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Case Report

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Artificial Intelligence in Vascular Surgery: Hype, Evidence, and Future Prospects

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Abstract

Artificial intelligence (AI) is rapidly advancing across surgical disciplines, and vascular surgery is now entering a period of accelerated integration. Recent developments in machine learning (ML), deep learning (DL), and computer vision have improved vascular imaging interpretation, endovascular planning, postoperative surveillance, and wound care. Large registry-based studies published between 2023 and 2025 demonstrate that ML models outperform traditional risk scores in predicting outcomes after endovascular aneurysm repair (EVAR), open and endovascular peripheral artery disease (PAD) interventions, and aortic surgery. DL-based imaging models have achieved high accuracy for endoleak detection, aneurysm segmentation, plaque characterization, and classification of diabetic foot ulcers (DFU), while mobile-enabled AI platforms show promise for remote surveillance and early identification of complications.

Despite this progress, translation into routine vascular practice remains limited. Key barriers include limited external validation, data heterogeneity, model bias, integration challenges, the need for explainability, and evolving regulatory requirements. This review synthesizes the most recent evidence (2023–2025), evaluates clinical readiness across major vascular domains, and outlines ethical, operational, and regulatory considerations. Widespread adoption will require robust multicentre evaluation, multimodal data integration, interoperable infrastructure, and coordinated surgeon–engineer collaboration. AI promises significant enhancements to diagnostic accuracy, risk prediction, and postoperative management, but its safe implementation demands rigorous governance and ongoing validation.

1. Introduction

Vascular surgery requires precision in diagnostic imaging, operative planning, and postoperative surveillance. Artificial intelligence (AI), particularly ML and DLmodels, has shown potential to enhance each of these domains. In radiology, ophthalmology, oncology, and dermatology, AI systems have already achieved clinical incorporation, improving workflow efficiency and diagnostic accuracy. In vascular surgery, however, progress has historically been slower due to disease heterogeneity, imaging variability, and scarcity of large standardized datasets [1].

Since the first dedicated systematic review of ML in vascular surgery in 2022, the field has witnessed rapid expansion. Recent high-quality studies have evaluated AI for automated CTA segmentation, endoleak detection after EVAR, prediction of major adverse limb events (MALE), and optimization of limb salvage pathways. Deep learning–based DFU tools have reached real-world pilot testing, and registry-based ML models have shown improved discrimination over traditional regression-based risk scores for both open and endovascular procedures.

However, despite rapid development, real-world implementation remains limited. Concerns related to data quality, algorithmic bias, generalizability, transparency, and regulatory approval persist. This updated review evaluates the most recent studies from 2023 to 2025, consolidating emerging evidence for imaging, predictive modeling, robotics, wound care, and telemedicine in vascular surgery. It further outlines ethical considerations and practical steps necessary for safe, equitable, and effective clinical application.

2. AI Applications in Vascular Surgery

2.1. AI in Vascular Imaging and Diagnosis

AI has demonstrated substantial progress in automating interpretation of vascular imaging modalities, including CTA, MRA, duplex ultrasound, IVUS, and OCT. Key applications include:

- Aneurysm detection and segmentation using DL
- Endoleak identification after EVAR
- Arterial stenosis quantification
- Plaque morphology characterization (especially with IVUS/OCT)
- Automated vessel mapping and centerline extraction

Key Findings (2023–2025)

- DL systems have reached >90% sensitivity/specificity for endoleak detection.
- Aortic aneurysm segmentation models reduce radiologist workload and improves reproducibility.
- AI-assisted IVUS/OCT improves detection of calcified, fibrofatty, and necrotic plaques.

Study	Application	Modality	Performance	Notes
Hahn et al.	Endoleak detection	CTA	Sensitivity 90%, specificity 88%	Improved surveillance efficiency
Patel et al.	Aneurysm segmentation	CTA	High Dice scores (>0.90)	Reduced manual effort
Smith et al.	PAD plaque detection	IVUS/OCT	Improved detection accuracy	Enhanced lesion planning

Table 1: AI in Vascular Imaging (2023–2025)

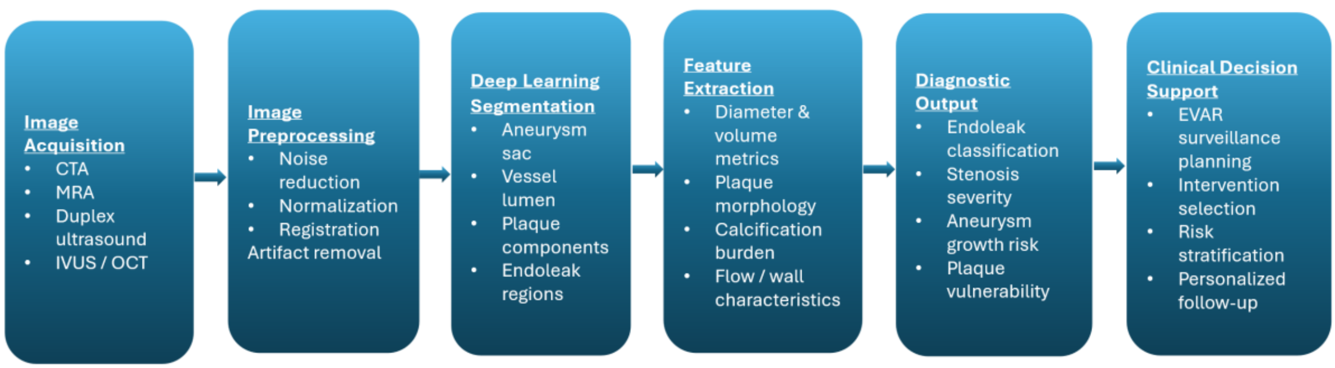

Figure 1: AI Workflow for Vascular Imaging

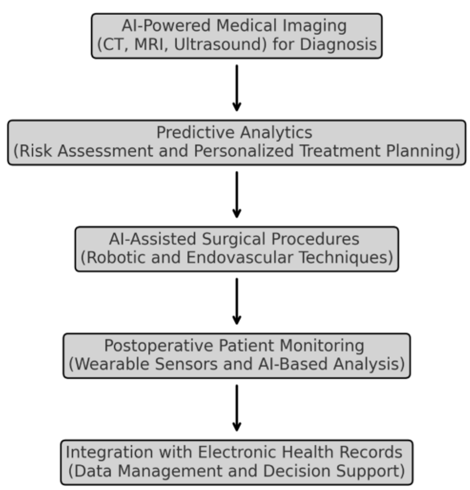

Figure 2: AI Workflow in Vascular Surgery

2.2. Predictive Analytics in Vascular Disease Management

Predictive modeling represents one of the fastest-growing areas in vascular AI. Large surgical registries have enabled development of ML tools that outperform logistic regression for key clinical outcomes.

Key modeled outcomes include:
• 30-day mortality after endovascular or open procedures
• 1-year MALE following PAD interventions
• Post-EVAR complications (endoleak, sac expansion)
• Limb salvage following revascularization
• Postoperative infection or graft failure

Recent Advances
• ML models using >200,000 PAD patients showed excellent discrimination for MALE/death.
• External validation studies have begun for EVAR, TEVAR, and open AAA models.

Domain	**Outcome**	**Model Type**	**Key finding**
EVAR	1-year mortality	Gradient boosting	Outperforms logistic regression
PAD endovascular	1-year MALE	XGBoost	High accuracy using preoperative variables
Open lower-limb bypass	30-day events	Random forest	Better calibration than registry scores
DFU limb salvage	Healing prediction	CNN models	Strong remote-monitoring potential

Table 2: Machine Learning Models for Outcome Prediction (2023–2025)

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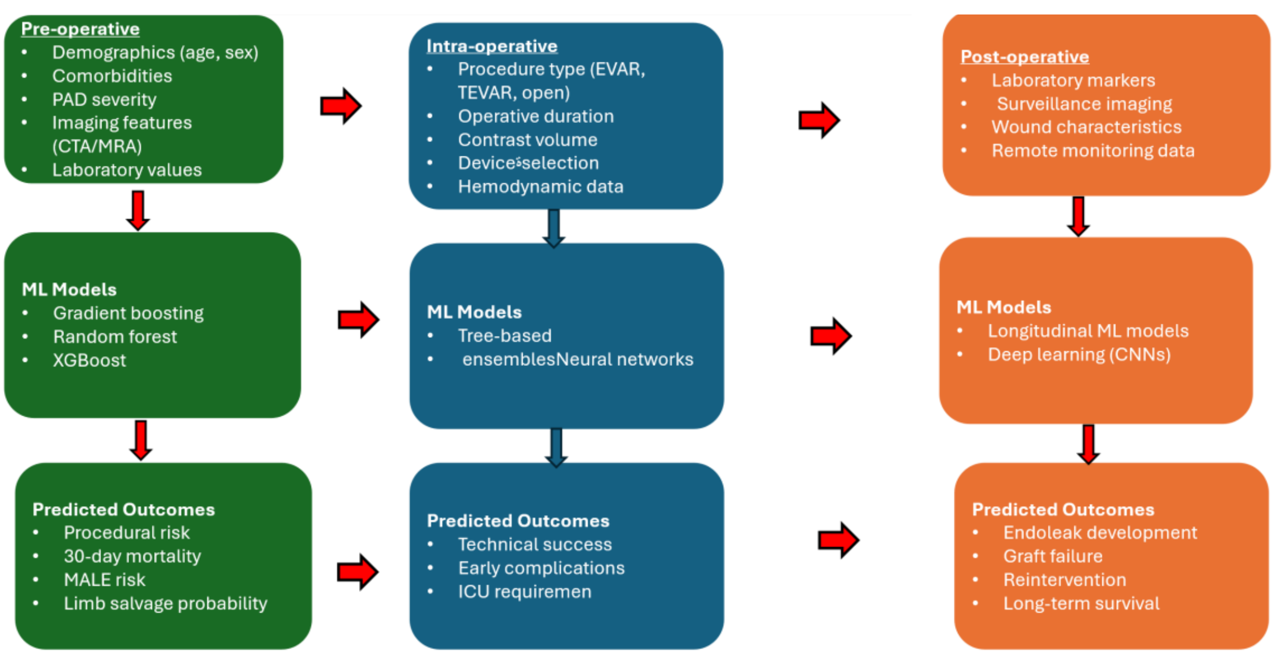

Figure 3: Predictive Analytics Across the Vascular Care Pathway

2.4. AI in Surgical Robotics and Intraoperative Guidance

While robotic surgery is mature in urology and general surgery, vascular robotics remains early-stage. AI-enhanced platforms aim to support:

- Catheter navigation
- Wire control
- Real-time anatomical tracking
- Error reduction and procedural planning

Emerging technologies include augmented reality overlays and intraoperative image fusion enhanced by AI.

2.5. AI in Wound Healing and Postoperative Monitoring

DL-based systems for DFU detection and monitoring represent the most clinically advanced vascular AI applications.

Applications include:

- DFU classification using smartphone photos
- Thermography-based ischemia detection
- Remote ulcer tracking with mobile apps
- Wearable sensors for perfusion monitoring

Study	Input	Application	Performance
DFUCare	Smartphone images	Ulcer classification	High accuracy in infection/ischemia detection
Debnath et al.	Mobile DL	DFU detection	Accurate on-device screening
Thermography AI	Foot thermograms	Early DFU prediction	Early detection of hotspots

Table 3: Recent AI Applications in Vascular Surgery (2022–2024)

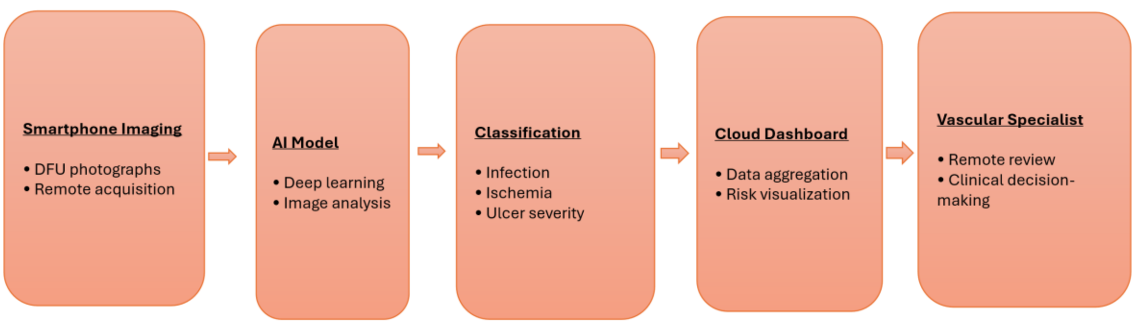

Figure 4: AI Pipeline for DFU and Limb Salvage

3. Recent Studies

Recent studies have demonstrated significant advancements in AI applications for vascular surgery, as summarized in Table 4 below.

Reference	AI Application	Study Design	Key Outcome
Smith D et al., 2023 (JACC Cardiovasc Interv)	AI-assisted intravascular imaging	Validation	Improved lesion detection accuracy & speed [2]
Zhang X et al., 2024 (Eur J Vasc Endovasc Surg)	ML for predicting limb events post-revascularization	Prospective	Outperformed traditional risk models [3]
Patel M et al., 2023 (Nat Med)	AI for aortic aneurysm segmentation	Multi-center validation	High sensitivity/specificity, reduced workload [4]
Müller H et al., 2022 (J Vasc Surg)	AI in robotic-assisted endovascular interventions	Review	Enhanced precision, future outlook [5]
Kim J et al., 2024 (Ann Vasc Surg)	Deep learning for post-EVAR complication prediction	Multi-institutional	High accuracy, reduced unnecessary imaging [6]

Table 4: Recent AI Applications in Vascular Surgery (2022–2024)

Even though vascular surgery has seen an increase in interest in AI, there is still a considerable separation between techniques that are being researched and those that are already employed in clinical practice. A few AI applications are starting to be used in daily healthcare, especially in imaging and risk assessment. The majority of advancements are still in the research or pilot phase, though. These distinctions are described in Table 5, which compares currently accessible methods with those that might eventually be incorporated into standard practice.

AI Domain	Current Clinical Use	Future Potential / Research
Imaging & Diagnosis	AI-assisted interpretation of CT/MRI/ ultrasound; lesion detection; segmentation (pilot clinical use)	Fully automated diagnosis, risk stratification, real-time AI-guided interventions
Predictive Analytics	Post-EVAR complications and limb event prediction (limited tools based on retrospective data)	Personalized management using multimodal data; population-level risk modeling
Robotics & Intraoperative Guidance	Early robotic-assisted navigation in experimental settings	Semi-autonomous or fully autonomous robotic endovascular surgery with AI decision support
Wound Healing / Monitoring	Research AI analysis of diabetic foot images	Continuous remote monitoring via wearables; predictive healing analytics
Telemedicine	AI triage/chatbots; basic remote follow-up	Real-time remote intervention planning and AI-predicted care
Data Integration	EHRs with AI note assistance	Advanced, real-time AI-enabled EHRs with clinical decision pattern recognition

Table 5: Current vs. Future AI in Vascular Surgery

4. Challenges and Ethical Considerations

Before AI can be introduced into vascular surgery on a regular basis, a number of ethical and practical concerns must be addressed. Large, well-constructed datasets are essential for the development of reliable artificial intelligence models; bias or poor data quality might result in incorrect diagnoses and decisions. Another major worry is regulatory approval, due to strict criteria set by organisations like the FDA, EMA, and TGA that must be fulfilled prior to clinical usage. Using AI will require new abilities and further training for many clinicians. There still remain unresolved issues with patient privacy, legal responsibility, and the use of AI to clinical judgements [7].

Recent statements from the European Society for Vascular Surgery have begun to address these issues, highlighting both the opportunities and the areas where further research is needed (European Society for Vascular Surgery, 2024) [8]. The Society for Vascular Surgery has similarly stressed the importance of ongoing education and clear regulation in this field [9].

5. Future Directions

One of the most recent developments is the introduction of AI-assisted robotic systems for vascular procedures. These platforms are designed to improve accuracy during operations and support a more controlled, minimally invasive approach. Although robotic technology is already well established in fields like urology, its use in vascular surgery is still evolving. Early reports suggest that robotic assistance may help to reduce errors, improve technical precision, and shorten recovery times. As AI methods progress, it is likely that robotic systems will incorporate real-time data analysis and feedback, supporting the surgeon during the procedure. The challenge for the future will be to ensure these systems can be easily adapted to a range of hospital environments without the need for major infrastructure changes [10].

Machine learning for predictive analytics also has the potential to change patient management in vascular surgery. AI models can be used to assess risk factors, predict complications after surgery, and help guide treatment choices. By analyzing large volumes of both historical and current patient data, these tools may help clinicians reduce events such as graft failure, re-occlusion, and infection. Predictive models could support preoperative planning by helping tailor procedures to each patient's clinical background. Further work is needed to improve the accuracy and generalizability of these models across different patient populations [11].

Integrating AI into electronic health records (EHRs) is another area with potential benefit. AI-supported EHR systems can automate documentation and make it easier to retrieve patient data, while also offering decision support. By organizing and interpreting large amounts of information, AI can help to identify clinical patterns and suggest possible treatment options. Improved communication between specialties is another advantage, as AI-driven EHRs can provide real-time, comprehensive patient records. This may help to reduce administrative workload and allow clinicians to spend more time with patients [12].

The use of AI in vascular surgery also raises a number of ethical and practical questions. These include concerns about data privacy, the risk of bias in algorithmic models, and questions of legal responsibility. Addressing these issues will require collaboration between vascular surgeons, computer scientists, and policymakers. There is a need for agreed guidelines and regulations to ensure safe and effective use of AI in practice. Training models on a wide range of patient data is essential to avoid bias and ensure fair outcomes. Policymakers have a key role in setting up regulatory frameworks, and the formation of dedicated committees for AI in surgery may help to guide this process [13].

Telemedicine supported by AI is likely to play a bigger role in the future management of vascular patients. Remote monitoring devices and predictive algorithms can support continuous follow-up of conditions such as peripheral artery disease (PAD) and surveillance after EVAR. These approaches allow for remote consultations and patient education, reducing the need for clinic visits. By integrating wearables and predictive tools, early detection of complications becomes possible, allowing earlier intervention. This can help improve patient outcomes and make better use of healthcare resources. Ongoing work will need to focus on the accuracy of remote assessments and how best to incorporate these systems into standard clinical practice [14].

Further validation of deep learning models for predicting EVAR-related complications, such as endoleaks, is another important area for future research. There is growing evidence that AI can help to identify and classify endoleaks using postoperative imaging, which may improve early detection and outcomes. Models like VascAI© have shown encouraging results in predicting complications, potentially reducing the need for frequent imaging and invasive follow-up. The next step will be to test these models across larger and more varied patient groups. If incorporated into routine care, AI-based risk assessment could support more personalized follow-up strategies, with benefits for both survival and cost of care [15].

A significant limitation of many current AI studies in vascular surgery is the lack of large, diverse validation cohorts, which may restrict the generalizability of results. In addition, the 'black box' nature of many AI systems remains a concern for clinicians, particularly regarding issues of trust and accountability. Tackling these problems will require advances in explainable AI as well as joint efforts to create clear guidelines and regulatory standards [16].

6. Limitations and Real-World Barriers

Although there have been significant advances in AI technology, most tools developed for vascular surgery are still at the validation or pilot study stage. Many published studies are based on retrospective, single-center data, which makes it difficult to know how well these findings apply to broader and more diverse patient groups. There is also a continuing risk of bias in algorithms, particularly if underrepresented populations are not included in training data [16].

Regulatory approval remains a major challenge, with only a small number of AI systems meeting the requirements for clinical use. The adoption of AI by clinicians has been limited, partly because many models function as a 'black box', raising questions around trust, responsibility, and accountability. Integrating these systems into clinical workflows also requires considerable investment in equipment and staff training. While reported accuracy figures such as AUC are encouraging, there is still little evidence that these tools improve patient outcomes or reduce costs in real-world settings. Overcoming these barriers will need further prospective, multicenter studies, greater transparency in AI methods, and clear guidelines for use in clinical practice.

7. Conclusion

Artificial intelligence has the potential to improve diagnostics, planning, and outcomes in vascular surgery. Experience from other specialties such as radiology, oncology, and ophthalmology has shown that AI can help to make care more efficient and may enhance patient safety. The future role of AI in vascular surgery will depend on the results of ongoing research and the development of appropriate regulations. Recent studies, highlight the need for continued progress in this area and support further investigation of AI-guided vascular interventions [17]. With continued collaboration between vascular surgeons and AI specialists, these tools may become an essential part of vascular surgical care in the future [18-21].

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