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EDITORIAL

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Embracing the future: The integral role of artificial intelligence in modern surgical practice

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Objective of the review

The objective of this review is to demystify the application of artificial intelligence (AI) in the field of surgery by presenting it in a practical, use-case-oriented manner. By dissecting the sequential steps involved in surgical procedures, we aim to identify and explore potential AI use cases at each stage, offering surgeons a clear understanding of how AI technologies can be integrated into their practice.

Advent of Artificial Intelligence in Surgery

Surgical practices have witnessed profound evolution, transitioning from traditional open surgeries to minimal access techniques, with robotic surgery now a standard in various fields [1]. This evolution underscores a push towards precision and a reduced invasiveness. The integration of AI into surgery marks a significant shift, poised to enhance surgical education, practice, and patient outcomes [2].

As AI technology advances, the demand for surgeons skilled in AI increases, highlighting its role in improving imaging, patient management, navigation, and robotic interventions [3-4]. The adoption of AI is critical for boosting accuracy, enhancing visualization, and potentially bettering patient recovery and satisfaction [5]. Despite mixed views on AI's impact on surgical times and outcomes, the consensus generally supports AI's transformative potential in surgery [6].

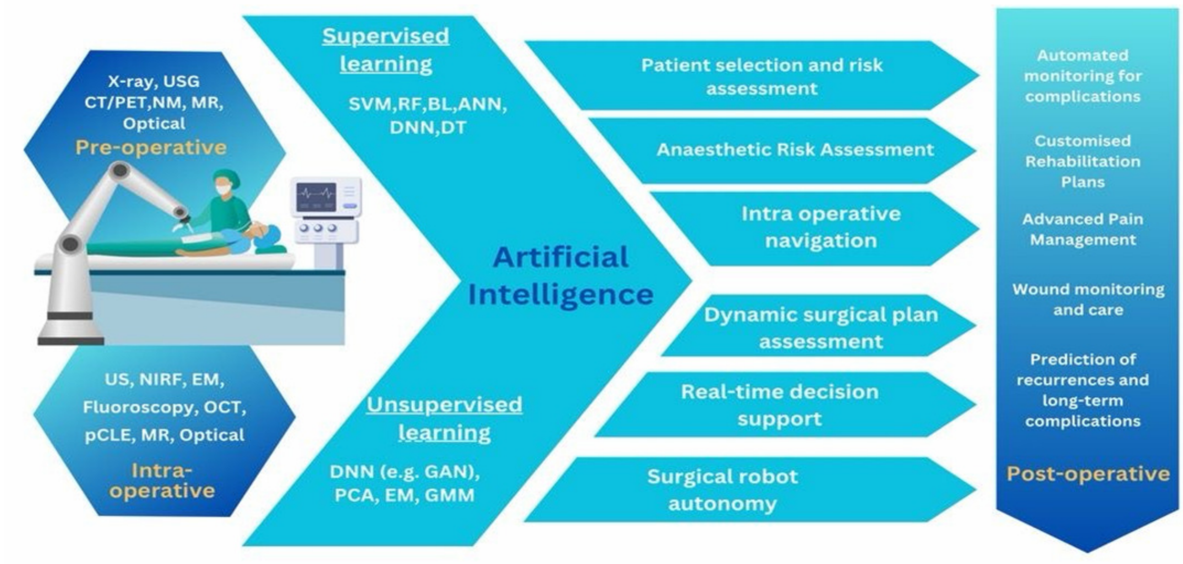
AI encompasses a wide area of computer science aimed at creating machines capable of tasks requiring human intelligence, including learning, problem-solving, perception, and decision-making [10].

Machine Learning (ML), a key subset of AI, uses statistical methods to improve outcome predictions, learning over time from historical data without specific programming for each task. Deep Learning, an advanced ML technique, involves neural networks that mimic the human brain, allowing machines to recognize patterns in large datasets. This has been crucial in advancing computer vision, natural language processing, and notably, medical diagnostics and treatment planning [11]. The integration of AI in surgery, amidst ethical and privacy challenges, indicates a promising future for enhanced patient care and outcomes [7-9].

Artificial Intelligence and Surgery

For our discussion, we've categorized the surgical process into pre-operative, operative, and post-operative phases to discuss AI's integration. In each category, we've identified specific steps where AI can be applied, provided examples of real-world use cases. **Image-1. Provides a summary of the entire discussion.**

Image-1: A summary of applications of AI in Surgery



Pre-operative phase

In the pre-operative landscape, AI is instrumental in refining patient selection [12] and enhancing diagnostic imaging analysis for meticulous surgical planning [13]. It also plays a crucial role in the design of patient-specific prosthetics [14], enriching patient education [15], and tailoring anesthetic risk assessment to individual profiles [16], setting the stage for successful surgical outcomes.

Steps in Pre-Operative Phases	Potential Benefits	Real Life Use Case
Patient Selection and Risk Assessment	Enhances precision in preoperative evaluation for optimal outcomes [12]	To predict the patients at risk of strangulation in cases of inguinal hernia.
Diagnostic Imaging Analysis	Offers detailed imaging for informed surgical decisions.[13]	Mapping coronary arteries for precise angioplasty planning.

Steps in Pre-Operative Phases	Potential Benefits	Real Life Use Case
Customized Prosthetics Design	Provides custom prosthetics for improved orthopedic surgeries. [14]	Creating bespoke hip implants for complex arthroplasty cases.
Patient Education and Engagement	Personalizes patient care plans for improved compliance [15]	To communicate more efficiently and effectively the surgical procedures to the patients.
Anesthetic Risk Assessment	To evaluate and predict the anesthetic risks tailored to individual patient profiles, ensuring safer anesthesia management [16]	Optimizing anesthetic protocols for high-risk lobectomy patients.

Operative Phase

During the operative phase, AI is pivotal in intraoperative navigation, avoiding critical structures [17], dynamically adjusting surgical plans [18], and granting semi-autonomous capabilities to surgical robots [19]. It also supports real-time decision-making [20] and assists in precise tissue characterization to minimize damage [21].

Steps in Operative Phases	Potential Benefits	Real Life Use Case
Intraoperative Navigation	Enhances surgical precision, promoting patient safety. [17]	Avoiding the 'Triangle of Pain' and 'Triangle of Doom' during hernia repair surgeries.
Dynamic Surgical Plan Adjustment	Modifies surgical strategy in response to real-time data. [18]	Adjusting resection margins on the fly in partial nephrectomies as new information emerges.
Surgical Robot Autonomy	Grants robotic systems semi-autonomous capabilities. [19]	Enabling advanced maneuvers in pelvic surgeries where manual dexterity is limited.
Real-Time Decision Support	Supplies immediate, data-based insights intra-operatively [20]	Adapting to intraoperative cardiac load changes during valve repair surgeries.
Tissue Characterization	Accurately differentiates between tissue types during surgery. [21]	Discerning fibrotic from normal liver tissue in hepatectomy procedures for cirrhosis management.

Post-Operative Phase

Post-operatively, AI aids in automated monitoring for early detection of complications [22], curates customized rehabilitation plans [23], manages post-operative pain [24], and facilitates wound care using smartphone images for timely interventions [25]. Moreover, it helps predict recurrence and long-term complications, ensuring comprehensive follow-up care [26].

Steps in Post-Operative Phases	Potential Benefits	Real Life Use Case
Automated Monitoring for Complications	Detects early indicators of post-surgical complications. [22]	Identifying early signs of sepsis in patients post-colectomy.
Customized Rehabilitation Plans	Creates recovery plans based on individual healing trajectories. [22]	Personalizing rehabilitation exercises for patients after ACL repair.
Advanced Pain Management	Customizes postoperative pain control protocols. [23]	Fine-tuning pain management for patients undergoing thoracotomy.
Wound Monitoring and Care	Utilizes mobile imaging for remote ulcer wound management. [24]	Monitoring diabetic foot ulcers using smartphone-based imaging for home care patients.
Prediction of Recurrence and Long-term Complications	Anticipates potential long-term postoperative issues. [25]	Forecasting the likelihood of hernia recurrence after mesh repair surgeries.

Use of AI beyond Operations

AI aids in healthcare administration by optimizing scheduling, patient flow, and resource allocation, using predictive analytics to forecast patient admissions and reduce waiting times. It simplifies billing and coding processes, enhancing accuracy and compliance while reducing the administrative burden [26]. In medical education, AI enables personalized learning experiences and simulation-based tools for risk-free surgical practice and decision-making [27]. AI improves healthcare accessibility, facilitating telemedicine for remote or underserved areas, ensuring high-quality care without the need for travel [28]. Additionally, AI transforms academic research by streamlining the Systematic Literature Review (SLR) process, automating data extraction and synthesis, and identifying research trends, contributing to knowledge advancement in various fields.

Challenges and Ethics

Integrating AI into surgical practices involves adapting to new technologies and ensuring data privacy and security, adhering to regulations like General Data Protection Regulation (GDPR) and Health Insurance Portability and Accountability Act (HIPAA). This integration must complement surgeons' skills without disrupting workflows. Ethical concerns such as consent, transparency, accountability, and mitigating biases in AI are crucial [29]. The effectiveness of AI depends on large, diverse datasets, but its reliability may falter in complex cases [30]. Additionally, the cost of AI technologies poses financial barriers, impacting access in low-resource areas, making equitable healthcare access a significant issue [31].

Future Considerations

The integration of artificial intelligence (AI) into surgical practices marks a transformative step towards advanced healthcare, emphasizing the significance of AI in enhancing patient outcomes, precision, and the overall delivery of care. Surgeons are encouraged to familiarize themselves with AI and machine learning basics, particularly Python programming, to leverage AI's capabilities in healthcare effectively.

This knowledge enables surgeons to collaborate with technical teams, contributing to AI tool development tailored to surgical needs. As healthcare continues to evolve, the adoption of AI promises more efficient, precise, and personalized care, extending its benefits across research, patient care, and education. However, navigating this innovation requires addressing ethical, security, and access considerations to balance the potential of AI with responsible healthcare delivery in the AI era.

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