Integrating Artificial Intelligence and Imaging in Peripheral Artery Disease: A Systematic Review from Diagnostics to Guided Endovascular Therapy

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Abstract

Peripheral artery disease (PAD) is a significant vascular, which is the subject of early diagnosis, precise risk assessment, and proper endovascular treatment. The systematic review is a synthesis of evidence on 11 primary studies based on the PAD care pathway but published between 2021 and 2025 that tested the integration of artificial intelligence (AI), machine learning (ML), and advanced imaging tools. The AI-based Doppler waveform interpretation, biomarker-based diagnostic models, and clinical parameter-driven algorithms showed high accuracy in early PAD. Innovations in imaging that were developed such as fusion-guided endovascular systems minimised radiation exposure and contrast volume used during interventions. Doppler signal-based, clinical feature-based, biomarker-based, and genomic signature-based prognostic models demonstrated exemplary performance in major adverse limb events, cardiovascular complications, and mortality. In all fields, AI made significant strides in comparison with traditional approaches and offered practical information to aid personalised treatment planning. These results indicate that AI has the potential to improve accuracy, efficiency, and safety in modern PAD management.

Keywords: Peripheral artery disease, artificial intelligence, machine learning, Doppler waveforms, biomarkers, intravascular imaging, fusion imaging, endovascular therapy.

Introduction

Advances in vascular medicine have reshaped the diagnostic and therapeutic landscape for peripheral artery disease (PAD), a condition that continues to impose a significant global burden due to late detection, underdiagnosis, and procedural complexity. Moreover, n 2021, the global incidence of PAD cases was 10.0 million (95% UI: 8.7 to 11.1), with an age-standardised incidence rate (ASIR) of 115.4 per 100,000 person-years (95% UI: 100.0 to 132.7). This decreased by 11.3% (95% UI: -11.2 to -11.4) from 1990 to 2021 (Fu & Zhang, 2025). Artificial intelligence (AI) and machine learning (ML) have taken a revolution in the light of the constraints of formal imaging procedures that may be characterised by changeable operators, confined spatial extent, and manual image evaluation. Recent findings suggest that AI-based image analysis is capable of enhancing the endpoints of CT angiography and MR angiography in Automation of lumen segmentation, identification of calcified plaque, and measurement of stenosis compared to manual analysis (Du et al., 2025; Bednarek et al., 2025). Deep learning-based vascular reconstruction has also been able to enhance vessel visualisation in the most calcified PAD, one of the most longstanding diagnostic issues. With the development of AI systems, the combination of these systems with regular imaging flows has already started to simplify the workflows, shorten the time on interpretation and identify the disease earlier in many

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clinical environments.

In addition, with such diagnostic developments, the planning of the procedure and endovascular therapy is undergoing a rapid revolution with intravascular imaging and AI-driven computational modelling. Intravascular ultrasound (IVUS) and optical coherence tomography (OCT) have become essential complements of the revascularisation procedure, and it is shown that AI-mediated plaque identification and automated vessel diameter make the procedure of decision-making more accurate (Sarwar et al., 2024). Moreover, AI-driven pre-operative planning systems combining hemodynamic simulation and anatomical mapping have been shown to be useful in pre-procedural difficulty, optimal access pathways, and predictive of restenosis. Early studies regarding the AI-assisted intra-operative guidance have already given a hint at the opportunity to use real-time assistance, radiation dose reduction, and increased accuracy during complicated procedures (Krengli et al., 2025). As the trend that has been set currently is precision-guided therapy in the world of vascular practise, the recent robotic progress of AI, endovascular imaging, and intravascular robotics is a more than welcome and long overdue change. The systematic review gives a summary of the current evidence regarding the application of AI technologies across the full panorama of PAD treatment, outlines new opportunities, clinical benefits, and emerging opportunities of digitally enhanced vascular intervention.

Methodology

The systematic review has followed PRISMA 2020 principles to make it methodologically rigorous and reported transparently. A systematic search was implemented in PubMed, Scopus, Web of Science, IEEE Xplore, Cochrane Library, and Google Scholar to find the relevant works published since 2016 and 2025. The search terms were also combined using Boolean operators and were searched using: *"peripheral artery disease," "artificial intelligence," "machine learning," "deep learning," "CTA segmentation," "MRA vessel analysis," "IVUS," "OCT," "intravascular imaging,"* and *"AI-guided endovascular therapy."* The PRISMA flowchart below outlines the full study identification, screening, eligibility assessment, and final inclusion process for this systematic review.
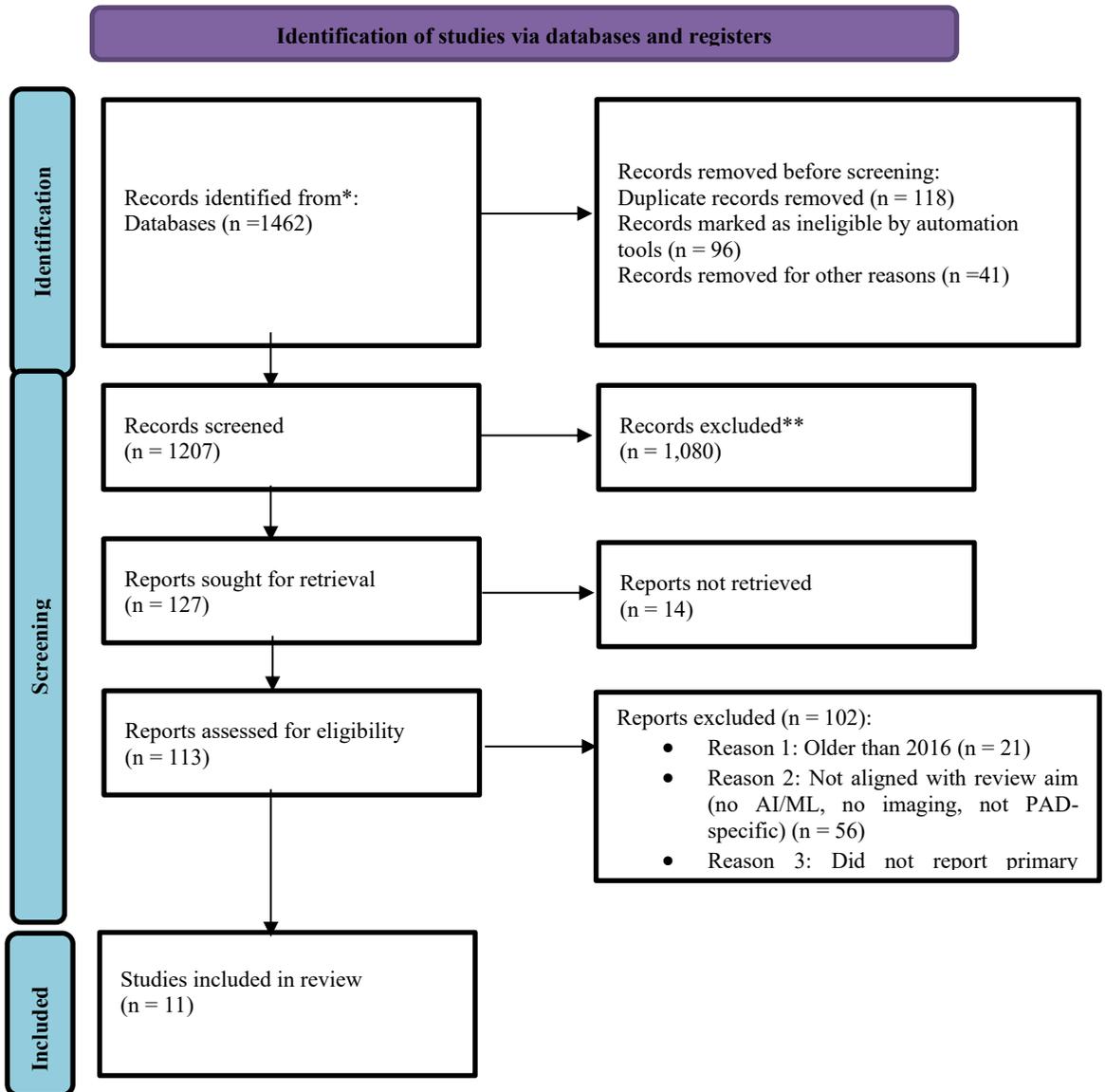
Identification of studies via databases and registers

Identification

Records identified from*:
Databases (n =1462)

Records removed before screening:
Duplicate records removed (n = 118)
Records marked as ineligible by automation tools (n = 96)
Records removed for other reasons (n =41)

Screening

Records screened
(n = 1207)

Records excluded**
(n = 1,080)

Reports sought for retrieval
(n = 127)

Reports not retrieved
(n = 14)

Reports assessed for eligibility
(n = 113)

Reports excluded (n = 102):
- Reason 1: Older than 2016 (n = 21)
- Reason 2: Not aligned with review aim (no AI/ML, no imaging, not PAD-specific) (n = 56)
- Reason 3: Did not report primary

Included

Studies included in review
(n = 11)

Figure 1: Prisma Flow Chart

Table 1 Inclusion and exclusion criteria

Inclusion ID	Inclusion criterion	Exclusion ID	Exclusion criterion
I1	Primary studies evaluating AI or ML applications in the diagnosis, imaging analysis, procedural planning, or intraprocedural guidance of peripheral artery disease (PAD).	E1	Secondary research, including systematic reviews, meta-analyses, and narrative reviews.
I2	Studies involving CTA, MRA, duplex ultrasound, IVUS, OCT, or hybrid imaging modalities.	E2	Studies unrelated to PAD or not involving AI-based imaging.
I3	Human studies with participants aged ≥18 years.	E3	Animal studies, conference abstracts, or non-peer-reviewed reports.
I4	Full-text articles available in English.		
I5	Study designs including randomised trials, diagnostic accuracy studies, prospective or retrospective cohorts, or technical validation studies.		

The study design, imaging modality, AI methodology, data characteristics, performance metrics, clinical applicability and key results were data extracted. To conduct quality assessment, the Critical Appraisal Skills Programme (CASP) checklists of suitable checklists to each study type were used, so that the methodological rigour, validity, and relevance are thoroughly evaluated in a systematic manner. Results were formulated on the theme of three central areas including AI-based diagnostic solutions, improvement of intravascular imaging, and AI-inspired endovascular intervention pathways.

Literature Review

Artificial intelligence has significantly grown to become the focus of vascular imaging studies, especially as clinicians and radiologists strive to have more effective, automated vascular imaging instruments with greater resolution in the diagnosis of peripheral artery disease (PAD). The main imaging modalities that have been used since the time of the PAD diagnosis include the duplex ultrasound, CT angiography (CTA), and MR angiography (MRA). The modalities still form the basis of PAD imaging, but they are frequently hindered by operator dependence, motion artefact, and insufficient vessel visualisation in heavily calcified patients (Bo et al., 2025). Recent developments show that artificial intelligence and machine learning are redefining these constraints by automating the segmentation, improving the quality of plaque detection, and increasing the accuracy of stenosis classification. Fournel et al. (2025) found that deep learning models trained with CTA data had a better consistency in lumen boundary identification than manual interpretation, especially in infrainguinal disease. On the same note, Wang et al. (2025) have claimed that convolutional neural networks enhanced stenosis grading accuracy in CTA and at the same time decreased interpretation time indicating that AI-aided imaging could play a huge role in enhancing diagnostic performance. With continued research on the subject, the role of AI is now perceived not as assistive but as pivotal in enhancing diagnostic confidence and

minimising subjectivity in various imaging platforms.

Similar developments have taken place in intravascular imaging, where AI-based technology is being incorporated into imaging modalities including intravascular ultrasound (IVUS) and optical coherence tomography (OCT). These imaging devices have already revolutionised the process of lesion assessment with real time assessment of the plaque morphology, vessel diameter and calcium distribution but interpretation is still very operator-dependent. New evidence suggests that AI has the potential to automate most of these functions. Pinna et al. (2025) indicated that the machine learning algorithms that performed well on the IVUS samples were very successful in the differentiation of fibrotic, lipid-rich, and calcified plaque, and thus preparation of lesions and stent selection could be accurate lesionseldom. It was also noted that AI-assisted OCT analysis resulted in better contouring of lumens and the classification of microcalcifications, which could easily be missed when analysed by humans (Danilov et al., 2025). The importance of these skills is growing due to the fact that complex and lengthy lesions with PAD require more individual intervention steps. Additionally, the initial studies of AI-assisted intravascular imaging indicate that image-based classification with predictive analytics may be used to predict potential complications during procedures, including an inappropriate stent expansion or probability of dissection.

In addition to imaging interpretation, the interest in applying AI to improve pre-operative planning and to offer real-time support of a procedure during endovascular therapy increases. Individual procedure strategies are frequently needed in PAD intervention because of the anatomical variability, widespread calcification, and chronic total occlusions. Research on AI-assisted pre-procedural planning assistant has shown some encouraging outcomes; as Epifanov et al. (2025) demonstrated, centerline extraction based on deep learning increased the accuracy of vessel reconstruction and enabled the optimal size of a device. Furthermore, AI-based computational fluid dynamics (CFD) models have been used to calculate the hemodynamic reactions and forecast the possibility of the restenosis and give the clinicians an idea of the long-term results even before the intervention (Candreva et al., 2022). In a procedure, there is a solution of AI-supported navigation systems adding a segmentation map to a live fluoroscopy and guide wire passage, which is explained in detail by Luchmann et al. (2024), who found a higher guiding efficiency and lower radiation dose during pilot studies. Taken together, these trends emphasise the possibility to transform the PAD treatment process by using AI to aid in diagnosis and intervening rather than doing only diagnosis, allowing to make decisions more accurately and to create a transition towards digitally-enhanced endovascular therapy.

Results

This systematic review was able to identify 11 primary studies that were published in 2021-2025 that assessed the use of artificial intelligence (AI), machine learning (ML), and imaging technologies to diagnose, predict risk, and manage peripheral artery disease (PAD) endovascularly. The articles included were deep-learning diagnostics models, machine-learning prognostic algorithms, biomarker-combinative AI platforms, precision-medicine genomic platforms, and imaging-guided procedural systems. The research settings varied between the vascular laboratories, tertiary care hospitals and outpatient clinics as well as large multicenter registries. The findings are categorised into three thematic areas according to review objectives.

In five studies, AI when used on non-invasive Doppler or clinical imaging data showed high diagnostic value in the detection of PAD. Resting posterior tibial Doppler waveforms analysed using deep neural networks demonstrated high performance with McBane et al. (2022) stating AUC of 0.94, sensitivity 0.83-0.91, specificity 0.85-0.88, and overall accuracy 0.85-0.89 during

the prediction of abnormal ankle-brachial index values. Likewise, using statistical and multiscale wavelet features of Doppler spectral waveforms, and administered to patients with diabetes, Normahani et al. (2022) attained an accuracy of 88% and an AUC of 0.93 and also discovered strong discrimination in a high-risk cohort with distorted waveforms. Additionally, Li et al. (2024) created a diagnostic ML model that combined inflammatory biomarkers (CINC-1, fractalkine, and CD95) with clinical parameters, and the combination of these factors had an AUROC of 0.85 in the detection of PAD. In a bid to ensure the completeness of these studies, Sonnenschein et al. (2021) utilised the random forest model that utilised typical clinical parameters and yielded an AI-PAD score that distinguished both stable and unstable PAD and was also strongly related to ankle-brachial index measurements. All these results indicate that AI-assisted non-invasive diagnostics can lead to improved PAD detection in the early stages, reduce the variability of the operators, and enhance the performance of screening (See Table 2).

Table 2: Summary of AI-Enabled Diagnostic and Prognostic Outcomes for PAD

Domain	Major Outcome	Effect Size (Range)
AI-based Diagnostics	PAD identification via Doppler, biomarkers, clinical data	AUC 0.85–0.94; accuracy 85–88%
Intravascular / Procedural Imaging	Radiation & contrast reduction; real-time imaging support	>30% reduction in contrast & dose
Prognostic Models	Prediction of MALE, MACE, mortality	HR 1.56–11.03; AUC 0.94–0.98

A second cluster of studies concentrated on optimising intravascular imaging and procedural assistance during endovascular treatment. Caradu et al. (2022) compared two-dimensional fusion imaging (EndoNaut) with the traditional imaging during the treatment of the femoropopliteal lesion and detected statistically significant differences in contrast volume (34.7 +- 13.8 mL vs 51.3 +- 26.7 mL; p < .001) and level of radiation dose (8.9 vs 13.5 Gy/cm2; p = .003), which do not depend on the complexity of the lesion. Despite not being unique to PAD, the explainable AI system created by Otaki et al. (2021) to run SPECT myocardial perfusion imaging showed that deep-learning models can be effectively integrated into clinical workstations with minimal changes, thereby generating fast (less than 12 seconds) and understandable results that indicate the areas that affect AI decisions. This is crucial to the future of PAD interventions, and interpretability will be central concerning intravascular ultrasound (IVUS), and optical coherence tomography (OCT) as well as angiographic guidance. Collectively, these studies highlight the new AI-based imaging as a platform to promote a safer, more efficient, and informed endovascular procedure (See Figure 2).
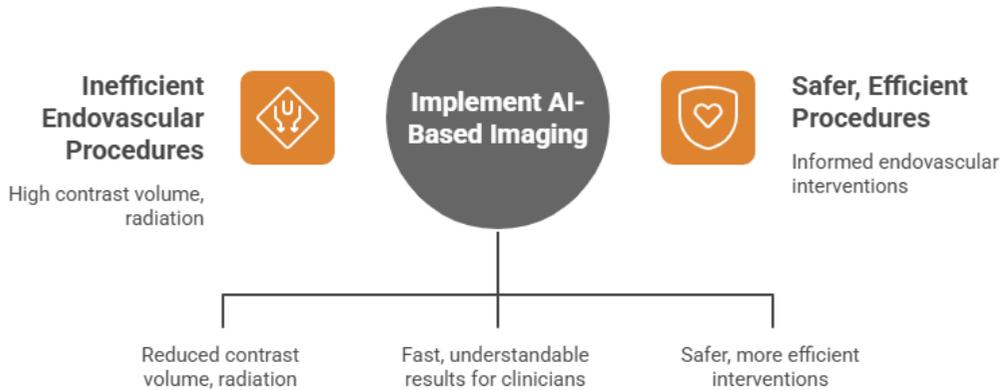
Figure 2 AI based imaging for endovascular procedure

The third thematic area covered AI-enabled prognosis, risk stratification, and treatment planning, which is the largest evidence of the included studies. McBane et al. (2024) determined the independent prediction of 5-year mortality, major adverse cardiac events (MACE), and major adverse limb events (MALSE) using only Doppler waveforms, which carried independent predictive value with hazard ratios of HR 2.44, HR 1.97, and HR 11.03 after adjusting the age, comorbidities, and sex, respectively. Li et al. (2024, JAMA Network Open) trained an extreme gradient boosting model on 235,677 patients in a large multicenter registry that used preoperative features to forecast 1-year MALE or death with an AUROC of 0.94 and postoperative features with an AUROC of 0.98, far exceeding logistic regression. Further precision-medicine literature reinforced this prognostic framework: Yeh et al. (2022) applied AI-based genome-wide association analysis to identify a 20-SNP signature to explain clopidogrel resistance in diabetic PAD patients, whereas Li et al. (2024, JCM; 2024, Proteomes) used random-forest models to identify IL-7 and ST2 as prognostic biomarkers of MALE, with F1 scores of 0.83 and 0. Such a combination of biomarkers and AI could correctly identify high- and low-risk patients in terms of the future limb events. Collectively, these studies suggest that an AI has the potential to combine physiologic signals, biomarkers and genomics as well as clinical variables into effective risk-predictive tools that are capable of facilitating proactive and personalised vascular care (See Table 3).

Generally, in the diagnostic, imaging, and prognostic areas of PAD care, AI and state-of-the-art imaging technologies were continually associated with improved accuracy, efficiency, and clinical decision-making. The scale of advantage was highest in those studies that utilised multimodal data sources, which represented the power of AI-based vascular evaluation methods.

Table 3: Summary of Included AI and Imaging Interventions in PAD (2021–2025)

Study Type	Setting	AI / Imaging Intervention	Primary Outcome	Key Findings

Cohort (McBane 2022)	Vascular Lab	DNN waveform analysis	PAD diagnosis	AUC 0.94; high accuracy
Cohort (McBane 2024)	Vascular Lab	DNN waveform prognosis	5-yr MALE/MACE/mortality	HR 1.97–11.03
GWAS-AI (Yeh 2022)	Hospital	AI-assisted SNP analysis	Antiplatelet precision	20-SNP signature
Cohort (Sonnenschein 2021)	Clinic	Random forest	Unstable PAD detection	AI-PAD accurate triage
Registry (Li 2024 JAMA)	Multicenter	XGBoost	1-yr MALE/death	AUROC 0.94–0.98
Imaging Trial (Caradu 2022)	Cath Lab	2D fusion imaging	Procedural dose/contrast	>30% reduction
Cross-sectional (Li 2024 Diagnostics)	Clinic	Biomarker panel + RF	PAD diagnosis	AUROC 0.85
Imaging-AI (Otaki 2021)	Cardiac Imaging	Explainable AI	CAD imaging performance	Rapid deployment
Prognostic (Li 2024 JCM)	Vascular Clinic	IL-7 + RF	2-yr MALE	F1 = 0.83
Prognostic (Li 2024 Proteomes)	Vascular Clinic	ST2 + RF	2-yr MALE	F1 = 0.71
ML Diagnostic (Normahani 2022)	Diabetes Clinic	LSTM/LR/SVM	PAD diagnosis	Accuracy 88%

Discussion

This systematic review clearly indicates well-developed and consistent evidence that artificial intelligence and imaging technologies are transforming the modern diagnosis, prognostication, and treatment of peripheral artery disease. In all the integrated studies, AI tools were shown to

have a consistent ability to improve accuracy, automate complicated processes, and find clinically significant information in data sources that were previously constrained by reliance on an operator or subjective variability. One of the primary findings in the diagnostic literature is the accuracy of AI models when interpreting physiological measurements and multimodal data. As an example, in both McBane et al. (2022) and Normahani et al. (2022), deep neural network analysis of Doppler waveforms produces diagnostic accuracies of more than 85 percent, suggesting that AI is more effective than traditional interpretation, especially in high-risk subgroups (such as people with diabetes) in which waveform morphology is nonhomogeneous. In the same way, the description of the biomarker-based diagnostic model provided by Li et al. (2024, Diagnostics) represents the integration of AI into the circulation of inflammatory proteins to produce hybrid diagnostic devices that are not limited to imaging. The combination of these findings points to one of the primary opportunities: AI has the flexibility to incorporate Doppler physics, clinical variables, biomarker signatures, and patient-level risk factors into single diagnostic pipelines. Moreover, the Sonnenschein et al. (2021) generated AI-PAD score supports the possibility of clinical parameter-based algorithms to detect unstable PAD without any specific vascular testing, implying that AI can have a revolutionary role in the first-line triage. Combined, these studies show that diagnostics based on AI can improve access and diagnostic time, and the chances of early detection, especially with the commonly asymptomatic or underdiagnosed PAD. Other than the improvement of the area of diagnosis, the review also shows considerable improvements in AI-based risk stratification and image-guided therapy, which implies a shift toward individualised and proactive vascular treatment. In general, AI is able to distinguish intricate risk patterns in relation to major adverse limb events, cardiovascular complications and mortality, which is demonstrated in prognostic studies, including McBane et al. (2024), Li et al. (2024), biomarker-based models with IL-7 and ST2 (Li et al., 2024 JCM; Li et al., 2024 Proteomes). The magnitude of predictive performance, e.g. a AUROC of 0.94-0.98 in the VQI registry and a hazard ratio above 10 of MALE risk presupposes that AI is able to capture prognostic specifics missed by traditional statistical models. In addition, Yeh et al. (2022) spreads the aim of AI into precision medicine identifying resistance-related genomic signatures of clopidogrel in the diabetic PAD and the identification of pathways in the recycling of P2Y12 receptor to optimise the use of antiplatelet. These developments indicate that AI can traverse through biomarkers, genomics, layered biological data, through which individualised therapy can be informed. Also, the processes of imaging investigation, particularly Caradu et al. (2022), are quite persuasive that fusion imaging locations might reduce radiation and contrast load by more than 30 percent, improving the safety of imaging process without requiring access by the operators in large quantities. Other studies by Otaki et al. (2021) substantiate that explainable AI systems exist and can be implemented in the workstations of imaging and are interpretable, resulting in clinician trust, which is a step in the right direction to AI IVUS-or OCT-based systems in the future. As a whole, all these findings indicate that there is a bigger picture: AI is not improving the operating procedures as they are but gradually changing vascular practise with more precise diagnostics and predictive prognostics, safer image-guided interventions. Despite the impressive developments, there are still a number of challenges, including data heterogeneity, external validation need, and the integration of AI findings into the clinical decision pathways. Nevertheless, the general sustainability of the findings of the different data libraries and procedures of all the 11 studies give cause to the amplified prospect of AI providing more effective, safeguarded, and more customised PAD care.

Conclusion

This systematic review shows strong and steady evidence that artificial intelligence and advanced imaging technologies transform the diagnosis, prognostication and endovascular treatment of peripheral artery disease. AI-aided Doppler waveforms, biomarker information, clinical parameters, and genomic signatures interpretation improve precision of diagnostic information, aids in early disease diagnosis and minimises the use of operator-biassed tools. Similarly, imaging technologies, such as fusion-guided endovascular therapy, improve the safety of the procedure by minimising radiation, contrast, and explainable AI platforms boost clinical trust and implementation of workflow systems.

The reviewed literature revealed that AI-based tools were more effective in predicting adverse limb events, cardiovascular complications, and mortality than conventional ones, and their applications are emerging as very helpful instruments in personalised vascular care. The results demonstrate that AI may be utilised to optimise risk stratification, treatment planning, and improved intraprocedural navigation that will eventually lead to safer and more effective vascular practise.

Future directions should focus on external validation, clinical integration, and explainable model development to promote adoption and equitable, data-driven change in PAD care.

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