Review Article • บทฟื้นฟูวิชาการ

Living with Artificial Intelligence in Anesthesia Practice

Napichayakarn Phanthananphokhin, Kornnika Yangan, Ingpisa Sritanapongsa, Phongthara Vichitvejpaisal
Department of Anesthesiology, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand

Abstract

This article delves into the burgeoning utilization of artificial intelligence (AI) technologies and their profound impact on the field of anesthesia. AI-driven decision support systems empower anesthesia practitioners, enabling informed choices for optimized drug dosing and enhanced patient outcomes. The collaborative partnership between AI and anesthesia practitioners is emphasized, highlighting the symbiotic relationship that achieves optimal results. Ethical considerations, encompassing patient autonomy and data privacy, are thoroughly discussed, alongside an exploration of potential limitations and biases inherent in AI implementation. The article advocates for a responsible and considered integration of AI, advocating for ongoing education and interdisciplinary collaboration to ensure the ethical and effective utilization of AI. Overall, anesthesia practitioners are encouraged to embrace AI as a valuable tool that magnifies their expertise, elevates patient care, and propels a future where innovation and compassionate care seamlessly intertwine.

Keywords: anesthesia practice, artificial intelligence, ethical consideration, personalized care

Key points:

- Integration of AI in anesthesia practice demands active collaboration among healthcare professionals, administrators, and AI developers.
- Ethical considerations are paramount when implementing AI in anesthesia practice.
- Integrating AI responsibly improves patient outcomes, healthcare processes, and the overall healthcare ecosystem.

In recent years, the field of anesthesia practice has undergone a profound transformation due to the rapid integration of AI technologies. This surge in AI adoption holds the promise of revolutionizing anesthesia care, enhancing patient outcomes, and streamlining clinical processes. As AI continues to advance, its presence in anesthesia practice becomes increasingly pervasive, reshaping traditional approaches and opening new avenues for patient treatment. There has been a notably positive response rate for several advantages, including a substantial reduction in medical errors (79.5%), the real-time delivery of large volumes of high-quality data (65.9%), the elimination of physical and emotional limitations (56.8%), and the acceleration of anesthesia processes (54.4%).[1] This article delves into the multifaceted landscape of AI's role in anesthesia practice, aiming to explore its impact while addressing the interplay of benefits and challenges that accompany this paradigm shift.

Correspondence to: Phongthara Vichitvejpaisal, E-mail: phongthara@gmail.com
Received October 21, 2023, Revised August 14, 2024, Accepted August 14, 2024

AI applications span the entire spectrum of anesthesia care, from preoperative risk assessment to postoperative care.[2] Examples of AI-powered tools, such as automated monitoring systems, predictive analytics, and personalized dosing regimens, are fundamentally reshaping how anesthesia practitioners approach patient care.[3] This transformative evolution underscores both the potential benefits and the challenges that necessitate meticulous consideration in the ongoing integration of AI within the field of anesthesia. Given the burgeoning impact of AI, it is essential to comprehensively examine its influence on anesthesia practice. The article's objective is to investigate AI's potential in transforming anesthesia while addressing the challenges it presents. It will analyze how the integration of AI affects patient safety, clinical efficiency, and the roles of healthcare professionals. Additionally, it highlights benefits, all while acknowledging obstacles like trust, ethics, and the importance of human oversight.

Understanding artificial intelligence

AI is a broad field that encompasses various techniques and technologies aimed at enabling machines to perform tasks that typically require human intelligence. The field is constantly evolving, with new techniques and technologies emerging to address various challenges and applications. These are some of the main components of AI:

Machine learning (ML) involves developing algorithms that allow computers to learn from and make predictions or decisions based on data. It is categorized into three main types:

1. Supervised learning: The algorithm learns from labeled data, meaning the input data is paired with the correct output. It learns to map inputs to outputs and can make predictions on new, unseen data.

2. Unsupervised learning: The algorithm works with unlabeled data to find patterns or structure within the data. Clustering and dimensionality reduction are common tasks in unsupervised learning.

3. Reinforcement learning: This type involves training algorithms to make a sequence of decisions to maximize a reward. It learns through trial and error, where actions lead to rewards or penalties.

Deep learning (DL) is a subset of ML that specifically deals with neural networks, which are models inspired by the human brain's structure. Deep Learning has shown remarkable success in various tasks such as image and speech recognition, natural language processing, and more.[4] Deep neural networks consist of multiple layers that progressively learn higher-level features from raw data.

Natural language processing (NLP) focuses on enabling computers to understand, interpret, and generate human language. It involves tasks like language translation, sentiment analysis, text generation, and speech recognition. NLP combines techniques from linguistics, computer science, and machine learning.[5]

Data analytics involves the process of examining raw data to extract insights and useful information. It encompasses various techniques, including descriptive analytics (summarizing and visualizing data), diagnostic analytics (identifying patterns and correlations), predictive analytics (forecasting future outcomes), and prescriptive analytics (suggesting actions to achieve desired outcomes).[3]

Computer vision is the field of AI that focuses on enabling machines to interpret and understand visual information from the world. This includes tasks like image recognition, object detection, facial recognition, and scene under-

standing.[6] Deep Learning has significantly advanced computer vision capabilities.

Natural language generation (NLG) involves generating human-like language from structured data, while *Natural language understanding (NLU)* involves teaching machines to understand and interpret human language. These components are critical for applications like chatbots, virtual assistants, and automated content generation.[5]

Expert systems are AI programs that mimic the decision-making abilities of a human expert in a particular domain. They use knowledge representation and reasoning techniques to provide solutions to complex problems.[7]

Robotics involves the design, construction, and operation of robots, which are physical machines that can perform tasks autonomously or semi-autonomously. AI techniques are often used to enable robots to perceive their environment, plan actions, and execute tasks.[8]

AI applications in anesthesia practice

The integration of diverse AI technologies has reimagined the landscape of anesthesia practice. These technologies include ML, DL, NLP, and data analytics.[2] Core to many applications are ML algorithms, designed to learn and adapt from data. While, DL excels at deciphering complex patterns within extensive datasets, enabling nuanced insights.[9] AI-powered monitoring and decision support systems are transformative tools in anesthesia. Real-time patient vital and physiological parameter monitoring is bolstered by AI algorithms detecting subtle anomalies that may elude human observation. These algorithms promptly alert anesthesia providers to potential complications, enabling timely intervention. AI-driven decision support systems assist anesthesia practitioners in informed decision-making concerning drug dosing, fluid management, and anesthetic administration.

Examples of AI applications

1. Predictive analytics: AI algorithms and models analyze extensive patient data, including factors like patient history, physiological parameters, and drug interactions. These analyses predict anesthesia outcomes and identify high-risk individuals, providing insights into potential complications.[3] This empowers anesthesiologists to make informed decisions, allocate resources efficiently, tailor interventions, and refine postoperative care planning.

2. Automated monitoring: AI-powered monitoring systems continuously track vital signs, detecting anomalies in real-time and alerting healthcare providers to potential issues, facilitating quicker interventions and reducing the risk of adverse events.[10]

3. Drug dosage calculation and delivery: AI assists in calculating precise drug dosages tailored to individual patients, considering factors like age, weight, and medical history, thereby preventing medication errors and improving patient outcomes. Moreover, AI-driven systems take this a step further by optimizing drug administration through continuous adjustments based on real-time patient responses.[11]

4. Intelligent decision support: AI-based decision support systems offer recommendations to anesthesiologists based on the patient's condition and the surgical procedure. These suggestions optimize drug selection, dosage adjustments, and fluid management for more personalized and effective care.[12]

5. Risk stratification: AI models assess patient risk factors, estimating the likelihood of complications or adverse events during anesthesia. This information helps clinicians

develop personalized care plans and allocate resources accordingly.[13]

6. Closed-Loop anesthesia: Closed-loop systems use AI to automatically adjust anesthesia levels in response to a patient's physiological changes, maintaining an optimal depth of anesthesia throughout the procedure, thereby minimizing the risk of under- or over-administration of anesthesia drugs.[14]

7. Post-anesthesia care: AI assists in post-anesthesia care by continuously monitoring patients as they recover from anesthesia. Any signs of distress or complications trigger alerts for timely intervention and reduced post-operative complications.[2]

8. Data analysis and research: AI facilitates the analysis of large datasets to uncover patterns, trends, and insights related to anesthesia practices, aiding in identifying best practices, protocol improvements, and advancements in patient care.[2]

9. Virtual reality and simulation: AI-powered virtual reality simulations allow anesthesia providers to practice various scenarios and refine their skills in a safe and controlled environment, improving decision-making and response to critical situations.[10]

10. Patient-specific modeling: AI creates patient-specific models that simulate individual responses to anesthesia based on unique characteristics, aiding in tailoring anesthesia plans to patients' needs and minimizing risks.[10]

Enhancing patient safety and care

The integration of AI technologies has ushered in a new era of patient monitoring and safety in anesthesia practice. AI-driven monitoring systems excel at processing real-time data, surpassing human capacity. They continuously analyze vital signs like heart rate, blood pressure, and oxygen saturation, detecting deviations from baseline.

Detecting anesthesia-related complications

AI's pattern recognition extends to identifying anesthesia-related complications. For instance, postoperative respiratory depression, potentially life-threatening, is challenging to detect manually. AI algorithms monitor respiratory patterns and identify deviations signaling distress. AI analyzes data from patient history, anesthesia administration, and physiological parameters to predict complications.[15] This empowers providers to take proactive actions, mitigating risks and optimizing outcomes. For instance, the Zeus® closed-circuit anesthesia ventilator from Dräger Medical in Germany utilizes AI and closed-loop technology to precisely target end-tidal concentrations of inhaled anesthetics while regulating fresh gas flow.[16] Additionally, innovative apparatuses for monitoring exhaled concentrations of intravenously administered propofol employ advanced techniques like proton transfer mass spectrometry and gas chromatography-mass spectrometry.[17]

Optimizing anesthesia dosing and patient outcomes

Precision in anesthesia dosing is crucial for optimal outcomes with minimal side effects. AI excels by customizing drug administration to individual patient characteristics. Continuous analysis of patient responses and profiles enables real-time anesthesia dosage adjustment. This is beneficial in dynamic scenarios, like surgeries with varying invasiveness. AI fine-tunes dosing for enhanced anesthesia depth and duration, reducing over-or under-sedation.[3] Predictive capabilities extend to forecasting

postoperative complications, enabling early interventions and tailored care plans, enhancing recovery and minimizing hospital stays. For example, continuous measurement of expired concentrations of inhaled anesthetics like desflurane, sevoflurane, and isoflurane is possible through spectrometric gas analyzers in anesthesia monitors.[18] Patient-controlled analgesia or patient-controlled sedation systems provide patients with control over their pain management, allowing self-administration of top-up doses with medications like morphine, piritramide, fentanyl, and tramadol.[19]

SEDASYS® was a computer-assisted personalized sedation system developed by Ethicon, New Jersey, USA. Designed primarily for colonoscopies and upper endoscopies, it aimed to simplify sedation processes, delivering adjustable propofol-based sedation while continuously monitoring vital signs.[20] A trained healthcare provider oversaw the process to ensure patient safety. Despite FDA approval in 2015, SEDASYS® was withdrawn from the market in 2016 due to commercial considerations, sparking mixed reactions in the medical community regarding its potential for patient comfort and efficiency, as well as concerns about automation.

Streamlining workflow efficiency through AI integration

The integration of AI into anesthesia practice has led to significant improvements in workflow efficiency and overall patient care. By automating various administrative tasks, enhancing documentation and data analysis, and optimizing resource management and scheduling, AI has revolutionized how anesthesia services are delivered.[2]

Automation of administrative tasks

AI-driven systems have proven effective in automating routine and time-consuming administrative tasks in anesthesia practice. Tasks such as appointment scheduling, patient registration, and billing processes can be streamlined through AI automation.[21] AI chatbots and virtual assistants streamline patient communication and education by providing preoperative and postoperative instructions, addressing common queries, and offering support, ultimately boosting patient satisfaction while reducing administrative workload.

Documentation and data analysis

AI's impact extends to documentation and data analysis, transforming how anesthesia practice operates. AI-powered tools can convert voice dictations into structured medical records, reducing manual documentation time.[22] An illustrative example includes AI's seamless integration with Electronic Health Records systems, extracting relevant patient data and populating anesthesia records automatically, thereby eliminating the need for manual data entry and mitigating transcription errors.[23] The overarching objective of AI-driven systems is to grant computers access to real-time patient data alongside insights derived from medical literature.

Resource management and scheduling optimization

Effective resource management and scheduling are crucial for optimizing anesthesia services. AI algorithms, leveraging predictive modeling and optimization techniques, excel in efficiently allocating resources. By analyzing historical data and surgical schedules, AI can anticipate resource demands and suggest optimized staffing levels, equipment allocation,

and room utilization. AI-driven telemedicine platforms facilitate remote interactions between anesthesia providers and patients, reducing the need for in-person visits for routine follow-ups and consultations, further enhancing efficiency and accessibility in healthcare delivery.[2]

Ethical considerations and challenges

The successful integration of AI into anesthesia practice requires collaboration between healthcare professionals, administrators, and AI developers. Ethical considerations, data security, and continuous refinement are vital aspects of this transformation. Patient autonomy and informed consent are crucial as AI becomes a part of clinical decision-making. Ensuring patients understand AI's role and have the opportunity for human intervention maintains trust and autonomy. Transparency in AI's decision-making processes and the possibility of overrides are essential components of ethical AI use.[24]

Navigating limitations and risks

While AI holds significant transformative potential, its integration into anesthesia practice is not without limitations and associated risks. The accuracy of AI models directly depends on the quality and diversity of their training data. Developing interpretable AI models and clear decision-making pathways is essential for fostering trust and understanding among healthcare providers and patients.[25] AI's practical limitations include its inability to provide opinions in unforeseen scenarios (72.7%), its limited adaptability to all patient profiles (68.2%), its relevance to contentious topics (77.3%), and its deficiency in addressing emotional aspects and displaying empathy in patient care (72.7%). Furthermore, concerns about the absence of emotional engagement in patient care are supported by a study involving primary care physicians, where the majority (94%) asserted that technology cannot replicate empathic caregiving.

Balancing AI's role with anesthesia practitioners

Concerns about AI replacing anesthesia practitioners can be addressed by recognizing AI as a complementary tool rather than a replacement.[26] The expertise and judgment of human anesthesia practitioners remain indispensable. Anesthesia providers can focus on complex case management and interdisciplinary collaboration. Guarding against "automation bias" is crucial. Anesthesia practitioners must be trained to strike a balance between AI support and independent clinical judgment.

AI as a decision-making tool

Anesthesia practitioners can utilize AI as a powerful tool to enhance decision-making. AI algorithms process real-time data, offering insights that aid them in assessing patient status and predicting complications. Integrating AI-generated recommendations with clinical expertise leads to informed choices about drug dosing, fluid management, and patient care. This collaborative approach ensures evidence-based decisions tailored to each patient.[27]

AI training and education

Continuing medical education plays a critical role in keeping practicing anesthesia providers updated on AI advancements. Workshops, seminars, and online courses facilitate AI skill acquisition and encourage ongoing

learning. AI-powered augmented reality (AR) and virtual reality (VR) systems revolutionize medical training and intraoperative visualization. Anesthesia practitioners use AR/VR for simulations, crisis scenarios, and real-time patient anatomy visualization, enhancing situational awareness and understanding of patient physiology.[28] Proper integration, training, and education allow anesthesia personnel to harness AI capabilities confidently. This collaboration reshapes healthcare, ushering in a new era of precision, innovation, and compassionate patient care.

Future directions and possibilities

The future of anesthesia practice is undergoing a transformative shift due to emerging AI technologies. These innovations have the potential to revolutionize patient care, streamline workflows, and advance medical knowledge. Advanced AI algorithms predict patient responses to anesthesia, surgical outcomes, and recovery paths with precision. This empowers providers to tailor interventions, anticipate complications, and create personalized care plans for improved outcomes and patient satisfaction. Integration of NLP and voice recognition will redefine documentation and communication in the operating room. Anesthesia practitioners can dictate notes, access records, and interact with AI systems through voice commands, streamlining tasks and focusing on patient care.[5]

The future operating room will seamlessly integrate AI with other healthcare technologies. AI collaborates with robotic surgical systems to enhance precision and decision-making. Real-time data from robotic instruments informs AI analysis.[2] Furthermore, AI enables personalized anesthesia care by analyzing patient data to optimize dosing, drug selection, and monitoring. Personalized risk assessments and treatment options empower patients to participate in their care, enhancing satisfaction and clinical outcomes.

Conclusion

The integration of AI into anesthesia practice brings significant changes with both advantages and challenges. AI-driven monitoring improves patient safety, predictive analytics enable proactive care, and streamlined workflows reduce administrative tasks. AI optimizes dosing and personalization of care for better outcomes. However, ethical concerns, patient autonomy, and data privacy need ongoing attention. Bias handling and transparent AI algorithms are crucial. Anesthesia practitioners must adapt roles, balancing human judgment and AI assistance.

References

1. Ejikem M, Eya J, Ibu F. Perspectives of anesthesiologists towards the use of artificial intelligence in anesthesia practice in a developing country. J Anaesth Surg Res. 2022;3:1-10.
2. Singh M, Nath G. Artificial intelligence and anesthesia: a narrative review. Saudi J Anaesth. 2022;16:86-93.
3. Jayatilake SMDAC, Ganegoda GU. Involvement of machine learning tools in healthcare decision making. J Healthc Eng. 2021;2021:1-20.
4. Bellini V, Carna ER, Russo M, et al. Artificial intelligence and anesthesia: a narrative review. Ann Transl Med. 2022;10:528.
5. Ahmed U, Iqbal K, Aoun M. Natural language processing for clinical decision support systems: a review of recent advances in healthcare. J Intell Connect Emerg Technol. 2023;8:1-16
6. Kitaguchi D, Takeshita N, Hasegawa H, Ito M. Artificial intelligence-based computer vision in

surgery: recent advances and future perspectives. Ann Gastroenterol Surg. 2022;6:29-36.
7. Duan Y, Edwards JS, Dwivedi YK. Artificial intelligence for decision making in the era of big data-evolution, challenges and research agenda. Int J Inf Manage. 2019;48:63-71.
8. Zaouter C, Joosten A, Rinehart J, Struys MM, Hemmerling TM. Autonomous systems in anesthesia: where do we stand in 2020? a narrative review. Anesth Analg. 2020;130:1120-32.
9. Gupta B, Sahay N, Vinod K, Sandhu K, Basireddy HR, Mudiganti RKR. Recent advances in system management, decision support systems, artificial intelligence and computing in anaesthesia. Indian J Anaesth. 2023;67:146-51.
10. Shaik T, Tao X, Higgins N, et al. Remote patient monitoring using artificial intelligence: current state, applications, and challenges. WIREs Data Mining Knowl Discov. 2023;e1485.
11. Bibian S, Ries CR, Huzmezan M, Dumont G. Introduction to automated drug delivery in clinical anesthesia. Eur J Control. 2005;11:535-57.
12. Hemmerling TM, Cirillo F, Cyr S. Decision support systems in medicine-anesthesia, critical care and intensive care medicine. InTech. 2012;p17-48.
13. Stones J, Yates D. Clinical risk assessment tools in anaesthesia. BJA Educ. 2019;19:47-53.
14. Wingert T, Lee C, Cannesson M. Machine learning, deep learning, and closed loop devices-anesthesia delivery. Anesthesiol Clin. 2021; 39:565-81.
15. Ermer SC, Farney RJ, Johnson KB, Orr JA, Egan TD, Brewer LM. An automated algorithm incorporating Poincare analysis can quantify the severity of opioid-induced ataxic breathing. Anesth Analg. 2020;130:1147-56.
16. Struys MMRF, Kalmar AF, De Baerdemaeker LEC, et al. Time course of inhaled anaesthetic drug delivery using a new multifunctional closed-circuit anaesthesia ventilator. in vitro comparison with a classical anaesthesia machine. Br J Anaesth. 2005;94:306-17.
17. Miekisch W, Fuchs P, Kamysek S, Neumann C, Schubert JK. Assessment of propofol concentrations in human breath and blood by means of HS-SPME–GC–MS. Clin Chim Acta. 2008;395:32-7.
18. Brattwall M, Warrén-Stomberg M, Hesselvik F, Jakobsson J. Brief review: theory and practice of minimal fresh gas flow anesthesia. Can J Anesth. 2012;59:785-97.
19. Ng KFJ, Yuen TST, Ng VMW. A comparison of postoperative cognitive function and pain relief with fentanyl or tramadol patient-controlled analgesia. J Clin Anesth. 2006;18:205-10.
20. Goudra BG, Singh PM, Chandrasekhara V. SEDASYS(®), airway, oxygenation, and ventilation: anticipating and managing the challenges. Dig Dis Sci. 2014;59:920-7.
21. Stanfill MH, Marc DT. Health information management: implications of artificial intelligence on healthcare data and information management. Yearb Med inform. 2019;28:56-64.
22. Chen M, Decary M. Artificial intelligence in healthcare: an essential guide for health leaders. Healthc Manage Forum. 2020;33:10-8.
23. Bowman S. Impact of electronic health record systems on information integrity: quality and safety implications. Perspect Health Inf Manag. 2013;10:1-19.
24. Cohen IG, Amarasingham R, Shah A, Xie B, Lo B. The legal and ethical concerns that arise from using complex predictive analytics in health care. Health Aff. 2014;33:1139-47.
25. Boulemtafes A, Derhab A, Challal Y. A review of privacy-preserving techniques for deep learning. Neurocomputing. 2020;384:21-45.
26. Hofer IS, Burns M, Kendale S, Wanderer JP. Realistically integrating machine learning into clinical practice: a road map of opportunities, challenges, and a potential future. Anesth Analg. 2020;130:1115.
27. Phillips-Wren G. AI tools in decision making support systems: a review. Int J Artif Intell Tools. 2012;21:1240005.
28. Chu LF, Erlendson MJ, Sun JS, Clemenson AM, Martin P, Eng RL. Information technology and its role in anaesthesia training and continuing medical education. Best Pract Res Clin Anaesthesiol. 2012;26:33-53.