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Review article

Role of CT Angiography and Doppler Ultrasound in the Evaluation of Peripheral Vascular Diseases: A Review on Diagnostic Challenges and Insights from Special Populations

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Abstract: Peripheral Vascular Diseases (PVD) are a group of diseases that damage or block the blood vessels present outside the heart and brain. The arteries and veins that are affected by these diseases are responsible for carrying blood to the limbs and other peripheral parts of the body. Blood flow is reduced, commonly in the lower body parts, and symptoms such as pain, cramping, numbness, and in severe cases, tissue damage or gangrene result due to these diseases. Atherosclerosis, diabetes, smoking, and hypertension are associated with PVD, and now it has become a threat to public health worldwide. Improved quality of life and reduced risk of cardiovascular events can be achieved by early diagnosis and proper management, and complications can also be prevented. Many individuals are affected by PVD, and it contributes to morbidity and mortality, so it is a global challenge. Doppler Ultrasound and Computed Tomography Angiography (CTA) are the available imaging techniques for evaluating vascular anatomy and hemodynamics, and these are the most widely used external diagnostic methods. The current review provides an overview of the role of CTA and Doppler ultrasound for the evaluation of PVD with special focus on diagnostic challenges in the special population.

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Introduction

Global Burden of Peripheral Vascular Disease

Peripheral Vascular Disease (PVD) is a common circulatory disease that results from the narrowing or blockage of peripheral arteries, mostly due to atherosclerosis. The extent and severity of vascular involvement are determined by the imaging techniques in recent years (Haider, 2023). Non-invasive diagnostic modalities like Computed Tomography Angiography (CTA) and DUS (DUS) are two widely used methods to diagnose it. Arterial or venous obstruction is detected through DUS by evaluating blood flow dynamics. While detailed anatomical visualization of the vessels is acquired through CT Angiography. Treatment planning for patients with PVD is solved by these two methods. Morbidity, disability, and mortality are the results of PVD, also known as peripheral artery disease (Haider, 2023).

The prevalence of PVD continues to increase, especially in low and middle-income countries where hypertension, diabetes, and smoking are widespread, according to recent Global Burden of Disease (GBD) studies (2019–2023) (Kim et al., 2023). More than 200 million people are affected by PVD, with the majority living in underdeveloped regions. The risk of arterial calcification and microvascular dysfunction which further accelerates disease progression in diabetes mellitus, so the disease burden is especially high among individuals with diabetes mellitus and aging populations. PVD is not only the systemic effects of atherosclerosis that reflect widespread vascular involvement, but also causes localized limb conditions. Myocardial infarction, stroke, and cardiovascular deaths are high in patients with PVD. In severe cases, Serious physical, psychological, and socioeconomic consequences can occur in patients with critical limb ischemia and gangrene by limb loss. The advanced imaging modalities are required for early detection and rapid management of PVD because it is also associated with other cardiovascular disorders (Horváth et al., 2022).

Role of Imaging in PVD Diagnosis and Management

PVD diagnosis is managed by imaging. Imaging gives definitive insight into the site, severity, and nature of arterial lesions, and clinical examination and ankle brachial index (ABI) testing often provide initial clues. Clinicians identify treatable disease before irreversible tissue loss occurs by early vascular imaging, so limb salvage rates are improved and overall morbidity is reduced. With unique strengths and limitations, several imaging techniques are now available (Marra et al., 2022). DUS allows immediate evaluation of blood flow, hemodynamic changes, and vessel wall morphology. Accurate measurement of stenoses and occlusions is possible because of CTA, as it gives three-dimensional visualization of the entire arterial tree. Excellent soft tissue contrast is provided by Magnetic Resonance Angiography (MRA), though it is more costly and less accessible, it avoids ionizing radiation. Digital Subtraction Angiography (DSA) is invasive and primarily used for therapeutic interventions, and it is known as the gold standard for vascular evaluation. In contemporary practice, clinical urgency, availability, and patient comorbidities are some factors that determine the selection of an imaging modality. So, comprehensive vascular assessment and informed therapeutic planning depend on the integration of these tools (Sato et al., 2021).

Rationale for Comparing CTA and DUS

CTA and DUS are the most widely used and complementary techniques for evaluating PVD among the available imaging options. Plaque characteristics, calcification, and collateral circulation are visible by CT Angiography. The entire arterial system can be seen by it from the aorta to the distal limb arteries in a single scan, which makes it invaluable for endovascular planning. In contrast, DUS helps clinicians understand real-time hemodynamic patterns without exposing patients to radiation. It is safe, portable, and affordable, which makes it particularly useful in outpatient and bedside settings (Martinelli et al., 2021a). However, the choice between CTA and DUS depends on the patient's individual condition. For example, in older patients and diabetics, hardened or calcified arteries can make it harder for Doppler waves to pass through and give accurate results. Similarly, the contrast used in CTA poses a risk of nephropathy in patients with chronic kidney disease, which makes ultrasound the safer option. Therefore, where accurate diagnosis is more challenging comparing these two methods helps to determine them in different clinical situations (Cantador and Guillaumon, 2024).

Aim and Scope of the Review

In the assessment of PVD, with special focus on their application in diverse patient subgroups, the primary objective of this review is to study carefully the comparative diagnostic roles of CTA and DUS. Basically, this review seeks to clarify how each imaging modality performs under different pathological and physiological conditions, including age-related vascular changes, chronic kidney disease, diabetes, and obesity (Babington et al., 2024). This work aims to highlight both the strengths and limitations of DUS and CTA, so clinicians can select the most appropriate imaging strategy for each patient by synthesizing evidence from recent studies and clinical practice. Moving beyond general comparisons to address real-world complexities, the novelty of this review lies in its focus on diagnostic challenges and population-specific considerations. Ultimately, in optimizing diagnostic accuracy, improving patient safety, and promoting personalized care in the management of PVD, the goal is to provide a comprehensive and practical framework that guides healthcare professionals. Yet, for patients with complex health conditions or unusual vascular anatomy, it is difficult to choose the right technique. So this review explores how both methods contribute to the diagnosis of the disease, along with their limitations (Divya et al., 2023).

Overview of Imaging Modalities

Computed Tomography Angiography

CTA offers a rapid and non-invasive means to visualize arterial anatomy with good clarity and has revolutionized vascular imaging. To generate cross-sectional images that can be reconstructed into detailed three-dimensional representations of blood vessels, this technique depends on X-rays and iodinated contrast media. CTA allows clinicians to assess both the lumen and wall of arteries across extensive vascular territories from the abdominal aorta to the pedal arteries in a single imaging session by acquiring thin-slice images through helical or spiral CT scanning (Serruys et al., 2023).

There is a principle behind CTA that lies in differentiating contrast-enhanced blood from surrounding tissues. The CT scanner captures a series of high-resolution images timed precisely to the arterial phase of contrast flow by following intravenous administration of an iodinated contrast agent. Comprehensive visualization of vessel morphology, stenoses, occlusions, and collateral pathways can be seen by post-processing techniques such as multiplanar reformation (MPR), maximum intensity projection (MIP), and volume rendering. For surgical planning, stent placement, and endovascular interventions, CTA's ability to visualize minor vascular irregularities makes it invaluable (Liao et al., 2022).

Accurate depiction of vessel diameter, wall irregularities, calcifications, and surrounding structures depends on the exceptional spatial resolution of CTA. A complete vascular roadmap, facilitating preoperative mapping and postoperative evaluation, is possible through its three-dimensional reconstruction capability. CTA is faster, less invasive, and often requires lower volumes of contrast medium as compared to conventional angiography (Kumar et al., 2021). Vascular calcification and plaque morphology, which are crucial for determining the stability and composition of atherosclerotic lesions, are assessed through it. CTA's speed and comprehensiveness make it the preferred imaging method in emergency settings such as acute limb ischemia or trauma (Di Serafino et al., 2022).

CTA is not without weaknesses despite its diagnostic power. The patients with chronic kidney disease or dehydration, the primary limitations include radiation exposure and the potential nephrotoxicity of iodinated contrast agents (Baz et al., 2024). Acute kidney injury can occur from the overuse of contrast in vulnerable populations, which can precipitate contrast-induced nephropathy (CIN). Additionally, Overestimation of stenosis can also occur due to heavy arterial calcification, which can obscure luminal visualization. Metallic stent interference, motion artifacts, and high equipment costs that limit accessibility in resource-constrained environments are some other challenges. In addition, Careful patient preparation, including adequate hydration and contrast allergy screening to ensure safety, is required by CTA (Alalawi and Budoff, 2022).

The diagnostic performance and safety profile of CTA are enhanced by technological innovations. Artifacts are reduced and plaque characterization is improved by Dual energy CT (DECT), which has emerged as a powerful tool and is capable of distinguishing between calcium, iodine, and soft tissue (Smith et al., 2021). As compared to conventional CT systems, photon-counting CT is an advanced detector technology that offers higher contrast-to-noise ratios, superior spatial resolution, and reduced radiation doses.

Doppler Ultrasound

For the evaluation of PVD, DUS is one of the most widely used and precious tools. Sound wave reflection is its principle. High-frequency ultrasound waves produced by the transducer are reflected by moving red blood cells within the bloodstream and produce frequency shifts proportional to the velocity and direction of flow (Nguyen and Nguyen, 2023). Then, real-time information on hemodynamics and vessel patency is provided by these Doppler shifts, which are converted into visual and audible signals. Unlike CTA, it is a safe and repeatable imaging option suitable for all patient populations, including pregnant women and those with renal impairment, because it does not require ionizing radiation or contrast agents (Vasconcelos-Berg et al., 2023).

Its ability to offer both anatomic and functional assessment simultaneously is the primary strength of DUS. Detailed visualization of vessel wall structure, plaque morphology, and lumen diameter is provided by B-mode imaging, while spectral and color Doppler techniques detect turbulent flow indicative of stenosis or occlusion and quantify blood flow velocities. DUS is particularly valuable in emergency departments, outpatient clinics, and postoperative follow-up scenarios because it can be performed at the bedside. It is free from radiation-related or nephrotoxic risks and is also cost-effective and widely available. Additionally, DUS makes it possible to evaluate collateral circulation and vascular reactivity dynamically, which is difficult for static imaging methods to capture (Miranda and Carneiro, 2024).

Along with its advantages, diagnostic accuracy is also sometimes affected because DUS has inherent limitations. To obtain and interpret high-quality images, this technique is highly operator-dependent and requires substantial expertise. The underlying lumen may be obscured by acoustic shadowing from extensive calcified plaques, which could result in an incorrect assessment of the severity of stenosis or underestimation. Similarly, ultrasound wave penetration is reduced in obese patients or those with extensive edema, and visibility of deep-seated vessels such as the iliac or tibial arteries becomes limited (Islam et al., 2021). Moreover, although DUS offers a thorough local assessment, it does not provide the same thorough anatomical overview as CTA, which makes it less appropriate for mapping extensive illness or for surgical planning in complicated situations (Malaichamy et al., 2024b).

Current technological improvements have enhanced both image quality and diagnostic confidence and addressed several of these limitations. Contrast-enhanced ultrasonography (CEUS) improves the visibility of small-caliber or low-flow arteries without the nephrotoxicity that comes with iodinated contrast by using intravascular microbubble contrast agents (Chis, 2024). Volumetric visualization of vascular territories and dynamic tracking of blood flow over time is introduced by the development of three-dimensional (3D) and four-dimensional (4D) Doppler imaging. More comprehensive assessment of plaque morphology and flow turbulence is provided by these innovations. Additionally, for automated vessel segmentation, velocity estimation, artifact correction, reducing operator dependency, and improving reproducibility, the use of artificial intelligence (AI) and machine learning (ML) algorithms is increased. Advanced Doppler capacity in portable ultrasound equipment have made vascular imaging more accessible in remote or resource constrained environments, hence increasing DUS's status as a vital diagnostic tool (Bhalke et al., 2022).

Overall, in the evaluation of PVD, CT Angiography and DUS are complementary imaging methods. DUS offers real-time hemodynamic evaluation without the risks of radiation or nephrotoxic contrast, while CTA delivers precise anatomical imaging and detailed vascular representation (Khalifa et al., 2021). The selection of these modalities is based on the diagnostic goals, patient characteristics, and clinical situation. In both fields AI AI-driven image optimization to low-dose contrast protocols promises to further increase their accessibility, accuracy, and safety, opening the way for more precise and personalized vascular imaging by continued technological evolution (Eid et al., 2021).

Diagnostic Challenges and Insights from Special Populations

Diabetic Patients

In diabetic patients, PVD shows one of the most complicated diagnostic scenarios in vascular medicine. Microvascular and macrovascular damage occur when Diabetes mellitus accelerates systemic atherosclerosis through chronic oxidative stress, hyperglycemia, and endothelial dysfunction. Diabetic vascular disease is distinguished from normal atherosclerosis by its early onset, diffuse involvement, and propensity for medial arterial calcification (MAC) (Wiles, 2025). Vessel stiffening without significant luminal narrowing occurs by this unique pathology, deposition of calcium within the tunica media rather than the intima. Therefore, even substantial perfusion impairment, vascular compressibility, and Doppler waveform patterns can appear misleadingly normal. DUS which depends on sound wave transmission and flow velocity patterns to infer stenosis or obstruction, this anatomical and hemodynamic discordance introduces considerable diagnostic difficulty (Sugandh et al., 2023).

From a pathophysiological perspective, medial calcification disrupts the acoustic interface necessary for precise Doppler signal capture, changes pulse wave propagation, and reduces vascular compliance. This results in a higher incidence of false-negative DUS findings in diabetic limbs, especially below the knee. Neuropathy, which decreases ischemic symptoms and microangiopathy and changes the capillary perfusion, exacerbates the issue. Research has indicated that when calcification is present, the sensitivity of DUS for identifying infrapopliteal artery disease may be reduced significantly. Additionally, diabetic patients frequently exhibit small vessel involvement and multilayer illness, both of which exceed the spatial resolution limitations of traditional Doppler systems. Consequently, its diagnostic accuracy in diabetic PVD is naturally weak due to the underlying pathophysiology, although DUS remains an essential first-line method due to its portability and safety (Misra et al., 2023).

In contrast, a Detailed anatomical overview of the entire arterial tree and visualizing both luminal patency and the extent of calcification are obtained by CTA. For endovascular interventions, CTA's cross-sectional and 3D reconstruction capabilities enable precise localization of stenotic segments, plaque morphology assessment and preoperative planning. However, contrast nephrotoxicity is a significant drawback of this resolution's benefit (Kumar et al., 2023). The administration of iodinated contrast material carries a well-established risk of CIN because Diabetic nephropathy is one of the most common microvascular complications of diabetes. Particularly at risk are those whose estimated glomerular filtration rate (eGFR) is less than 60 mL/min/1.73 m². This poses a diagnostic challenge since the people who benefit most from accurate vascular imaging are also the ones who are most vulnerable to contrast-induced kidney impairment (Jin and Ma, 2021).

These safety concerns are overcome by emerging imaging innovations. In diabetic PVD evaluation, DECT technology is a game-changer. DECT can distinguish between calcium, iodine, and soft tissue more effectively, thus decreasing calcium blooming artifacts and improving lumen visualization in calcified vessels by acquiring data at two different X-ray energy levels (Jin and Ma, 2021). Where heavy arterial calcification often masks residual luminal flow, this feature is particularly valuable in diabetics. DECT provides a surrogate marker of tissue perfusion and ischemic risk and also allows iodine quantification. Additionally, iterative reconstruction methods and extremely low contrast protocols have been developed, which drastically lower contrast dose without losing image quality. Together, these developments make CTA a more attractive option, even for diabetic patients with mild to moderate renal impairment, while nephroprotection techniques and hydration regimens are followed (Krishnan et al., 2022).

Conversely, DUS has changed with the emergence of CEUS. In diabetic patients, low-flow distal vessels are affected, so CEUS enhances their visualization. It can monitor tissue perfusion in real time and differentiate between near and total blockage. Evidence suggests that diagnostic accuracy is improved in the tibial and pedal arteries by CEUS, where conventional Doppler shows limited efficacy. For detecting hemodynamically significant stenoses and offering superior safety in high-risk patients, studies have compared CEUS with CTA and showed comparable sensitivity and specificity (Khalifa and Albadawy, 2024).

In diabetic vascular imaging, recent research has focused on the interconnection of AI. AI-powered image analysis can automate plaque quantification, calcium scoring, and vessel segmentation, decreasing human dependence and improving standardized outcomes (Binhowemel et al., 2023). For earlier and more personalized management, these technologies are continuously evolving the diagnostic strategy from descriptive imaging to predictive vascular modeling. Multiple comparative studies highlight that CTA maintains superior sensitivity and spatial resolution in diabetic PVD, mainly for popliteal, iliac, and femoral segments in terms of diagnostic performance. However, for assessing distal flow, vessel patency post-intervention, and dynamic hemodynamics, Doppler and CEUS remain indispensable. The addition of CEUS to standard Doppler increased sensitivity for below-the-knee stenoses from 72% to over 90%, narrowing the gap with CTA in one multicenter evaluation. Thus, rather than viewing the two modalities as competitive, currently best practice focuses on a complementary approach that is CTA or DECT for comprehensive anatomical mapping and preoperative evaluation, and Doppler or CEUS for functional and follow-up assessments (Xi et al., 2024).

Clinically, the individual's vascular status and renal function should match with imaging strategy. CTA remains the gold standard for full limb assessment and treatment planning for diabetics with preserved kidney function. In contrast, DECT is for cases where surgical or endovascular planning needs detailed anatomic definition, while patients with reduced renal reserve or extensive calcification should undergo DUS with CEUS as the primary evaluation. To minimize CIN risk, preventive measures such as pre- and post-scan hydration, the use of low osmolar contrast agents, and renal function monitoring are essential (McBane et al., 2024). Overall, in understanding the diffuse, calcific, and microvascular nature of the disease, the diagnostic challenge in diabetic PVD lies in detecting occlusive lesions. Clinical protocols offer the most effective path forward by combining advanced imaging methods with AI-driven analysis. The ultimate goal of earlier detection, optimized treatment planning, and improved limb salvage in diabetic populations is achieved by this multimodal, patient-centered approach, which ensures diagnostic precision and safeguards renal health (Sadagopan, 2023).

Patients with Chronic Kidney Disease (CKD)

Patients with CKD are at risk for diffuse medial arterial calcification and accelerated atherosclerosis, which changes the vascular landscape. Endothelial dysfunction and arterial wall stiffening occur through the interplay of uremic toxins, oxidative stress, calcium phosphate imbalance, and chronic inflammation. In contrast to normal atherosclerosis, calcification linked with CKD frequently spreads circumferentially across the tunica media, resulting in vascular rigidity and impaired compliance (Zoccali et al., 2023). This vascular phenotype poses major imaging challenges, such as calcified segments disrupting both ultrasound wave transmission and CT attenuation values, and also contributes to increased cardiovascular morbidity and mortality (Lubas et al., 2023). Furthermore, the severity of vascular disease is increased and image analysis is made more difficult by the frequent association of CKD with related conditions, including diabetes and hypertension.

For mapping peripheral arteries and characterizing plaque morphology, CTA is a powerful tool. However, in CKD patients, there is a serious safety concern as it is dependent on iodinated contrast agents. When the eGFR falls below 60 mL/min/1.73m², the CIN is a proven risk. Even minimal contrast doses can trigger acute kidney injury, possibly enhancing progression to end-stage renal disease in advanced CKD (stages 4 and 5). Additionally, image distortion caused by vascular calcification linked to CKD hides the real lumen on CT scans, so it overestimates the severity of stenosis. Eventually, its use in CKD must be carefully justified and strictly controlled, but CTA gives high-resolution anatomical detail (Shan et al., 2024).

DUS is widely recognized as the first-line modality for evaluating PVD in CKD patients, as it addresses the renal safety concerns of contrast-enhanced imaging (Han and Park, 2021a). After revascularization or bypass procedures, it is particularly useful for follow-up imaging. Image quality can be degraded by the presence of dense calcification, deep-seated arteries, and edema, while diffuse multilevel disease complicates segmental analysis. In spite of all that, DUS has great importance in CKD imaging due to its cost-effectiveness, accessibility, and superior safety profile. The role of CT imaging, even in high-risk renal patients, has been expanded by recent research. Vascular imaging is revolutionized by low-contrast and non-contrast CTA protocols, which are supported by AI, hence balancing diagnostic precision with renal safety. By differentiating iodine, calcium, and soft tissue using spectral data, DECT allows imaging with significantly decreased contrast volumes. Even in heavily calcified arteries common in CKD, it minimizes calcium blooming and enhances lumen visualization. Moreover, Iterative reconstruction and AI-based denoising algorithms maintain diagnostic quality at contrast volumes as low as 80 percent by compensating for low signal-to-noise ratios (Han and Park, 2021b).

An emerging advancement, Photon counting CT (PCCT) expands this by providing better spatial resolution and contrast-to-noise ratio, and also lower radiation exposure. In some pilot studies, for patients with severe renal impairment, PCCT produced diagnostic-quality vascular images with ultra-low or even non-contrast techniques, suggesting potential future applications. CT-based imaging can be cautiously reintroduced for CKD patients by these developments, where anatomical mapping is clinically essential (Yamada and Nakano, 2023). Strict adherence to hydration and nephroprotection protocols is important to decrease renal injury when CTA becomes unavoidable. The cornerstone of CIN prevention remains the intravenous isotonic saline hydration, initiated both before and after contrast administration. For less osmotic stress on renal tubules, low osmolar or iso osmolar iodinated contrast agents are preferred. Standard safety practices are limiting total contrast volume, avoiding repetitive contrast studies within short intervals, and ensuring post-procedure renal monitoring. Adjunctive measures such as N-acetylcysteine or sodium bicarbonate hydration may provide additional renal protection in high-risk individuals, though evidence remains variable (Martelli et al., 2024).

By automatically adjusting exposure parameters and contrast injection timing based on patient body composition and cardiac output, safety is further enhanced by AI-assisted imaging. Optimal image acquisition with minimal contrast dose and radiation exposure is ensured by it. CTA can now provide near diagnostic quality even in CKD by integrating these innovations (Cho et al., 2022). Imaging strategy for CKD-associated PVD should follow a risk-stratified, multimodal approach in clinical practice. The primary screening and monitoring tool should be considered the DUS due to its renal safety and functional insights. Before surgical or endovascular intervention, low contrast DECT or AI-assisted ultra-low dose CTA can be considered when anatomical visualization is essential, as long as hydration protocols are strictly observed. High-resolution perfusion imaging without renal toxicity is offered by the CEUS. Ultimately, the most accurate and patient-safe diagnostic framework for CKD individuals with PVD is provided by the integration of functional (DUS/CEUS) and anatomical (low contrast CTA) data (Markewitz et al., 2025).

Obese and Overweight Patients

Obesity and overweight conditions are closely linked with increased risk of PVD and represent a growing global health burden. Chronic low-grade inflammation, endothelial dysfunction, and accelerated atherogenesis are caused by excess adipose tissue through mechanisms involving insulin resistance, dyslipidemia, and oxidative stress. Lower limb circulation is affected by these metabolic changes and results in early onset and more diffuse arterial disease. Obesity brings specific technical and physiological challenges that adversely affect image clarity and technical accuracy during vascular imaging in terms of diagnostic perspective. The distance is increased by the thick subcutaneous fat layers between the transducer or detector and target vessels, hence decreasing signal strength and spatial resolution (Guzik et al., 2021).

Additionally, in patients with a body mass index (BMI) above 35 kg/m² deep deep-seated arteries such as the iliac, femoral, and tibial segments may become difficult to visualize. Furthermore, venous insufficiency, lymphedema, and edema further degrade image quality by scattering ultrasound waves in obesity associated disorders. Optimal probe positioning and angle correction are more difficult in larger body habitus, so operator dependence becomes a critical factor. Studies have reported that, as compared to normal-weight patients, DUS sensitivity for detecting significant stenosis can decline by up to 20 to 30% in obese populations. Despite these challenges, when image optimization strategies are applied, operator expertise and technical improvements can still make DUS a useful tool for targeted evaluation. Additionally, when diagnosing PVD in obese patients, DUS and CTA must be adapted to resolve these limitations (Wellnhofer, 2022).

For obese people, CTA is a useful substitute because it offers deeper tissue penetration and high-resolution anatomical visualization that is unaffected by obesity. The CT scanner’s ability to automatically calibrate for bigger body sizes and change exposure parameters guarantees uniform image brightness and contrast. Unlike ultrasound, from the abdominal aorta to the distal tibial vessels, CTA is not limited by acoustic access and can comprehensively map the entire arterial system. For treatment planning, especially when surgical or endovascular interventions are considered, this is significantly beneficial (Sloan et al., 2022).

However, CTA has challenges for obesity patients. Higher radiation output is required by the increased body mass to achieve sufficient image quality, rresulting in increased radiation exposure. In addition, to maintain optimal vascular enhancement, larger patients often require higher volumes or injection rates, and intravenous contrast administration must be carefully calibrated. The risk of contrast-induced nephropathy is increased in those with comorbid diabetes or CKD by these adjustments. Additionally, as patients get bigger, picture noise may rise, minimizing the contrast between the vessel and the background. However, modern scanners, through adaptive algorithms, automatic tube current modulation, and AI-assisted noise reduction, have solved many of these issues, hence allowing diagnostically acceptable results even in high BMI patients (Jiang et al., 2023).

Now, the diagnostic performance of both DUS and CTA in obese populations has significantly improved. The development of high-frequency and wide-aperture probes has enhanced penetration and spatial resolution in ultrasound imaging, particularly when used with harmonic imaging and tissue-specific contrast settings. Real-time visualization of blood flow patterns, perfusion dynamics, and collateral networks has become more precise with the advent of a dynamic, time-resolved extension of 3D imaging. 4D Doppler provides superior assessment of distal perfusion and microcirculation when combined with CEUS and helps to overcome some of the limitations imposed by body habitus (Kudla et al., 2021).

In CT imaging, for overweight and obese patients, iterative reconstruction algorithms and deep learning-based post-processing have transformed image quality. These AI-driven systems can enhance vessel edges, suppress image noise, and correct beam hardening artifacts caused by large tissue volumes. Signal-to-noise ratios are improved by DECT and PCCT, and allow lower contrast doses and radiation levels. As compared to conventional CTA, studies have shown that PCCT can produce consistent image quality across varying BMI ranges with up to 40% dose reduction. Additionally, now comfortable and safe imaging of patients is enabled by advanced table weight capacities and wider gantry apertures, previously considered too large for standard scanners (Sousa et al., 2023).

A multimodal approach is required for optimal imaging of obese and overweight patients with PVD. Image optimization strategies such as using lower frequency probes, applying compression techniques to reduce tissue depth, and utilizing CEUS or 4D Doppler are essential to improve accuracy, but DUS should remain the initial diagnostic tool. CTA gives superior visualization and should be employed with dose optimization protocols, iterative reconstruction, and contrast injection linked to body weight and renal function when comprehensive anatomical mapping is required. These advanced methods should be prioritized to minimize radiation exposure while preserving diagnostic clarity for facilities equipped with DECT or AI-assisted CT platforms. Ultimately, accurate patient-specific assessment of PVD in obese and overweight populations is ensured by combining the functional strengths of DUS with the anatomical precision of optimized CTA (Probyn et al., 2023).

Elderly Populations

Elderly individuals are more suffered to PVD and it reflects the cumulative impact of aging, endothelial dysfunction, and long-term exposure to cardiovascular risk factors such as hyperlipidemia, hypertension, and diabetes. Arterial stiffening, reduced compliance, and calcific degeneration are caused by vascular aging, which collectively impair perfusion and increase susceptibility to ischemic events. Moreover, multiple disorders are present in elderly patients, including chronic kidney disease, heart failure, and limited mobility, which complicate both disease manifestation and diagnostic imaging. Further, image clarity is disrupted by the presence of severe atherosclerotic calcifications and tortuous vessels, particularly in distal arteries. Reduced tolerance for long procedures, frailty, and cognitive impairment introduce additional barriers to imaging accuracy and patient compliance. For minimized procedural risk, these physiological and logistical factors necessitate careful selection of imaging modality and protocol to achieve accurate diagnosis (Gornik et al., 2024).

In elderly populations, DUS is the first-line diagnostic tool due to its safety, portability, and absence of radiation or nephrotoxic contrast agents. Without imposing physiological stress on frail patients, it allows real-time visualization of blood flow, hemodynamic alterations, and stenotic regions. For immobile or hospitalized individuals, DUS can be performed at the bedside, which makes it especially suitable. Peak systolic velocity and flow direction can be measured by it, which enables functional assessment of anatomical findings (Malaichamy et al., 2024a).

However, DUS in elderly patients also has limitations. Ultrasound wave transmission is degraded by age-related changes such as increased vessel calcification and reduced arterial wall elasticity, leading to shadowing artifacts and reduced visualization of deeper vessels. Image resolution is also disturbed by motion artifacts caused by tremors, involuntary movements, or respiratory variability. Furthermore, constant probe contact is challenging due to weak acoustic windows brought on by skin thinning, oedema, or scarring. Therefore, operator expertise is critical to ensure stability and accuracy. Studies constantly present DUS as an invaluable screening tool for peripheral arterial occlusive disease in the elderly, especially when combined with ABI measurements and waveform analysis to confirm diagnosis, despite these challenges (Kashetsky et al., 2022).

For analysing PVD among elderly patients, CTA provides unparalleled anatomical details and complete three-dimensional mapping of arterial networks from the aorta to the pedal vessels. It precisely defines stenosis, collateral formation, and occlusion, which is important for surgical or endovascular planning. Additionally, CTA helps with simultaneous aortic aneurysm and plaque morphology detection, enabling detailed cardiovascular analysis in one comprehensive scan (Costantini et al., 2024). However, geriatric patients remain particularly susceptible to procedural risks during CTA, and the use of iodinated contrast media raises concern for CIN, especially in those with diabetes, dehydration, or preexisting renal impairment. Age-related reduction in GFR diminishes contrast clearance, thereby increasing the risk of nephrotoxicity. In addition, older patients commonly struggle to maintain adequate breath-hold duration, resulting in motion-related artifacts that decrease diagnostic image quality. Discomfort or agitation is caused by the prolonged positioning on the scanner table and affects compliance. Radiation exposure increases risk in multimorbid patients getting repeated scans, even though it is often low per study (Chen et al., 2023).

Modern CTA protocols now emphasize patient-tailored dose management and procedural efficiency to minimize these risks. Radiation burden is reduced by low-dose acquisition techniques, fast gantry rotation, and iterative reconstruction algorithms while maintaining diagnostic precision. To reduce contrast toxicity, hydration protocols and pre-scan renal function optimization are routinely implemented. The DECT and ultra-low contrast protocols, sometimes combined with AI-based noise reduction, allow diagnostic imaging with significantly reduced iodine dose, sometimes below 20% of standard levels for patients with compromised renal function (Yong et al., 2025).

It's important to balance patient comfort and safety with diagnostic precision when imaging older individuals. This balance is achieved through recent innovations in both CTA and DUS. In patients unable to maintain long breath holds, rapid acquisition protocols and motion correction algorithms have significantly improved image stability in CTA. Modern scanners can capture the entire lower limb vasculature in less than two seconds, equipped with wide detector arrays and high pitch helical modes, and minimize motion blur and procedure duration. By adjusting for motion artefacts and improving the visibility of calcified arteries, AI-assisted image reconstruction further improves clarity (Kosmala et al., 2022).

On the other hand, ultrasound technology has become advanced and expanded its role in elderly vascular assessment. Even in highly calcified vessels, arterial flow can be better visualized with high-frequency linear probes, CEUS, and harmonic imaging. CEUS increases lumen visualization without nephrotoxic contrast, making it best for elderly patients with renal impairment. Connecting the functional anatomical gap between DUS and CTA, the introduction of 3D and 4D Doppler systems also enables dynamic flow evaluation and volumetric vessel reconstruction (Liga et al., 2024).

A hybrid imaging approach offers the best diagnostic yield in elderly populations. DUS plays a role as the initial screening modality, providing hemodynamic information with minimal physiological stress. CTA should be performed using optimized low-dose, fast acquisition protocols when detailed anatomical mapping or intervention planning is necessary. Low contrast or dual energy CT should be prioritized for patients at high nephropathy risk, combined with adequate hydration and renal protection strategies. When CTA is contraindicated, CEUS serves as a valuable adjunct. Ultimately, safe, accurate, and customized vascular assessment in the elderly population is ensured by the combination of different imaging modalities guided by the patient's comorbidity profile, renal function, and mobility status (Martinelli et al., 2021c).

Pediatric and Young Adult Patients

PVD is often linked to congenital abnormalities, inflammatory vasculitides, or genetic disorders, rather than atherosclerosis relatively uncommon in pediatric and young adult populations compared to older adults. Both central and peripheral arteries may experience severe vascular stenosis, aneurysm formation, or occlusion as a result of diseases such as Takayasu arteritis, Kawasaki disease, and fibromuscular dysplasia. As vascular involvement progresses silently until severe ischemic or organ-threatening complications arise, early and accurate imaging is critical in these patients. However, the need to minimize radiation exposure, avoid nephrotoxic agents, and accommodate smaller vessel calibers and patient motion during scans, imaging children and young adults, presents unique challenges. As a result, selecting the right imaging modality requires achieving a balance between long-term health concerns, safety, and diagnostic accuracy (Leeper and Hamburg, 2021).

In children and young adults, DUS is the preferred first-line tool for evaluating peripheral and systemic vascular disease. In the tiny caliber arteries that are characteristic of pediatric anatomy, high-frequency linear transducers provide exceptional resolution, making it possible to precisely visualize stenotic or aneurysmal alterations. For detecting early hemodynamic disturbances in inflammatory or post-reconstructive states, DUS can also evaluate flow velocity, waveform morphology, and turbulence. DUS can identify characteristic segmental narrowing, wall thickening, and reduced flow in the carotid, subclavian, and renal arteries in Takayasu arteritis. Similarly, in Kawasaki disease, during both acute and chronic phases, ultrasound is used to monitor coronary and peripheral artery aneurysms. The portability of DUS allows serial monitoring without radiation risk, which makes it ideal for long-term follow-up of chronic vascular conditions in young patients (Normahani et al., 2021).

DUS is highly operator dependent, and acoustic access may be restricted in thoracic vessels such as the aorta and its major branches or in deeper branches. Turbulent or collateral flow patterns can lead to false positive interpretations in some cases. Moreover, image quality can be degraded because pediatric patients may find it difficult to remain still during prolonged examinations. Nevertheless, DUS can be the cornerstone of vascular assessment in this age group (Martín-Rubio et al., 2024). CTA plays a secondary and necessary role in pediatric and young adult vascular imaging. CTA gives unmatched anatomical detail, enabling comprehensive visualization of complex vascular anatomy, post-surgical grafts or stents, and collateral networks. When rapid whole-body vascular mapping is required in emergencies such as trauma, thrombosis, or suspected aneurysmal rupture, it is particularly valuable. However, radiation exposure remains an important threat in younger patients, because of their increased tissue radiosensitivity and longer life expectancy, and also raises the lifetime cumulative risk of radiation-induced malignancy (Chen et al., 2021).

International guidelines strongly advocate for the ALARA (As Low as Reasonably Achievable) principle in pediatric imaging to address these risks. Without compromising image quality, modern scanners allow substantial dose reduction through low kVp settings, automatic tube current modulation, and iterative reconstruction algorithms. By shortening acquisition time and limiting scanning range to areas of interest, high pitch helical scanning and prospective ECG gating further minimize exposure. In addition, AI-assisted reconstruction and denoising techniques enable ultra-low dose CTA protocols while fine vascular details are preserved. CTA should only be employed when non-ionizing modalities (such as DUS or MRI) are inconclusive or unavailable for pediatric patients with suspected vasculitis or congenital vascular anomalies (Chuter et al., 2021).

The CEUS has emerged as a radiation-free and powerful alternative for vascular evaluation in children and young adults. CEUS provides real-time perfusion imaging with excellent safety even in patients with renal impairment, using microbubble-based contrast agents that remain intravascular and are exhaled via the lungs. It plays an important role in assessing slow flow in distal arteries, evaluating end-organ perfusion, and identifying small aneurysms or mural thrombi. In pediatric renal and mesenteric arteries, CEUS has demonstrated high diagnostic accuracy in detecting stenoses and post-intervention restenosis (Srivastava et al., 2024).

CEUS is especially advantageous in pediatric Takayasu arteritis because it avoids both radiation and nephrotoxic contrast, where repeated imaging is necessary to monitor disease activity and therapeutic response. Similarly, CEUS can delineate coronary and peripheral aneurysms when echocardiography is limited in Kawasaki disease, offering a noninvasive alternative to CTA or MRI. In Europe and Asia, these benefits have led to increasing endorsement of CEUS in pediatric vascular imaging guidelines (Dietrich et al., 2024).

Imaging strategies must prioritize safety, repeatability, and diagnostic yield for pediatric and young adult patients. CEUS provides enhanced sensitivity for perfusion and small vessel assessment without additional risk, while DUS should be the first-line modality for screening, diagnosis, and follow-up. When possible, AI-enhanced low-dose reconstruction is used, while CTA should be reserved for complex or inconclusive cases, which are performed using strict radiation reduction protocols. To minimize motion artifacts during imaging, adequate sedation or distraction techniques may be used (Della Pepa et al., 2020).

Ultimately, in pediatric and young adult patients, a multimodal and individualized approach leveraging the functional advantages of DUS and CEUS with the anatomical precision of low-dose CTA ensures comprehensive, safe, and effective vascular evaluation. Clinicians can achieve high diagnostic confidence while protecting young patients from avoidable long-term harm by adhering to radiation safety principles and exploiting recent imaging innovations (Liu et al., 2021).

Post Surgical or Post Intervention Patients

The most critical and challenging aspects of vascular imaging are post-surgical and post-intervention surveillance in patients treated for PVD. To ensure long-term vessel patency, detect early restenosis and evaluate complications like thrombosis, pseudoaneurysm, or graft failure following procedures such as endovascular stenting, angioplasty, or bypass grafting, timely and accurate imaging is essential. The type of treatment carried out, the arterial region involved, and patient-specific characteristics, including renal function, metal implants, and hemodynamic stability, all influence the choice of imaging methods in this situation. CTA and DUS play complementary roles in postoperative evaluation (Ko et al., 2024).

Due to its outstanding image clarity with accelerated scanning, CTA is widely regarded as the gold standard for assessing stent patency, graft integrity, and post-intervention anatomy. It gives a detailed assessment of the treated segment as well as adjacent vessels that may develop compensatory changes or new lesions. CTA makes it possible to measure aneurysm sacs or bypass grafts in three dimensions and can clearly identify constricted segments, blockages, leaks, and graft bends (Zubair and Lotfollahzadeh, 2025). However, CTA presents several technical challenges in post-surgical settings. Beam hardening and blooming artefacts produced by metallic stents, coils, and surgical clips might mask the actual artery lumen and resemble thrombosis or restenosis. When multiple overlapping stents are present, this is particularly problematic in smaller vessels. Additionally, risks of nephrotoxicity are caused by repeated exposure to iodinated contrast agents, especially in patients with impaired renal function or those requiring serial follow-up imaging (Shwaiki et al., 2021).

Recent improvements are solving these challenges. Now, better separation of metallic components from vascular structures, reducing artifact severity, and improving visualization of stent interiors is possible by DECT and photon counting CT technologies. Image quality is enhanced by AI-assisted post-processing algorithms that automatically correct streak artifacts and reconstruct accurate vessel contours. Research has shown that AI-driven artefact reduction can greatly increase diagnostic confidence in stent evaluation, particularly in peripheral and coronary artery systems. Furthermore, CTA is safer for prolonged surveillance because ultra-low contrast procedures and iterative reconstruction techniques enable recurrent imaging at lower radiation and contrast doses (Necker and Yamamoto, 2023).

After vascular treatments, DUS remains the first-line modality for routine follow up and it offers a safe, noninvasive, and cost-effective means of assessing flow dynamics and graft function. Real-time information is provided by DUS about velocity profiles, turbulence, and flow direction, enabling early detection of restenosis, graft occlusion, thrombus formation, or distal embolization. Serial measurements allow trend-based tracking over time, and peak systolic velocity ratios are quantifiable markers of luminal narrowing (Adiarto et al., 2023).

DUS is particularly valuable in identifying anastomotic stenosis or graft kinking before clinical symptoms arise for bypass grafts. It can detect neointimal hyperplasia, a common cause of in-stent restenosis, by evaluating localized increases in flow velocity in endovascularly treated segments. Additionally, spectral and color Doppler imaging help in distinguishing low-flow stages from actual occlusion, directing prompt reintervention (Liu et al., 2021). Nevertheless, in post-surgical evaluation, DUS has limitations. Deep graft placement, patient obesity, overlying dressings, or postoperative edema affect visualization. Acoustic shadowing and reverberation artifacts may obscure key regions, especially in cases with metallic stents, especially in iliac or femoropopliteal arteries. Despite these limitations, DUS is indispensable for long-term graft surveillance (Tehan et al., 2022).

Modern vascular imaging increasingly adopts hybrid protocols to ensure comprehensive assessment, given the distinct strengths and weaknesses of CTA and DUS. Before structural failure occurs, the integration of functional and anatomical data allows clinicians to identify subtle hemodynamic changes. When detailed anatomical mapping is required for re-intervention planning, a practical approach involves initial DUS screening, followed by CTA confirmation when significant abnormalities are suspected. In complex bypass grafts or multi-level stenting, hybrid imaging is very helpful since DUS gives dynamic flow measurement at critical places and CTA provides panoramic graft path visualization. The CEUS serves as a valuable adjunct, offering detailed perfusion imaging of grafts or anastomoses without nephrotoxic risk in patients with contraindications to iodinated contrast. Low-flow endoleaks and microthrombi that might be overlooked by standard DUS can be found using CEUS (Gao et al., 2022). Another advancement in hybrid imaging is the implementation of AI-enhanced image fusion. During follow-up or interventional procedures, emerging platforms can overlay ultrasound findings onto CT-derived 3D vascular maps in real time, improving spatial orientation. These fusion methods decrease the need for contrast-based imaging while improving diagnostic accuracy (Zhang et al., 2023).

Imaging strategy should follow a stepwise, risk-adapted protocol for post-surgical and post-intervention PVD patients. For the detection of early restenosis or graft dysfunction, DUS should be performed regularly for surveillance at fixed intervals (e.g., 1 month, 6 months, and annually thereafter). CTA should be reserved for cases when precise anatomical visualization is necessary before reintervention or where ultrasound findings are inconclusive. Artefact reduction algorithms, dual energy methods, and ultra-low contrast protocols should be used where CTA is necessary to improve safety and image quality. Combining DUS, CEUS, and optimized CTA guarantees thorough and customized vascular monitoring, reducing procedural risks and optimizing diagnostic precision (Andonotopo et al., 2025).

Patients in Low-Resource or Rural Settings

In low-resource and rural settings, PVD poses a considerable diagnosis and management problem due to limited access to specialized healthcare personnel and advanced imaging equipment. In these regions, the accurate detection of vascular pathology requires imaging strategies that are not only clinically effective but also economically feasible and operationally adaptable. Global imaging equity and accessibility are being promoted by the progressive transformation of vascular diagnostics through the increasing Coordination of telemedicine networks, AI, and portable ultrasound technologies (Lareyre et al., 2023).

In low-resource settings, DUS stands as the first-line diagnostic tool for vascular assessment. The advantages of this method make it particularly valuable in rural clinics and community hospitals, where sophisticated infrastructure and imaging suites are scarce. Batteries or solar energy can power portable ultrasound devices, enabling field-based operation in areas with inconsistent electricity (Hallström et al., 2025). Economically speaking, DUS is much less expensive than CTA or MRA, which makes it appropriate for vascular screening and triage programs at the population level. Compared to CTA in many clinical scenarios, clinical studies have demonstrated that when performed by trained personnel, DUS achieves sensitivity and specificity exceeding 85 to 90% for detecting significant arterial stenosis. In rural healthcare frameworks, its role extends beyond diagnosis to follow-up after revascularization procedures, surveillance of grafts, and assessment of peripheral perfusion, where repeated imaging must be both sustainable and safe (Czap and Sheth, 2021).

However, the diagnostic accuracy of DUS is extremely operator dependent, and patient anatomy, technical proficiency, and environmental factors all affect image quality. To overcome these limitations, healthcare initiatives have implemented training programs for non-specialist practitioners, focusing on fundamental Doppler techniques and vascular interpretation in Africa, South Asia, and Latin America. E-learning modules and online mentorship frequently help these skill-building initiatives, making it possible to provide trustworthy vascular imaging even at remote clinics (Jadhav and Masand, 2022).

In resource-limited environments, technological innovation has revolutionized the potential of ultrasound. High-resolution vascular images can be produced by modern handheld ultrasound systems, which are compact and affordable. These gadgets, which connect wirelessly to smartphones or tablets, are now essential tools for point-of-care assessment in emergency and screening situations. Preprogrammed vascular presets, automatic Doppler waveform analysis, and cloud-based picture storage have all been offered by manufacturers to make their products easier to use for nurses or general practitioners (Li et al., 2024).

The integration of AI and ML algorithms is a transformative addition to this field. Operator dependence is reduced because AI-based software can automatically identify arterial structures, assess flow dynamics, and highlight potential stenoses. Now, remote interpretation platforms allow experts located in tertiary centers to review images in real time, provide diagnostic feedback, and guide local clinicians through teleconsultation. In rural areas, this “hub-and-spoke” model ensures that patients receive specialist-level interpretation without physical referral, significantly shortening diagnostic delays (Golemati and Cokkinos, 2022).

AI-augmented portable ultrasound achieves diagnostic accuracies comparable to conventional hospital-grade equipment demonstrated from field studies. For example, pilot programs in India and sub-Saharan Africa showed that non-specialist users could identify clinically significant arterial disease with over 90% sensitivity, supported by AI guidance and remote expert review. These developments highlight how new technology can address geographic gaps in the provision of diagnostic healthcare. CTA provides detailed anatomical visualization and allows surgeons to map arterial structures, quantify calcifications, and identify collateral circulation information, which cannot be fully captured by DUS. However, high capital and maintenance costs, limited availability of iodinated contrast agents, radiation exposure, and the need for skilled radiographers and radiologists are barriers to CTA (Paraskevas et al., 2024).

In many regions, where DUS is used for initial screening and CTA is reserved for pre-intervention planning or when ultrasound findings are inconclusive, a tiered referral system has been developed. This selective use model increases diagnostic efficiency while preserving limited resources. Additionally, to reduce radiation and contrast risks, low-dose and low contrast CTA protocols, often guided by AI-based reconstruction techniques, are being explored, hence further broadening CTA's feasibility in intermediate resource hospitals (Nurmohamed et al., 2024). A larger problem of healthcare injustice is brought to light by the differences in access to vascular imaging. PVD is routinely diagnosed using multimodal imaging pathways in high-income countries, while in low-resource regions, many cases remain undetected until advanced stages, contributing to high rates of limb amputation and cardiovascular mortality. This gap requires global strategies to focus on diagnostic accessibility, training, and technology dissemination (Miceli et al., 2022).

The use of portable ultrasound systems in underserved communities is increased by international collaborations between academic institutions, non-governmental organizations (NGOs), and industry partners. For example, the imaging Initiative emphasizes the integration of vascular ultrasound screening into community health campaigns for diabetes and hypertension, the two major risk factors for PVD, by the programs led by the World Health Organization and the global health. These efforts reduce the economic burden associated with late-stage vascular interventions and promote preventive healthcare and early detection (Francis et al., 2024).

Moreover, telemedicine, cloud-based data sharing, and AI-assisted ultrasonography are redefining egalitarian imaging. Local clinicians can now conduct vascular assessments and receive expert confirmation within minutes, with proper infrastructure, regardless of geographic isolation. This system improves diagnostic precision while enabling local health systems to function independently and sustainably (Ukoaka et al., 2024). Ultimately, in vascular care, achieving imaging equity requires a holistic approach, one that integrates technology innovation, global policy support, and workforce training. The global medical community can ensure that patients in low-resource and rural areas receive timely, accurate, and lifesaving vascular diagnostics, narrowing one of the most persistent divides in modern medicine by expanding access to DUS and utilizing the potential of AI-driven tele-imaging (Zhang et al., 2023).

Comparative Diagnostic Accuracy and Clinical Utility

For the diagnosis and management of PVD, accurate imaging is central as it defines the extent and severity of arterial involvement, guides revascularization strategies, and monitors post-procedural outcomes. DUS and CTA are the two most widely used methods, which offer distinct diagnostic strengths that complement one another. CTA delivers high-resolution anatomical mapping essential for surgical or endovascular planning, while DUS provides real-time assessment of hemodynamics and vessel patency. Many comparative studies and meta-analyses have shown the sensitivity, specificity, and overall diagnostic accuracy of both methods against DSA, which remains the gold standard. For optimizing patient outcomes, minimizing risk, and ensuring cost-effective care, understanding their relative performance and appropriate clinical use is crucial (Gao et al., 2022).

For the diagnosis of lower extremity arterial disease, multiple meta-analyses and systematic reviews have compared CTA and DUS, hence revealing a general trend of high diagnostic concordance between the two methods. Superior spatial resolution and remarkable precision in visualizing calcifications, stenoses, and collateral circulation are demonstrated by CTA. The CTA achieves sensitivity values between 94 to 98% and specificity between 92 to 97% for detecting hemodynamically significant stenosis (≥50%) when compared with DSA suggested by the Pooled data. CTA's dependability in ruling out serious illness is confirmed by the fact that its negative predictive value (NPV) frequently surpasses 95% and its positive predictive value (PPV) is usually above 90% (Parwani et al., 2023).

On the other hand, DUS performs well as a noninvasive and cost-effective screening tool. DUS achieves sensitivity rates of 85 to 92% and specificity of 83 to 90% across different vascular territories indicated by meta-analysis. DUS accuracy is comparable to CTA for femoropopliteal segments, where acoustic windows are advantageous. However, its performance may decline in deeper or calcified vessels such as tibial or iliac arteries due to signal attenuation and operator limitations. Despite this, DUS is nevertheless very useful in clinical practice since it detects blood flow velocity and turbulence directly, which indicates the severity of physiological rather than just structural diseases (Martinelli et al., 2021b).

Technological evolution is another important consideration. Even in heavily calcified vessels, recent advances in dual-energy CT and AI-based image reconstruction have significantly improved CTA's diagnostic precision. Similarly, DUS's capacity to distinguish intricate flow patterns and microvascular perfusion has been improved by CEUS and 3D Doppler imaging. As a result, the diagnostic gap between CTA and DUS is progressively narrowing, particularly with experienced operators and modern equipment (Giordano et al., 2022). CTA consistently exhibits higher interobserver agreement (κ values 0.8–0.9) compared to DUS (κ 0.6–0.75) in clinical validation studies, highlighting CTA's superior reproducibility. However, DUS continues to have a significant benefit in long-term monitoring, enabling repeated evaluations without exposure to radiation or contrast. Therefore, the available data support a hybrid diagnostic approach in which CTA is saved for situations needing precise anatomical mapping or intervention planning, while DUS is used as the first line of treatment (Sorour et al., 2024). The choice between DUS and CTA is rarely binary in real-world clinical settings. Rather, it is determined by clinical presentation, patient comorbidities, the availability of resources, and the goals of the diagnosis.

In patients presenting with intermittent claudication, critical limb ischemia, or non-healing ulcers, DUS is typically employed as the initial imaging test. It can be performed at the bedside in acutely ill or immobile patients and is readily available. When serially monitoring bypass grafts and stents, DUS is especially helpful in detecting thrombus formation or restenosis without the dangers of contrast chemicals. DUS represents the safest option for patients with CKD, iodine allergy, or pregnancy. However, CTA becomes fundamental when detailed mapping of the arterial tree is needed, such as for endovascular or surgical revascularization. CTA provides the necessary detail for procedural planning in patients with multilevel disease or inconclusive ultrasound results. CTA's speed and accuracy are critical for prompt decision-making in emergency settings, such as acute limb ischemia (Antonopoulos et al., 2022).

Conclusion

The PVD is a growing global health concern that needs early and precise diagnosis to avoid potentially deadly and limb-threatening cardiovascular events. This review emphasizes that DUS and CTA are both important imaging modalities, each with special benefits that make them complementary rather than competitive. Unparalleled anatomical resolution, three-dimensional vascular mapping, and precise visualization of stenosis, occlusions, and calcified plaques, qualities that are invaluable for surgical and endovascular planning, are provided by CTA. On the other hand, DUS provides real-time assessment of hemodynamics, vessel patency, and flow turbulence, and also a radiation-free, bedside, and cost-effective diagnostic option suitable for screening and longitudinal follow-up.

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