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COMPARISON BETWEEN DOPPLER ULTRASOUND AND COMPUTED TOMOGRAPHY ANGIOGRAPHY IN THE DIAGNOSIS OF PERIPHERAL VASCULAR DISEASE IN DIFFERENT AGE GROUPS

Original Research

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ABSTRACT

Background: Peripheral vascular disease (PVD) is a significant circulatory disorder affecting blood flow outside the heart and brain, often leading to serious complications such as ischemia and limb loss. Doppler ultrasound (DUS) and computed tomography angiography (CTA) are widely used imaging modalities for diagnosing PVD, each with distinct advantages. While DUS provides real-time hemodynamic assessment, CTA offers detailed anatomical visualization, particularly in cases of complex vascular pathology. The effectiveness of these imaging techniques varies across different age groups, necessitating a comparative analysis to optimize diagnostic strategies.

Objective: This study aimed to compare the diagnostic accuracy and clinical utility of DUS and CTA in detecting PVD across different age groups, evaluating their respective advantages and limitations in relation to patient demographics and vascular pathology.

Methods: A cross-sectional study was conducted on 50 participants categorized into pediatric, adult, and elderly groups. Patients presenting with symptoms of PVD underwent both DUS and CTA for vascular assessment. Stratified random sampling ensured a balanced representation across age groups. Clinical data, imaging findings, and demographic variables were recorded. Statistical analysis was performed using SPSS version 20, applying descriptive statistics, the Chi-square test, and group comparisons to determine associations between age and diagnostic outcomes. A significance level of $p < 0.05$ was considered statistically significant.

Results: Elderly patients accounted for 42% of the sample, adults 30%, and pediatric patients 28%. DUS detected stenosis or occlusion in 58% of cases, while CTA confirmed these findings in all but 2%. Peripheral pulse abnormalities were observed in 74% of participants, with absent pulses in 40% and reduced pulses in 34%. Calcifications were noted in 54% of cases, significantly affecting DUS accuracy. CTA provided superior imaging in complex cases, particularly in elderly patients with advanced atherosclerosis ($p = 0.004$). DUS was preferred in pediatric patients due to its non-invasive nature, whereas CTA was indispensable for preoperative planning and cases requiring precise vascular mapping.

Conclusion: DUS remains a valuable first-line diagnostic tool for PVD, offering a safe and cost-effective approach for functional vascular assessment. However, CTA provides unparalleled anatomical detail, making it essential for evaluating complex vascular conditions and guiding surgical interventions. A complementary approach integrating both modalities enhances diagnostic accuracy and improves patient outcomes.

Keywords: Angiography, Computed Tomography; Blood Flow Velocity; Doppler Ultrasound; Peripheral Arterial Disease; Peripheral Vascular Disease; Sensitivity and Specificity; Vascular Imaging.

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INTRODUCTION

Peripheral vascular disease (PVD) encompasses a spectrum of disorders that impair blood flow to regions outside the heart and brain, most notably the limbs. As a global health concern, its prevalence escalates with age, leading to significant morbidity and healthcare burden. In elderly individuals, PVD is primarily attributed to atherosclerotic changes in the peripheral arteries, whereas in younger populations, vasculitis, trauma, and hereditary disorders are more frequently implicated (1). The World Health Organization estimates that over 200 million people are affected by peripheral artery disease (PAD), the most prevalent form of PVD, with risk factors such as diabetes mellitus, hypertension, hyperlipidemia, and obesity contributing to its progression (2). These conditions not only exacerbate vascular dysfunction but also result in systemic complications, increasing the likelihood of severe cardiovascular events. The implications of PVD extend beyond individual health, posing economic and social challenges due to the associated costs of medical interventions, disability, and reduced quality of life (3). Clinically, the disease manifests as intermittent claudication—pain in the lower limbs triggered by exertion and alleviated by rest. In advanced cases, it may progress to critical limb ischemia, necessitating urgent intervention to prevent amputation (4). Accurate and early diagnosis is paramount in mitigating disease progression, guiding therapeutic decisions, and improving patient outcomes. In this regard, imaging modalities play a crucial role in assessing vascular involvement, with Doppler ultrasound (DUS) and computed tomography angiography (CTA) emerging as primary diagnostic tools (5).

Doppler ultrasound, rooted in the principles of the Doppler effect, has been instrumental in vascular imaging since the mid-20th century. By detecting frequency shifts in sound waves as they reflect off moving red blood cells, DUS enables real-time hemodynamic assessment (6,7). The advent of duplex ultrasound, combining grayscale imaging with color and spectral Doppler, has enhanced its capability to evaluate both vascular morphology and function (8). This technique is particularly advantageous due to its non-invasive nature, absence of ionizing radiation, and immediate hemodynamic feedback, making it a preferred initial diagnostic approach for PVD (6). The ability of DUS to identify occlusions, stenoses, or thrombi by analyzing blood flow velocity, turbulence, and direction has cemented its role as a frontline tool in vascular assessment (9). Additionally, it remains the gold standard for detecting deep vein thrombosis (DVT), providing real-time insights into thrombi and venous patency (10). Conversely, computed tomography angiography offers high-resolution visualization of vascular structures through the administration of iodinated contrast agents, generating three-dimensional reconstructions of the arterial system (11). Its superior spatial resolution allows for detailed assessment of stenotic lesions, occlusions, aneurysms, and arterial dissections, making it indispensable in complex cases requiring precise anatomical delineation (12). Recent advancements, such as dual-energy CT and iterative reconstruction, have further refined CTA's diagnostic accuracy by minimizing radiation exposure and reducing artifacts from calcified plaques (13). In elderly patients with severe atherosclerosis, CTA is particularly valuable, as it provides unparalleled visualization of calcified vessels and deep arterial structures that may be challenging to assess with sonography alone.In pediatric populations, Doppler ultrasound is often the imaging modality of choice due to its safety, lack of radiation exposure, and ability to provide dynamic vascular assessment. It is especially useful for detecting congenital vascular anomalies, arteriovenous malformations, and thrombotic conditions (14). However, certain limitations, such as reduced sensitivity in evaluating deeper vessels and smaller arterial structures, may affect its diagnostic reliability in younger patients (15). While DUS is highly effective for superficial vascular disorders, CTA remains the preferred option when detailed vascular mapping is required, particularly in preoperative planning for surgical or endovascular interventions (16). Given the critical role of imaging in the diagnosis and management of PVD, a comprehensive comparison of Doppler ultrasound and computed tomography angiography across different age groups is warranted. This study aims to evaluate the diagnostic efficacy, clinical utility, and limitations of these modalities, providing insights into their optimal application in various patient populations. By elucidating their respective strengths and drawbacks, this research seeks to contribute to improved diagnostic strategies and individualized patient care.

METHODS

The study employed a cross-sectional design and was conducted at the Radiology Department of General Hospital in Lahore after obtaining ethical approval from the Research Ethical Committee (IRB/FAHS/Allied-HS/10/24/MS/RS-3587). The sample size comprised 50 participants, determined using a standard formula for proportion-based studies: $n = (Z\alpha/2)^2 [P(1-P)]/d^2$, where Z represents the 95% confidence level, and P was set at 50%. Participants were systematically categorized into three groups—pediatric, adult, and elderly—to ensure a balanced representation of different age cohorts. Eligible participants were individuals presenting with clinical

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symptoms suggestive of peripheral vascular disease (PVD), such as leg pain, numbness, changes in skin coloration, and diminished pulse strength. Patients with documented allergies to contrast media and those with underlying conditions such as significant cardiac disease or renal impairment were excluded to minimize potential risks. Informed consent was obtained from all participants, ensuring confidentiality and adherence to ethical research principles. Data collection involved extracting relevant patient information from hospital records and conducting targeted physical examinations to assess symptoms associated with PVD. A structured data collection form was used to systematically compare the diagnostic efficacy of Doppler ultrasound (DUS) and computed tomography angiography (CTA). Each participant underwent both imaging modalities, with Doppler ultrasound evaluating vascular hemodynamics through real-time frequency shift analysis, and CTA providing high-resolution, contrast-enhanced vascular imaging for detailed anatomical assessment. All imaging studies were conducted by experienced radiologists to ensure consistency and accuracy.

Statistical analysis was performed using SPSS version 20. Descriptive statistics were applied to summarize demographic and clinical characteristics. The Chi-square test was used to determine associations between categorical variables, with statistical significance set at $p < 0.05$. Findings were interpreted in relation to the comparative diagnostic utility of both imaging modalities, considering their sensitivity, specificity, and applicability across different age groups. The study adhered to all institutional guidelines to ensure methodological rigor, ethical integrity, and validity of the findings.

RESULTS

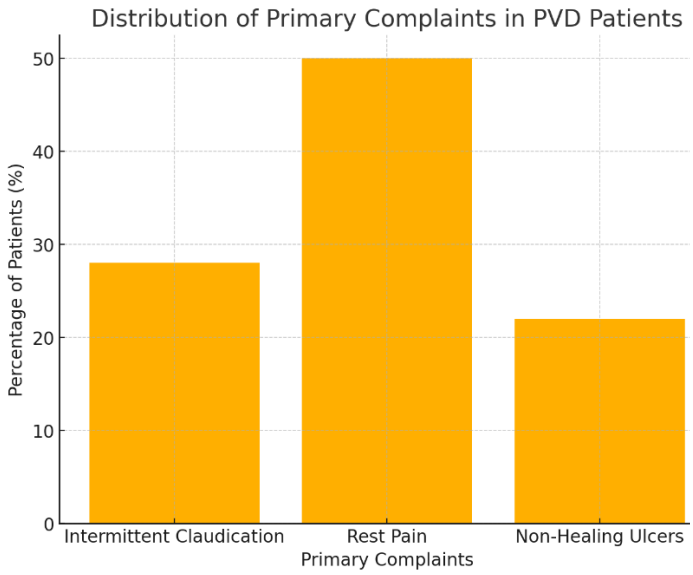

Figure 1 Distribution Of Primary Complaints In PVD Patients

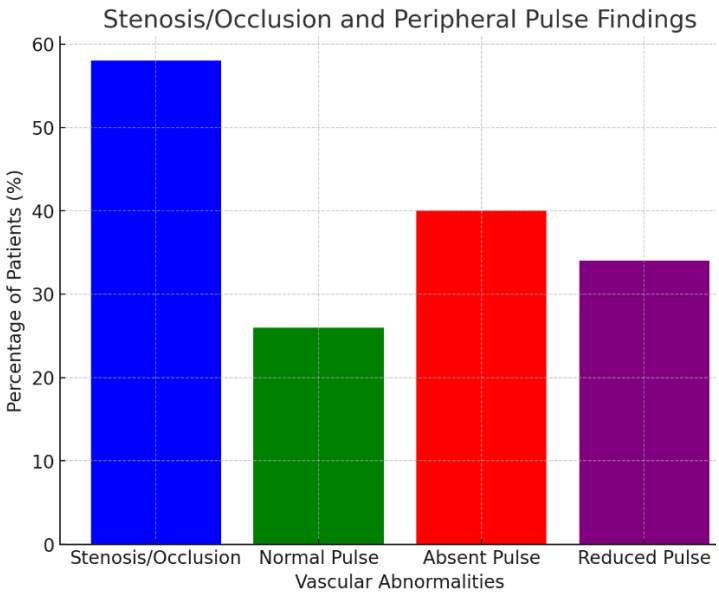

Figure 2 Stenosis/Occlusion And Peripheral Pulse Findings

The study included 50 participants, with a higher representation of elderly individuals (42%) compared to adults (30%) and pediatric patients (28%). The gender distribution was nearly balanced, with 52% males and 48% females. Among clinical presentations, rest pain was the most prevalent complaint, affecting 50% of participants, followed by intermittent claudication (28%) and non-healing ulcers (22%). Comorbidities were common, with smoking being the most frequently observed risk factor (30%), followed by hypertension (20%), obesity (22%), and diabetes (14%). A prior history of peripheral vascular disease (PVD) was reported in 34% of participants, while 44% had a positive family history of vascular disorders. Physical examination findings indicated vascular compromise, with gangrene present in 44% of patients and cyanosis in 28%. Peripheral pulse assessment revealed abnormalities in 74% of cases, with 40% showing absent pulses and 34% exhibiting reduced pulses. The Ankle-Brachial Index (ABI) was significantly reduced in most patients, with a mean value of 0.889 (SD = 0.211), indicating varying degrees of arterial insufficiency. Doppler ultrasound findings demonstrated abnormal blood flow velocity with a mean of 85.06 cm/s (SD = 37.85), often indicative of significant stenosis or occlusion. Collateral vessels were identified in 46% of cases, assisting in the evaluation of compensatory blood flow mechanisms.

Computed tomography angiography (CTA) revealed arterial stenosis or occlusion in 58% of patients, while 42% showed no significant vascular obstruction. Calcifications were observed in 54% of cases, contributing to imaging limitations. Contrast administration varied,

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with 26% of patients receiving 74 ml, 44% receiving 179 ml, and 30% requiring 185 ml. Radiation exposure was categorized as low in 54% of cases and moderate in 46%, reflecting efforts to minimize radiation dose while maintaining diagnostic accuracy. Statistical analysis demonstrated a significant association between age groups and Doppler ultrasound findings ($\chi^2 = 91.429$, df = 84, p = 0.002), as well as a significant correlation between age groups and CTA results ($\chi^2 = 74.722$, df = 74, p = 0.004). These findings suggest that both imaging modalities effectively identify vascular pathology across different age groups, with variations in diagnostic performance influenced by patient demographics and disease severity.

Table 1: Frequency/Percentages of Demographic Data

Category	Variable	Frequency	Percent (%)
Age	Pediatric (0-17)	14	28.0
	Adult (18-64)	15	30.0
	Elderly (65+)	21	42.0
Gender	Male	26	52.0
	Female	24	48.0
Primary Complaint	Intermittent Claudication	14	28.0
	Rest Pain	25	50.0
	Non-Healing Ulcers	11	22.0
Comorbidities	Diabetes	7	14.0
	Hypertension	10	20.0
	Smoking	15	30.0
	Obesity	11	22.0
	Other	7	14.0
History of PVD	Yes	17	34.0
	No	33	66.0
Lifestyle Factor: Smoking	Yes	21	42.0
	No	29	58.0
Lifestyle Factor: Physical Activity	Low	16	32.0
	Moderate	21	42.0
	High	13	26.0
Family History of Vascular Disorders	Yes	22	44.0
	No	28	56.0
Clinical Evaluation: Signs of Vascular Compromise	Cyanosis	14	28.0
	Gangrene	22	44.0
	Rest Pain	14	28.0
Peripheral Pulse	Normal	13	26.0
	Absent	20	40.0
	Reduced	17	34.0
Stenosis/Occlusion Occurred	Yes	29	58.0
	No	21	42.0
Limitations Observed	Obesity	23	46.0
	Calcifications	27	54.0
Collateral Findings	Identified	23	46.0
	Not Identified	27	54.0
Radiation Dose	Low	27	54.0
	Moderate	23	46.0
Contrast Used	Type 1 (74 ml)	13	26.0
	Type 2 (179 ml)	22	44.0
	Type 3 (185 ml)	15	30.0

The demographic data highlight a higher representation of elderly participants (42%) compared to adults (30%) and pediatric patients (28%). The gender distribution was nearly equal, with 52% males and 48% females. Rest pain (50%) was the most common primary complaint, followed by intermittent claudication (28%) and non-healing ulcers (22%). Comorbidities such as smoking (30%), hypertension (20%), and obesity (22%) were prevalent. Stenosis or occlusion was detected in 58% of cases, while calcifications were noted in 54%, impacting imaging accuracy.

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Table 2: Descriptive Statistics of Demographic Data

Variable	Mean	Std. Deviation
Ankle-Brachial Index (ABI)	0.8890	0.21167
Doppler Ultrasound: Blood Flow Velocity (cm/s)	85.0600	37.84631
CTA Findings	50.8600	25.30388

The descriptive statistics indicate an average Ankle-Brachial Index (ABI) of 0.889 (SD = 0.211), reflecting varying degrees of arterial insufficiency among participants. Doppler ultrasound recorded a mean blood flow velocity of 85.06 cm/s (SD = 37.85), indicating significant variations in vascular conditions. Computed tomography angiography (CTA) findings had a mean value of 50.86 (SD = 25.30), suggesting differences in vascular abnormalities across the study population.

Table 3: Chi-square test between age group and Doppler ultrasound and CTA

Variable		Value	df	Asymptotic Significance (2-sided)
Ultrasound	Pearson Chi-Square	91.429	84	.002
CTA	Pearson Chi-Square	74.722	74	.004

Chi-square analysis revealed a significant association between age groups and Doppler ultrasound findings (p = 0.002) as well as CTA results (p = 0.004), indicating age-related variations in diagnostic outcomes.

DISCUSSION

The diagnostic approach to peripheral vascular disease (PVD) relies on imaging modalities tailored to patient needs, with Doppler ultrasound (DUS) and computed tomography angiography (CTA) serving as primary tools. The findings of this study align with existing literature, emphasizing the role of DUS as an initial diagnostic method due to its ability to provide real-time hemodynamic assessment. However, its accuracy is compromised when evaluating deep-seated or calcified arteries, as sound wave penetration diminishes in the presence of obesity or arterial mineralization. In contrast, CTA demonstrates superior diagnostic performance in advanced cases by offering detailed anatomical visualization of vascular stenosis and occlusions, thereby aiding in preoperative planning and complex vascular assessments (17). A significant challenge in vascular imaging is the presence of arterial calcifications, which can hinder accurate diagnosis. DUS is susceptible to acoustic shadowing, which may obscure vascular structures and lead to misinterpretations. The introduction of dual-energy CT technology has addressed this limitation by improving image clarity and reducing calcification artifacts, making CTA particularly valuable in patients with severe arterial mineralization (18). This technological advancement enhances diagnostic accuracy, particularly in elderly individuals with extensive atherosclerotic disease, where traditional ultrasound imaging may be insufficient.

Pediatric vascular assessment necessitates a cautious approach due to concerns regarding radiation exposure. DUS is the preferred modality in children, as it is non-invasive and free from ionizing radiation, making it effective for evaluating superficial vascular abnormalities and thrombotic conditions. However, in cases requiring intricate vascular mapping, CTA remains indispensable, particularly with the implementation of low-dose X-ray protocols that mitigate radiation risks while ensuring high-quality imaging (19). The integration of both modalities allows for a more comprehensive evaluation, ensuring that diagnostic accuracy is maintained without unnecessary radiation exposure. In adult populations, the choice between DUS and CTA is influenced by clinical presentation and diagnostic requirements. DUS provides immediate hemodynamic data, making it valuable for the initial assessment of blood flow abnormalities. However, CTA remains the preferred choice in cases requiring precise anatomical delineation, particularly in patients with extensive vascular occlusions or collateral circulation. The ability of CTA to generate detailed three-dimensional reconstructions facilitates preoperative planning and endovascular intervention, making it an essential tool in complex vascular cases (20).

Elderly patients present additional diagnostic challenges due to the coexistence of multiple comorbidities, including diabetes mellitus and hypertension, which contribute to widespread arterial calcification. In such cases, DUS may provide limited diagnostic utility, necessitating the use of CTA for detailed vascular assessment. The capacity of CTA to identify critical limb ischemia and delineate vascular networks underscores its significance in guiding surgical decision-making. The combined use of DUS and CTA represents an optimal diagnostic strategy, where DUS serves as a first-line modality for functional assessment, while CTA provides confirmatory

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anatomical details when initial findings are inconclusive (21). Despite the valuable insights provided by this study, several limitations must be acknowledged. The relatively small sample size may limit the generalizability of findings to broader populations. Additionally, the diagnostic accuracy of DUS is highly operator-dependent, introducing potential variability in test results across different clinical settings. The use of CTA, while advantageous in anatomical assessments, poses risks related to radiation exposure and contrast-induced nephropathy, particularly in patients with renal impairment. Future research should focus on larger, multi-center studies to validate these findings and explore the development of advanced imaging protocols that minimize radiation dose and contrast-related complications. Enhancing practitioner training in DUS techniques can further improve diagnostic consistency, ensuring greater reliability in vascular assessments.

CONCLUSION

Doppler ultrasound and computed tomography angiography serve as essential diagnostic modalities in the evaluation of peripheral vascular disease, each offering distinct advantages based on clinical needs. As a non-invasive and widely accessible imaging technique, Doppler ultrasound is well-suited for initial assessments, providing real-time hemodynamic data and serving as the preferred choice for pediatric and low-risk patients. In contrast, computed tomography angiography excels in detailed anatomical visualization, making it invaluable for complex cases, preoperative planning, and severe arterial pathologies. The integration of both modalities ensures a comprehensive diagnostic approach, enhancing accuracy and guiding appropriate management strategies. By leveraging the strengths of each technique, clinicians can optimize patient outcomes, ensuring timely diagnosis and effective intervention.

AUTHOR CONTRIBUTIONS

Author	Contribution
Alina Sehar*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Ramsha Ashraf	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Maria Fatima	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Urwa Akhtar	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Fariha Saeed	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Muhammad Sibtain	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

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