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NARRATIVE REVIEW

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A Narrative Review on Translational Applications of Artificial Intelligence in Vascular Surgery

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Key Summary

- This focused narrative review searched PubMed, Medline, and Google Scholar from inception to July 2026 for English-language studies of artificial intelligence use in vascular surgery.
- Across 4 domains (predictive/biomechanical models, large language models, wearables, operating room tools), reported results included XGBoost area under the receiver operating characteristic curve of 0.93 vs 0.71 after open abdominal aortic repair; VASC.AI accuracy of 93.8%; and wearable detection of 17/21 postoperative events, median 2 days early.
- Clinically, artificial intelligence may support risk assessment, communication, monitoring, and operative planning; however, evidence was mainly exploratory, retrospective, small, or narrowly selected. Prospective external validation, regulation, privacy safeguards, and workflow integration are needed.

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Abstract

Objective: Artificial intelligence (AI) translational applications in vascular surgery are in the early stages of development but are progressing rapidly and have the potential to transform health care. AI has demonstrated possibilities to streamline patient care, improve preoperative counseling, and enhance perioperative surgical techniques. This review aims to provide an in-depth overview of the current translational applications of AI within vascular surgery, thereby highlighting the current and future directions in this field. **Methods:** A focused narrative review of translational AI applications relevant to vascular surgery was conducted. **Results:** The review identified 4 principal translation applications of AI in vascular surgery: disease predictive and biomechanical modeling, large language models, wearable devices, and intraoperative applications. Published studies demonstrate applications personalized preoperative risk assessments, perioperative decision support, patient education and communication, postoperative monitoring, and image-guided operative planning. While applications remain in the early stages of clinical translation, emerging evidence demonstrates broad applicability across the continuum of vascular surgical care. **Conclusions:** AI has emerged as a promising adjunct across the continuum of vascular surgical care, with early evidence supporting improvements in risk stratification, clinical decision-making, patient communication, postoperative monitoring, and operative planning. Most applications require further prospective evaluation before widespread clinical adoption. Successful implementation will depend on continued clinical validation, the development of appropriate regulatory frameworks, and successful integration into surgical practice.

Introduction

The rapid expansion of artificial intelligence (AI) across the field of health care presents novel opportunities to enhance patient care.[1] This new technology encompasses a broad spectrum of large data processing through various avenues, including machine learning (ML), large language models (LLMs), computer vision, and neural networks.[2] Presently, AI's applications primarily involve the retrospective analysis of expansive datasets and computing outputs to support complex medical decision-making. Its potential benefits in the medical domain are particularly compelling due to the complexity of decision-making based on objective data points in health care.

The transitional applications are still in the early stages, and current literature remains either within the technical development or the internal clinical evaluation stage of research. There are few applications within vascular surgery in the external evaluation stage, and even less in the clinical utility stage of development (**Table**). The present study largely focuses on retrospective prediction models and potential uses of AI rather than highlighting patient-facing applications. Nevertheless, the potential remains a strong argument for early adoption. Our own research team has previously published on this subject within the field of trauma and identified potential benefits in decision-making processes for various traumatic vascular injuries.[3] Additionally, studies have highlighted the potential advantages in vascular diagnostics, particularly analysis of noninvasive vascular studies for peripheral arterial disease and aortic pathologies.[4] Notably, neural networks have demonstrated the ability to predict peripheral vascular occlusions and the development of critical stenoses within lower extremity bypasses more accurately than the gold standard duplex surveillance.[5] Other studies have successfully detected rates of type Ia endoleaks post-endovascular aneurysm repair using postoperative computed tomography scans, suggesting the potential for personalized surveillance programs.[6]

Table. Stages of development for clinical applications of artificial intelligence in medicine.

Stage	Definition
Technical development	Algorithm or device developed and tested in silico.
Internal clinical evaluation	Retrospective testing at the development institution.
External evaluation	Prospective testing within a small sample size in an independent population or institution.
Prospective evaluation	Large-scale prospective testing in clinical workflow.
Clinical utility	Demonstrated effect on decision-making, outcomes, efficiency, and/or safety.
Deployed technology	Implemented with ongoing performance surveillance with quality metrics.

The literature is rapidly expanding and exhibiting promising developments within this clinical domain. The present narrative review aims to delineate the current, focusing on 4 primary domains: disease predictive and biomechanical modeling, LLMs, wearables, and the operating room (OR). We will discuss the future implications and limitations in this setting and strive to provide readers with contemporary applications, establishing a foundation for future research efforts.

Methods

A narrative review was conducted through PubMed, Medline, and Google Scholar to retrieve papers published from inception to July 2026 that describe AI in vascular surgery. The following search keywords (and their medical subject heading terms) in various combinations were used: "vascular surgery", "machine learning", "artificial intelligence", "operating room", "wearables", "disease predictive modeling", "biomechanical modeling", "large language models", and "operating room". The inclusion criteria were full-text journal articles reported in English that contained AI-based topics in vascular surgery. Articles were categorized into 4 main categories: disease predictive modeling and biomechanical modeling, LLMs, wearables, and AI in the OR. Due to the lack of wearable data specific to vascular surgery, published articles within cardiovascular medicine were included in this section.

Disease Predictive Modeling and Biomechanical Modeling

The rapid expansion of AI across health care presents novel opportunities to enhance clinical decision-making, risk stratification, and procedural planning.[1] While applications have been extensively studied in many nonsurgical specialties, its integration within vascular surgery remains underdeveloped.[7] Nevertheless, growing evidence suggests there is untapped

potential to transform multiple aspects of vascular care, ranging from disease prediction and operative planning to postoperative surveillance and outcome prognostication. As these technologies become increasingly available and incorporated into clinical practice, it is essential to understand their applications, advantages, and limitations.

One of the most promising applications of AI in vascular surgery lies in disease predictive modeling. In patients with abdominal aortic aneurysms (AAA), maximum aneurysm diameter remains the principal criterion used to guide elective repair.[8] However, contemporary evidence has shown that aneurysm diameter alone is an imperfect predictor of rupture risk, as it fails to account for other important variables such as aneurysm morphology and atherosclerotic disease burden.[9,10] Reliance on diameter-based thresholds alone may expose patients to unnecessary operative risk in some while delaying interventions in others who are at elevated risk despite smaller aneurysm size.[11,12] ML algorithms have been developed to predict adverse aortic events, including rupture, dissection, and mortality at various time points. By integrating 44 clinical and imaging variables, these models have consistently demonstrated superior predictive performance compared to diameter-based criteria alone.[13] Beyond clinical characteristics, biomechanical markers are currently being studied to power ML algorithms for more accurate rupture assessment. Computational fluid dynamics leveraging wall stress and intraluminal thrombus thickness has achieved great predictive success with an area under the curve of 0.92, with other models integrating segmental imaging to analyze eddy currents significantly contributing to rupture risk.[14,15]

Importantly, computational fluid dynamic modeling in itself is not a form of AI; rather, it is a physics-based simulation of hemodynamics and tissue mechanics. However, AI enters these workflows in 3 principal ways: (1) deep learning (DL) computer-vision models automatically segment the aorta and extract geometric features from cross-sectional imaging; (2) ML models rapidly estimate biomechanical parameters that would otherwise require computationally intensive simulation; and (3) ML classifiers categorize the resulting flow phenotypes and integrate geometric, biomechanical, and clinical variables into individualized predictive models. AI does not replace these established tools but augments them, primarily by automating measurement and integrating disparate data into a single risk estimate.

Outcome prognostication represents another important translational application of AI in vascular surgery. Predictive models can be used to estimate perioperative risk and identify patients most likely to benefit from intervention.[16,17] In 1 study evaluating outcomes after open AAA repair, ML algorithms incorporating preoperative demographics and clinical variables demonstrated substantially improved postoperative predictive accuracy compared to traditional regression models. Specifically, the XGBoost model achieved an area under the receiver operating characteristic curve of 0.93 for predicting major adverse cardiovascular events following open AAA repair, compared to 0.71 for traditional logistic regression models.[16] Such tools may enhance preoperative counseling, facilitate risk-adjusted decision-making, and support personalized treatment strategies to improve patient outcomes. Similar efforts are underway within the endovascular domain.[17] An ongoing international, multicenter observational study is developing DL algorithms to predict clinically relevant outcomes following endovascular aneurysm repair, including mortality, reintervention, endoleak, limb occlusion, and device migration.[17] Early AI-based risk assessment tools have already demonstrated promising results. An AI model designed to predict type Ia endoleaks following endovascular aneurysm repair analyzes more than 16,000 biomechanical measurements to generate a composite Endoleak Risk Index. In early validation studies, the Endoleak Risk Index achieved 100% sensitivity and 100% negative predictive value, successfully identifying all high-risk patients while accurately excluding endoleaks in low-risk cases. By comparison, conventional planning methods achieved an overall accuracy of only 51.1%.[6] These findings highlight the potential for AI-driven predictive analytics to augment preprocedural planning, improve patient selection, and reduce complications following endovascular intervention.

Large Language Models in Vascular Surgery

AI enables the analysis of complex clinical text into forms that are more actionable for clinicians and understandable for patients. This is largely capable through natural language processing (NLP) systems and LLMs. NLP is a subfield of AI focused on enabling machines to understand, interpret, and generate human language, allowing computers to derive meaning from text or speech.[18] Building on the foundations of NLPs, LLMs are more advanced AI systems trained on vast datasets to predict the next word in a sequence, allowing for wide-use applications. LLMs are trained with unnumerable parameters adjusted to minimize the difference between predicted and actual text, enabling LLMs to generate outputs with contextually relevant information.[18] These tools are particularly useful in the realm of vascular surgery for the summarization of clinical information and generation of patient educational materials.

LLMs can be effectively leveraged to increase efficiency in complex medical decisions. In a study with 25 fictional vascular consultations, 5 attending vascular surgeons and 4 LLMs (GPT-3.5, GPT-4, Bard, and Falcon-40B) were asked to answer the acuity of each consult and whether immediate intervention was required within the next hour. The rate of accurate identification of vascular emergencies were 88%, 100%, 76%, and 88% for GPT-3.5, GPT-4, Bard, and Falcon-40B, respectively.[19] With GPT-4 demonstrating 100% sensitivity and 100% specificity, this suggests that widely available LLMs can correctly identify vascular emergencies and aid in triage support tools. However, when prompted to identify the “next

best step", LLMs agreed with attending surgical opinion in 64%, 32%, 68%, and 36% for GPT-3.5, GPT-4, Falcon-40B, and Bard, respectively.[19] Further analysis of LLMs in predicting the "next best step" revealed that errors were attributed to incorrect or outdated data and the inability to comprehend clinical context, nuances, or medical classification systems.

When answering complex vascular surgery-related questions, retrieval-augmented generation has been used to develop vascular surgery-specific platforms such as VASC.AI. This platform incorporates international vascular surgery treatment guidelines, landmark trials, and published clinical articles within its dataset and has created a LLM that is specific to vascular surgery.[20] When prompted, this vascular-specific LLM is able to reference vascular-specific literature to increase accuracy in responses. When asked 244 text-based multiple-choice questions from 6 Vascular Education and Self-Assessment Program-5 models, VASC.AI significantly outperformed general LLMs (GPT-3.5, GPT-4, and GPT-4o), achieving a correct response rate of 93.8%.[21] The superior performance achieved by VASC.AI likely reflects its ability to retrieve and incorporate vascular surgery-relevant datasets rather than relying exclusively on publicly available data. Models such as these demonstrate the utility of LLMs for vascular emergency triage and clinical management aid.

One of the most compelling applications of LLMs is within patient communications. Effective communication regarding complex medical issues, management, and postoperative instructions is crucial in vascular surgery. Studies have demonstrated that publicly available patient education materials within vascular surgery do not meet the national literacy standards of a sixth-grade level, leading to misunderstandings and unintentional nonadherence.[22,23] Furthermore, the availability of patient education materials is particularly scarce among non-English-speaking patients.[24] LLMs can generate responses tailored to a patient's own language and health literacy level, enhancing comprehension and treatment understanding. GPT-4o and Gemini 1.5 Pro have been employed to significantly improve the readability of Society of Vascular Surgery educational flyers, lowering the reading level by 2 grades without comprising accuracy.[25]

Beyond educational materials, LLMs may enhance communication during the perioperative period. In a multicenter study involving 90 vascular surgery patients, AI-generated discharge summaries significantly improved readability and understandability compared to documents written by clinicians. However, limitations remain as 10% of discharge summaries contained omissions, and 8% exhibited some degree of hallucinations.[26] LLMs serve as tools that can facilitate and streamline patient communications, but clinician review of documents remains essential to ensure clinical accuracy.

Wearables in Vascular Surgery

The use of AI-integrated wearable devices (WDs) has only recently been introduced as a potential tool within the realm of vascular surgery, and the data remain sparse. Most of the current research supporting the use of WDs comes from cardiovascular medicine, where smartwatches, patches, rings, and other WDs are capable of gathering large amounts of data such heart rate, blood pressure (BP), heart rate variability, and oxygen saturation.[27] Consumer-grade devices, such as the Apple Watch, have received FDA clearance as a single-lead electrocardiogram that can predict atrial fibrillation and provide generic recommendations to seek further evaluation by a clinician. However, more advanced medical-grade devices are currently being used within the realm of cardiovascular medicine. A multifunctional "e-skin" that acts as an electrocardiogram electrode has been shown to have the ability to diagnose 4 different cardiac arrythmias with up to 99% accuracy. This technology utilizes a combination of convolutional neural networks (CNNs) and long- and short-term memory, 2 different types of DL.[28] Additional studies have demonstrated the efficacy of cuffless WDs, which use ML to predict BP. Random forest regression algorithms have effectively predicted BP based on photoplethysmography and bioimpedance sensors.[29] While more data are needed to establish external validity, WDs are becoming more prevalent and leverage AI to detect and treat cardiovascular disease.

Given the significant overlap in pathologies between cardiovascular medicine and vascular surgery, there is a clear role for WDs within vascular surgery, especially regarding disease prevention and modification. Some existing technologies for cardiovascular medicine have direct implications for vascular surgery patients. Detection of atrial fibrillation may allow for reduction in thromboembolic events and acute limb ischemia.[30] Furthermore, tighter and more consistent BP control with real-time feedback through watches and rings has implications for aortic pathologies. While the data specific to vascular surgery is limited, few articles exist. A small, single-center randomized controlled trial evaluated the efficacy of wearable activity monitors in patients with intermittent claudication. This study compared feedback-enabled, wrist-worn activity monitoring to a supervised exercise program, the latter of which is a standard recommendation for patients with peripheral arterial disease. This study found significant improvements in maximum walking distance, distance to claudication, and quality of life.[31]

Another systematic review analyzed the use of WDs in the detection and management of 3 key vascular-related pathologies: intermittent claudication, diabetic foot ulcers, and venous ulcers.[32] This included studies that used a variety of WDs and physiologic parameters, such as force sensors, pedometers, and temperature/humidity, to provide feedback to patients and prevent the development of such complications.

AI-integrated WDs may also have a role in the postoperative setting. While not specific to vascular surgery patients, a systematic review of AI methods, including gradient-boosted decision trees, CNNs, and reinforcement learning, showed they effectively identified postoperative complications based on the detection of physiologic changes from WDs. Observed benefits included early detection of complications such as hypoxia and arrhythmias, decreased readmission rates, and reduced lengths of stay.[33,34] Another study analyzed whether a ML algorithm could be used for detection of postoperative complications prior to symptom onset after cardiothoracic surgery. The NightSignal algorithm, which was initially designed for early detection of COVID-19, was used to analyze Fitbit data in patients undergoing cardiothoracic surgery. This algorithm detected 17 of the 21 postoperative events a median of 2 days prior to symptom onset, achieving a sensitivity of 81%.[35] NightSignal utilizes heart rate variability to detect postoperative complications, a finding that can be applied to Type B aortic dissections, sepsis detection, or venous thrombosis in vascular patients. These initial studies show promise regarding the use of AI-integrated WDs within the field of vascular surgery. WDs within vascular surgery are a vastly unexplored field, and additional research needs to be done to ensure accuracy and reliability, as well as safeguards to protect patient privacy, before widespread use.

Artificial Intelligence in the Operating Room

The integration of AI, augmented reality, and robotic systems is reshaping the OR, providing advanced visualization and objective intraoperative guidance, and enhancing procedural precision. Head-mounted displays such as Microsoft HoloLens and smart glasses such as Google Glass have broken ground within the OR and are utilized for image-guided surgery to enhance anatomical visualization.[36] These devices allow surgeons to superimpose digital 3-dimensional anatomy derived from preoperative computed tomography scans directly onto the patient's anatomy during the operation. This capability is particularly effective for tissue identification and localizing perforating vessels during complex vascular flap transfers. By providing a 3-dimensional visual environment within the surgeon's field of view, augmented reality head-mounted displays allow operators to maintain direct vision on the operative field, eliminating the "switching focus" issue inherent in traditional monitors. While promising, current limitations include the physical weight of devices, restricted battery life, and the potential for "cybersickness" among users.[37]

AI tools are being developed to mitigate procedural risks, such as dissection or vessel perforation caused by unintentional entry into the subintimal plane. Advanced robotic systems, such as the CorPath GRX (Siemens Healthineers), feature active device fixation, which stabilizes the guidewire position during endovascular surgery.[38] This prevents unintentional forward movement of the wire, a safety mechanism critical in neurovascular or small-vessel interventions where unintentional movements have dire consequences. Furthermore, research on autonomous navigation utilizes reinforcement learning to enable catheters and guidewires to navigate through vascular branches while avoiding entanglement. These tools are still in the experimental phase with success in over 90% of models, but they have not yet entered into clinical practice. Within vascular surgery, careful wire placement and management when cannulating the aortic arch and tibial vessels is essential to prevent stroke and unintentional vessel dissection.

DL algorithms, particularly those utilizing CNNs with a U-Net architecture, are revolutionizing the analysis of intraoperative fluoroscopic imaging. These tools can perform fully automatic segmentation of stent grafts on completion digital subtraction angiographic images in an average of 1.5 seconds per patient.[39,40] This pixel-detailed analysis provides a platform for advanced intraoperative applications, such as assessing stent graft deployment accuracy in millimeters and identifying subtle endoleaks or arterial deformations missed by the human eye. Furthermore, AI tools facilitate image fusion overlay correction, which accounts for anatomical distortions caused by stiff guidewires.

The CorPath 200 and CorPath GRX are 2 of the few commercially available systems for robotic-assisted endovascular surgery.[41] These systems allow operators to navigate devices from a radiation-shielded cockpit using joysticks and touchscreens with precise control in 1-mm increments. The GRX system includes advanced features such as "active guide control" for catheter manipulation and "rotate on retract", which automatically rotates the guidewire during retraction to facilitate branch catheterization and lesion crossing. Studies utilizing the CorPath GRX system in neurovascular intervention has shown 94% effectiveness without the need of operator manual intervention.[42] Beyond procedural precision, these robotic systems reduce operator radiation exposure by over 95% and have the potential to allow for tele-stenting, allowing surgeons to perform procedures via local area networks with command delays as low as 53 milliseconds.[41]

Limitations

There are several limitations to the applications of AI within vascular surgery. Most research is currently exploratory or retrospective proofs of concept. The most pressing limitation is the lack of data for real clinical support. Much of the work is still foundational in investigating the potential for AI in surgical practice. Even those with published literature utilize a small, highly specific sample size or are retrospective in nature. The external validity of many of these applications has yet to be uncovered. Additionally, AI is highly operator dependent. The field of research labeled "prompt engineering" investigates

optimal structuring inputs within LLMs to maximize the utility and accuracy of outputs. Without correct prompting, LLM outputs are inconsistent between operators and may provide hallucinogenic responses that are inaccurate in a field where margins of error can lead to morbidity and mortality.[43]

Overall trust in AI applications within medicine represents another limitation to real-life applications. Many patients, physicians, and surgeons alike limit their utilization of AI-derived and augmented tools due to distrust and unfamiliarity. Surveys have shown that the majority of Americans would feel uncomfortable if their physician used AI to help diagnose diseases, and about one-third feel these tools would lead to worse overall outcomes in patient care.[44] Patients and physicians share many of the same concerns with AI, including accountability, privacy, ethics, and regulation. Many platforms have a lack of model transparency and methodologies without reporting standards, which are essential in the field of health care. AI is largely unregulated within this profession, contributing to concerns surrounding accountability in medical decision-making. Data privacy and protected health information, especially with WDs in the OR, is a major concern. The use of smart glasses is currently under review, with several legislative bodies limiting the use of these devices in sensitive locations such as judicial courts and employment offices. Future work in the realm of AI should be cognizant of these possible pitfalls.[45]

Conclusion

This review presents numerous translational applications of AI within the realm of vascular surgery including disease predictive modeling, LLMs, wearables, and OR technologies. Applications of AI have the potential to improve clinical decision-making, perioperative surgical techniques, and patient counseling. While still in early development, vascular surgeons should be critical and evaluate the integration of AI within their own clinical practice. ■

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