20	66.7
Grade 2	Near-total	7	23.3

	occlusion/Monophasic or absent flow		
Total		30	100

Observation: Most patients (66.7%) were classified as Grade 1, indicating hemodynamic ally significant arterial stenos is with biphasic waveforms. Grade 2 disease, characterised by near-total occlusion or monophasic /absent flow, was present in 23.3% of patients, while only 10% demonstrated normal triphasic arterial flow.

Correlation of Clinical Presentation with Doppler Findings

Clinical severity was assessed using Rutherford's Classification, while radiological severity was graded according to Doppler waveform characteristics and arterial flow.

Table 7: Correlation Between Rutherford Clinical Stage and Doppler Severity Grading

Parameter	Value
Statistical test	Spearman's rank correlation
Correlation coefficient (ρ)	0.437
p-value	0.016
Level of significance	Statistically significant

Observation: Spearman's rank correlation demonstrated a moderate positive correlation between Rutherford clinical stage and Doppler severity grading (ρ = 0.437). The association was statistically significant (p = 0.016), indicating that increasing clinical severity was associated with increasing Doppler severity.

A total of 30 patients with clinically suspected peripheral arterial disease (PAD) were evaluated using Colour Doppler Ultrasonography. Most patients were 41–60 years old (73.3%) and were male (63.3%). Lower limb involvement was more common (90%) than upper limb involvement (10%). Diabetes mellitus was the most frequent comorbidity (63.3%), followed by hyper lipidemia (56.7%) and hypertension (23.3%).

Arterial stenos are being the most common Doppler finding (66.7%), while near-total occlusion was observed in 23.3% of patients. A statistically significant moderate positive correlation was found between Rutherford clinical stage and Doppler severity grading (ρ = 0.437, p = 0.016).

A total of 30 patients clinically suspected of peripheral arterial disease were evaluated using Colour Doppler Ultrasonography. Most patients belonged to the 41–60 years age group (73.3%) with a male predominance (63.3%). Lower limb involvement was considerably more common (90%) than upper limb disease (10%).

Among the associated co morbidities, diabetes mellitus (63.3%) was the most frequent, followed by hyper lipidemia (56.7%) and hypertension (23.3%), high lighting the importance of metabolic risk factors in patients with PAD.

Colour Doppler Ultrasonography revealed arterial stenosis as the predominant abnormality, accounting for 66.7% of cases, while 23.3% demonstrated near-total arterial occlusion. Normal Doppler findings were observed in only 10% of patients. According to Doppler severity grading, Grade 1 disease was the most common (66.7%), followed by Grade 2 disease (23.3%), whereas 10% of patients exhibited normal triphasic flow.

Correlation analysis between Rutherford clinical staging and Doppler severity grading demonstrated a statistically significant moderate positive correlation (ρ = 0.437, p = 0.016), suggesting good clinico-radiological agreement between patients' clinical presentation and Colour Doppler Ultrasonography findings.

Discussion

Peripheral arterial disease is one of the most common manifestations of systemic atherosclerosis and is associated with significant cardiovascular morbidity and mortality. Early diagnosis is essential for timely initiation of medical therapy, endovascular intervention, or surgical revascularisation. Colour Doppler Ultrasonography has emerged as the preferred first-line imaging modality because it provides accurate anatomical and hemodynamic assessment of peripheral arteries without radiation exposure or contrast administration[1,10].

In the present study, the majority of patients (73.3%) belonged to the 41–60 years age group, followed by patients older than 60 years (23.3%). These findings are consistent with previous epidemiological studies demonstrating that the prevalence of PAD increases progressively with age owing to cumulative atherosclerotic changes[2,3].

Male patients constituted 63.3% of the study population, indicating a male predominance. Similar observations have been reported by Criqui and Aboyans [2], who observed a higher prevalence of symptomatic PAD among males, although the prevalence among females increases after menopause.

Lower limb involvement (90%) was considerably more common than upper limb disease (10%). This observation agrees with previous studies showing that atherosclerosis predominantly affects lower extremity arteries because of increased hemodynamic stress and greater susceptibility to plaque formation[1,6].

Among the associated co morbidities, diabetes mellitus (63.3%) was the most common, followed by hyper lipidemia (56.7%) and hypertension (23.3%). Diabetes is recognized as one of the strongest independent risk factors for PAD because chronic hyperglycemia promotes endothelial dysfunction, inflammation, accelerated atherosclerosis, and diffuse distal arterial involvement [3,4]. Similar associations have been reported in the TASC II guidelines and other large epidemiological studies[3,5].

Colour Doppler Ultrasonography demonstrated arterial stenos is in 66.7% of patients, whereas near-total arterial occlusion was observed in 23.3%. Only three patients (10%) had normal Doppler findings despite clinical suspicion of PAD. These findings emphasize the high diagnostic utility of Colour Doppler in detecting hemodynamic ally significant arterial disease. Similar results have been reported by Moneta et al. [11], who demonstrated that peak systolic velocity measurements and Doppler waveform analysis accurately identify arterial stenos is.

Most patients (66.7%) exhibited Grade 1 Doppler abnormalities characterized by biphasic waveforms and significant arterial stenos is, while Grade 2 disease with monophasic or absent flow was observed in 23.3% of patients. These Doppler waveform alterations reflect progressive arterial obstruction and decreasing distal perfusion, consistent with previous vascular ultrasound studies[10,11].

An important finding of the present study was the statistically significant moderate positive correlation between Rutherford clinical stage and Doppler severity grading ($\rho = 0.437$, $p = 0.016$).

This indicates good clinico - radiological agreement, suggesting that increasing clinical severity is associated with worsening hemodynamic abnormalities on Colour Doppler Ultrasonography. Similar correlations have been reported in previous studies evaluating the

diagnostic performance of duplex Ultrasonography in PAD[8,13].

The present study supports the role of Colour Doppler ultrasonography as an effective, reliable, and non-invasive imaging modality for the diagnosis and grading of peripheral arterial disease. In comparison with CT angiography and digital subtraction angiography, Doppler Ultrasonography is inexpensive, repeatable, widely available, and does not require contrast administration or expose patients to ionising radiation[6,9,10].

However, the present study has certain limitations. The sample size was relatively small (30 patients), and the study was conducted at a single tertiary care centre. Furthermore, angiographic confirmation was not available in all cases. Larger multicentre studies with angiographic correlation are recommended to further validate these findings.

Overall, the present study demonstrates that Colour Doppler Ultrasonography is a valuable diagnostic tool for the evaluation of peripheral arterial disease. It accurately detects arterial stenos is and occlusion, correlates well with clinical severity, and plays an important role in patient management and treatment Planning.

Conclusion

Colour Doppler Ultrasonography is a reliable, non-invasive, and cost-effective imaging modality for the evaluation of peripheral arterial disease. In the present study, lower limb involvement was predominant, with diabetes mellitus being the most common associated co morbidity. Arterial stenos are being the most frequent Doppler finding, and Doppler severity showed a statistically significant positive correlation with Rutherford clinical staging. These findings highlight the usefulness of Colour Doppler Ultrasonography in the early diagnosis, severity assessment, and management planning of patients with peripheral arterial disease.

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