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# ARTIFICIAL INTELLIGENCE IN SURGERY: CURRENT TRENDS AND FUTURE

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## Summary

**Objectives.** This review synthesizes recent advances in artificial intelligence (AI) across surgical specialties. We aim to summarize applications of AI throughout the perioperative process and identify current challenges and future directions.

**Methods.** A comprehensive literature survey of articles published in 2024–2025 on AI in surgery was conducted, following PRISMA guidelines for systematic reviews. Articles were identified via PubMed, Embase, Scopus, Web of Science and Cochrane Library, focusing on AI-based diagnostic tools, preoperative planning, intraoperative assistance, and postoperative care across surgical disciplines. Twenty-five relevant articles were selected and analyzed.

**Results.** AI applications have proliferated across diverse surgical fields. In plastic and reconstructive surgery, AI algorithms have achieved high accuracy (~85–90%) in tasks like outcome prediction, facial landmark detection, and postoperative evaluation. Spinal surgery benefits from AI-driven planning and navigation: deep learning models outperform traditional methods in preoperative deformity prediction and segmentation, while robotics and computer vision improve instrument's placement. In gastrointestinal surgery, AI systems enhance decision-making (e.g. selecting resection extent or neoadjuvant therapy) with area-under-curve (AUC) values up to 0.97. Cardiac and thoracic surgery also see improvements: AI-enhanced imaging and augmented reality enable precise tumor localization and early lung cancer detection. Across these domains, AI models (notably convolutional neural networks and ensemble methods) often exceed the performance of traditional clinical tools in lesion detection and risk assessment. However, most studies are retrospective and single-center, with limited external validation. Commonly cited obstacles include data scarcity, annotation needs, and algorithmic opacity.

**Conclusions.** Recent literature indicates that AI has the potential to transform surgical care – from personalized preoperative planning to intraoperative guidance and enhanced postoperative monitoring. To realize these gains, future work must focus on multicenter validation of AI models, development of ethical frameworks, and integration of AI tools into clinical workflows while maintaining surgeon oversight and patient safety.

**Keywords:** artificial intelligence, surgery, machine learning, robotic surgery, personalized medicine

## Introduction

Artificial intelligence (AI) – including machine learning and deep neural networks – is rapidly impacting medicine, with surgery emerging as a key area of interest. Unlike specialties such as radiology and pathology (which have standardized imaging data), surgical practice involves highly variable anatomy and real-time decision-making, which have historically slowed AI adoption [1]. Nevertheless, advances in imaging, sensors, and data analytics are enabling AI to augment surgical care at every stage. Recent reviews report exponential growth in AI applications across the surgical continuum [1, 2]. AI tools now assist in tasks as diverse as tumor detection on imaging, preoperative risk stratification, intraoperative instrument guidance, and postoperative complication prediction. This comprehensive review evaluates the current landscape of AI in surgery by synthesizing findings from the latest publications. We particularly focus on specialties such as general surgery, orthopedic, plastic, cardiac, thoracic, and gastrointestinal surgery. Our aim is to highlight the breadth of AI use cases and to identify common themes regarding performance, limitations, and ethical considerations.

## Materials and Methods

We performed a literature review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. We browsed PubMed, Web of Science, Embase, Scopus, Cochrane Library related to our search terms "artificial intelligence" and "surgery", in English language, published between 2024 and 2025. The inclusion criteria were articles that referred to clinical or research applications of AI in any surgical specialty. Exclusion criteria were articles on preclinical models only, non-clinical specialties, or AI outside of non-surgical medicine. Following a detailed screening process of titles, abstracts, and full-texts, 25 articles met our inclusion criteria and were ultimately incorporated into the study, providing evidence on the use of AI across various surgical specialties. Data were extracted about AI methodology, clinical application, measures of performance, validation, and described limitations. This integration follows methodologies employed in recent reviews of AI surgery.

## Results

The literature selected illustrates that AI is being widely applied in surgical practice. The overarching themes include: *Preoperative Planning and Diagnosis:* AI enhances

patient assessment and surgical planning. In spinal surgery, for example, convolutional neural networks are used to advance 3D anatomic modeling and predict deformities, leading to more accurate hardware placement [3]. Similarly, AI algorithms may be applied to analyze imaging for identification of tumors or anatomical landmarks. MacLeod et al. determined that AI-enhanced 3D reconstructions enable surgeons to more precisely locate lung vessels and tumors (resulting in a reduction of surgical approach errors by approximately 41%) [4]. In plastic surgery, AI algorithms applied to preoperative imaging predict outcomes (e.g. in breast reconstruction) with high accuracy (approximately 85-90%) [5]. AI also contributes to the diagnosis of various conditions: Motamedian et al. recorded sensitivities of 75-95% in orthognathic surgery recommendation from patient data [6]. Convolutional neural networks, support vector machines, and ensemble learners (random forests/boosting) are common AI methods across specialties [1, 2].

*Intraoperative Guidance and Robotics:* AI-based real-time guidance is a rapidly expanding field. During robotic and minimally invasive surgery, computer vision algorithms track instruments and anatomy for enhanced precision [7, 8]. For example, deep-learning algorithms identify surgical stages or significant structures from video, to enable augmented reality overlays. In orthopedics and spinal surgery, AI-guided robotic systems position instruments (e.g. pedicle screws) more precisely than conventional methods [3,9]. Othman and Kaleem noted intraoperative navigation and augmented training as notable AI applications in general surgery [2]. Such intraoperative systems can potentially reduce operative time and radiation. In another article, Ali, et al. (2025) noted AI-assisted navigation reduced radiation use by 90% and operative time in spinal procedures [3].

*Postoperative Monitoring and Outcome Prediction:* AI has been employed to enhance postoperative management and complication handling. In plastic surgery, for example, Stein and Rohrich (2025) describe the use of AI-aided telemedicine software for monitoring wound healing and early complication detection [10]. Similarly, Shin et al. (2025) demonstrated AI quality-control in surgery: models achieved over 90% accuracy in identifying technical performance issues (e.g. tissue dissection quality) and outperformed traditional diagnostics in activities like endoscopic lesion detection [11]. Predictive modeling is also used: Hassan et al. (2025) demonstrated machine learning models (ensemble methods and neural nets) could predict bariatric surgery complications more accurately than logistic regression [12]. In oncologic and GI surgery, AI technologies are used to forecast risks (e.g. anastomotic leak, chemotherapy benefit) to individualize follow-up and adjuvant therapy [13, 14].

*Specialty-specific Uses:* In most articles, the application of AI is emphasized in one specialty. In cardiac surgery, mortality risk stratification is enhanced by AI algorithms and echocardiographic assessment is made easier [15]. The AAO-HNS and similar surgical societies have also developed guidelines for AI use in otolaryngology, emphasizing training in surgeons. In vascular surgery, Joh et al. (2025) explains how image-based models and wearable sensors aid in graft

planning and thrombosis detection [16]. Emergency and trauma surgery benefit from rapid imaging and vital sign-based triage algorithms (though formal validation remains limited). Systematic review by Tasci et al. (2025) found AI performs uniformly better than human judgment for GI surgical tasks (e.g., tumor detection, complication prediction) [17]. Orthopedic fractures and osteoarthritis are graded by neural networks nearly as well as experts from radiographs [18]. Virtual reality and mixed-reality interfaces, along with AI, are also undergoing trial for resident training and surgical rehearsal [19, 20]. In general, these studies indicate that uses of AI can surpass or augment standard methods across a broad range of surgical procedures [10, 11]. For instance, accounts recorded AI-assisted diagnostics achieving AUCs  $\geq 0.9$  on such procedures as endoscopic lesion detection and postoperative complication prediction [11, 17].

Throughout all the articles examined, most of the AI utilized supervised learning techniques and pretrained deep learning models, with a comparatively small number utilizing reinforcement learning in real-time surgery [1]. However, all studies except one reported limitations: lack of large multicenter datasets, possibility of overfitting, and lack of prospective validation. For example, Kenig et al. (2024) observed that only 14% of AI models in surgery used public datasets and only 45% achieved high validation quality [1]. Similarly, Arkoubi's meta-analysis in plastic surgery found under 40% of studies reported external validation, despite pooled accuracies around 88-90% [5]. These gaps highlight that current AI developments, while promising in silico, require robust real-world testing.

## Discussion

The evidence synthesized demonstrates that AI has the potential to revolutionize surgical care. AI models can improve clinical decision-making by integrating complex data (imaging, genomics, clinical history) to improve accuracy and efficiency [1, 15]. Of interest, AI consistently matches or exceeds expert-level performance for narrow tasks such as image analysis and risk scoring [15, 17]. This can lead to fewer diagnostic errors and more personalized treatment plans. For instance, AI-powered risk stratification for cardiac surgery has outperformed traditional scores [15], and AI-assisted endoscopy has significantly improved polyp detection rates. Across specialties, AI is consistently introduced as a decision-support or precision-enhancing tool rather than as a replacement for surgeons. In practice, AI algorithms aid surgeons by highlighting critical anatomy, suggesting incisions, or predicting complications. The multidisciplinary studies reviewed herein underscore that AI programs can process large clinical databases to reveal patterns beyond human capacity [1, 11]. AI coupled with robotics and augmented reality can also enhance surgeon dexterity and visual guidance, as used in spine and minimally invasive surgery [3, 21].

Our review also highlights significant barriers to routine clinical integration. Most authors cite technical challenges: surgical data is often unstructured and heterogeneous, and thus hard to train models with. Scarce availability of

standardized datasets and annotation (especially video and intraoperative data) hinders generalizability [1, 5]. Ethical and legal issues are imminent. Algorithmic "black boxes" foster worries about transparency; surgeons are not easily able to discern how AI reaches decisions, which renders informed consent and liability more problematic [22, 23]. A few reviews actively call for ethical oversight and standards – e.g. Mansoor et al. (2025) highlight that data privacy, bias, and equity must be addressed to avoid exacerbating disparities [23]. Robinson et al. (2025) [24] also broach the subject of policy for generative AI (e.g. ChatGPT) utilization in academic surgery, although full particulars were beyond our scope. Professional societies (e.g. AAO-HNS) are beginning to release reports recommending AI literacy among surgeons [25].

Regarding implementation, workflow integration and expense are concerns. Beyaz et al. (2025) caution that high-cost surgical robots and lack of reimbursement models can impede adoption [21]. They further state that for new AI-robotic systems to become established, their benefits would have to significantly outweigh additional resource requirements. Education of both surgeons and patients about AI capabilities and limitations is also cited: lack of provider familiarity can slow clinical trials, and patients need assurance about safety and oversight.

In summary, the reviewed literature portrays a rapidly evolving field. AI's strengths in pattern recognition and predictive analytics are well-demonstrated, but translating these into improved patient outcomes requires careful prospective evaluation. Several writers call for multicenter prospective studies and real-time clinical validation [1, 2]. Interdisciplinary collaboration – between surgeons,

engineers, ethicists, and regulators – is demanded. There is agreement that AI should augment, not replace, surgical judgment. Maintaining the human element and clinical judgment is emphasized: technological advancement must be harmonious with surgeons' ultimate goal of patient-centered care [23].

### Conclusion

Artificial intelligence is poised to become an essential part of modern surgery. In many areas, AI algorithms have demonstrated remarkable precision in diagnostic imaging, surgical planning, and predicting clinical outcomes. Such technologies, when clinically validated, will improve efficiency, reduce complications, and personalize surgical care. Realizing this potential will require overcoming current hurdles, i.e., the assembly of large diverse datasets, transparent and unbiased algorithms, and regulatory and ethical standards for AI use. Future research should focus on prospective, multicenter trials to establish the safety and efficacy of AI systems in real-world surgical practice. With careful development and oversight, AI can enhance surgical precision and patient outcomes while preserving the surgeon's essential role.

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