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Systematic Review

Large language models in anaesthesiology: Current insights and future directions– A narrative review

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Abstract

Large Language Models (LLMs) promise to revolutionize the field of anaesthesiology as they have the potential to solve major challenges in this high-stakes field requiring quick decisions with utmost reliance on data. LLMs can facilitate enhanced clinical workflows for improving patient safety and outcomes through real-time decision support, risk prediction, and patient monitoring during anaesthesia and surgery. They can also provide an alternative documentation route for streamlining the administrative burden. Another useful advantage is the ability to provide multilingual education to the patients, thus improving the efficiency and accessibility of healthcare. In training, LLMs can assume the role of simulating complicated scenarios, thus accelerating anaesthesiologists' learning and reasoning skills in critical events. Concerns regarding the ethics, biases, and possible over-reliance on AI represent a challenge that needs to be handled. It is the effective balance of this artificial power with proper human oversight that will ensure safety and trust. Thus, LLMs are a promising tool in the future vision to improve anaesthesia practice, enhance workflows, enable accurate care, and work for under-resourced areas. However, validation, transparency, legal and technical policies must support LLM use so that they complement rather than displace clinical judgment.

Keywords: Large language models (LLMs), Anaesthesiology, Artificial intelligence (AI), Machine learning in perioperative medicine, Natural language processing (NLP) in Anaesthesia, Automated documentation in anaesthesia practice, Clinical decision support.

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1. Introduction

Artificial Intelligence (AI) application in healthcare has greatly revolutionized various medical disciplines, and anaesthesiology stands to benefit immensely from its application. As a specialty that demands a high degree of data analysis, continuous monitoring and rapid decision-making in dynamic and high-risk settings, anaesthesiology is particularly suited for AI integration. "Large Language Models (LLMs) are a dedicated type of Artificial Intelligence (AI) program intended to process and generate human language, demonstrating the capability of AI to comprehend, learn from, and interact with vast amounts of textual data." Other AI categories include computer vision, robotics, and expert systems, each focusing on different aspects of intelligence. Examples of Large Language Models (LLMs) include GPT-4 (OpenAI), PaLM 2 (Google), LLaMA 2 (Meta), Claude 3 (Anthropic), and Mistral 7B (Mistral AI). These are among the most promising recent advancements in AI and, have proven useful in a various aspect of clinical practice, including perioperative services, in recent years.[1] Despite their potential to enhance anaesthesia practice, their implementation presents several challenges that must be carefully addressed. The landscape of today's LLMs in anaesthesiology is one where technology is surging ahead, but remains incomplete without human expertise. The integration of LLMs aims to improve the clinical workflows, decision support, and resource allocation, but it comes at the cost of heightened vigilance on ethical aspects and patient safety protocols.

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2. Materials and Methods

2.1. Study design

A comprehensive literature search was conducted to identify relevant studies on the application of Large Language Models (LLMs) in anaesthesiology. The search was performed using PubMed, Scopus, Web of Science, Embase, and ScienceDirect, covering articles published between January 2015 and December 2024. This timeframe ensured the inclusion of both early research on AI applications in anaesthesiology and recent advancements in LLM-based systems.

The research question was structured using the Population-Intervention-Comparison-Outcome (PICO) framework, as follows:

1. Population (P): Anaesthesiology professionals and patients receiving anaesthesia.
2. Intervention (I): Application of Large Language Models (LLMs) and AI-driven systems in anaesthesiology practice, including clinical decision support, documentation automation, perioperative risk prediction, and education/training.
3. Comparison (C): Conventional anaesthesiology practice without AI or LLM-based interventions.
4. Outcome (O): Primary outcomes included clinical decision accuracy, patient safety, workflow efficiency, and educational impact. Secondary outcomes focused on user satisfaction, ethical considerations, and model reliability.

2.2 Search strategy and study identification

The search strategy incorporated a combination of Medical Subject Headings (MeSH) terms and free-text keywords, including "Large Language Models (LLMs)," "Artificial Intelligence in Anaesthesiology," "Clinical Decision Support Systems," "Machine Learning in Perioperative Medicine," "Natural Language Processing (NLP) in Anaesthesia," "AI-based Risk Prediction in Surgery," and "Automated Documentation in Anaesthesia Practice." Boolean operators (AND, OR) were used to refine the search and retrieve studies specifically addressing the intersection of AI, LLMs, and anaesthesia-related applications. Additional manual searches were conducted by screening the reference lists of key publications to ensure the inclusion of relevant studies that may not have been captured through database searches.

2.3. Inclusion and exclusion criteria

Studies were included if they focused on the use of LLMs or AI-based models in anaesthesiology and evaluated their role in clinical decision support, patient safety, documentation automation, or education and training within anaesthesia practice. Eligible studies consisted of original research articles, systematic reviews, or meta-analyses published in peer-reviewed journals.

Studies were excluded if they discussed AI in general healthcare without specific relevance to anaesthesiology, editorials, or conference abstracts without full-text availability, or focused solely on robotics, imaging AI, or other non-text-based AI applications.

2.4. Study selection and data extraction

Study selection followed a two-step process to ensure a rigorous and unbiased review. First, title and abstract screening was performed independently by two authors, who classified studies into Yes, No, or Maybe categories based on their relevance. Studies categorized as "Yes" proceeded to the next stage, while those marked as "Maybe" were further evaluated for eligibility. In the second step, full-text screening of the selected studies was conducted by both authors, with any discrepancies resolved through discussion with the third author.

Data extraction was carried out using a standardized data collection form, which included key details such as the author, year of publication, journal, and country of origin, along with the study design (RCT, observational, or review), participant characteristics, type of AI/LLM intervention used, key benefits and challenges.

Any disagreements in data extraction were resolved through discussion or consultation with the third author to maintain the integrity and accuracy of the study selection process.

3. Key Applications of LLMs in Anaesthesiology

3.1. Clinical decision support

OpenAI’s GPT-3 and similar models can perform complex tasks without requiring extensive training. Drawing upon the vast datasets with diverse language inputs, on which they are trained on, these models generate human-like text, answer questions, and assist with tasks that traditionally require expert knowledge. In anaesthesiology, LLMs can aid in patient communication, education, clinical decision support, and administrative tasks. Automated decision support is one key application that uses patient specific data and integrates it with population-based analytics.[2] For example, these models can consider surgical history, laboratory results and surgical procedure to recommend the optimal anaesthetic management plan. Although it is potentially applicable to all clinical settings involving high expectations, such decision support has the possibility of assisting high risk surgeries to yield improved patient outcomes.

3.2. Perioperative care and patient safety

LLMs can be used in perioperative care in order to contribute to patient safety by constantly monitoring the vital signs of the patient, for instance heart rate, blood pressure, and oxygen levels.[3] Intraprocedural data processing with the help of AI can facilitate prediction of adverse events and provide necessary recommendations for intervention. It enhances anaesthesia team's readiness for potential complications. Similarly, LLMs can reduce miscommunication and omission errors, that are leading causes of medical mistakes in surgical settings, by improving coordination among surgical team members.[4]

3.3. Education and training

LLMs also hold great promise in anaesthesiology education and training. Due to the advanced complexity of anaesthesia management and necessity for crucial decision making, these models can provide valuable support to both, novice and experienced anaesthesiologists. LLMs can be used to teach from cases, explain complex phenomena and to simulate clinical scenarios for training.[5] They provide flexible and learner cantered alternatives to traditional education programs, and help anaesthesiologists stay informed on various medical topics through a lifelong learning and self-directed approach.

4. Challenges in Implementing LLMs in Anaesthesiology

4.1. Over-reliance on AI

Despite the benefits, bringing LLMs into perioperative care is not without challenges. A major concern is about over reliance on AI, weakening human oversight, critical thinking and analytic power. Although LLMs can process and synthesize information at speeds and volumes beyond human capability, they are limited by the quantity and quality of their input data. If the data is inaccurate or biased, the AI recommendations may be flawed and even compromise patient safety. For this reason, AI systems in anaesthesiology should be closely monitored and rigorously validated to maintain reliability.[6] AI generated recommendations must remain subject to the primary analysis of anaesthesiologists, who must use professional judgment in determining their suitability for patient care.

4.2. Accountability

The integration of AI in healthcare entails multiple legal and ethical issues. One major concern is accountability, it remains unclear who should be held responsible for a harmful AI generated recommendation. Should the liability fall on the AI developer, the healthcare practitioner or the institution that allowed the use of technology? Also, patient confidentiality and data security are important to LLMs, as they rely on large datasets that may contain patient sensitive information. The use of AI in anaesthesiology requires strict policies that prioritize patient privacy and ethical standards.[6,7]

4.3. Infrastructure and resource constraints

Adopting AI technology requires significant investment in infrastructure (IT systems, hardware), personnel and support services. Anaesthesiologists and other specialists must be trained extensively to work with AI systems and recognize both, technical and ethical, aspects of patient care with the aid of AI. Secure data storage and reliable electronic connectivity (internet) for real time monitoring require substantial resources, which the healthcare institutions must carefully consider. These problems are especially prominent in resource deficient regions where access to sophisticated technologies is limited.[6,8]

5. Potential of AI in Anaesthesiology

AI's potential in anaesthesiology is remarkable. Patient safety, clinical decision making and perioperative workflows could all be improved with the aid of LLMs. Successful integration of AI in perioperative care requires utilizing the collaboration between AI developers, healthcare practitioners, and policymakers. However, these technologies can be fully appreciated in anaesthesiology only by ensuring robust technical safety, transparency and accountability.[8,9] The implementation of LLMs in anaesthesiology represents an impactful shift in clinical decision-making, risk assessment, and patient interaction. As AI systems transition from theoretical concepts to practical applications, the specialty must address concerns regarding trust, responsibility, and human oversight.

6. Real-World Applications of LLMs in Anaesthesiology

6.1. Applications in clinical setting

Studies indicate that LLMs can predict postoperative complications with remarkable accuracy. For instance, the Barnes Jewish Hospital study involving over 84,000 surgical cases (2018-2021) found that specialized clinical LLMs outperformed generic word embeddings by up to 38.3% in AUROC metrics for predicting outcomes like acute kidney injury and 30-day mortality. These models excel in extracting prognostic information from unstructured clinical narratives, capturing subtle linguistic features such as patient frailty, medication adherence, and comorbidity assessments.[10] This advancement suggests that anaesthesiologists could eventually rely on AI-driven risk evaluations beyond standard lab values and vital signs, incorporating richer clinical documentation.

LLMs are being applied in various aspects of clinical practice, such as patient education, documentation optimization, predictive analytics, and more. The **Table 1** summarizes key applications, their benefits, and associated challenges:[11-28]

Table 1:

Study Focus	Applications	Key Benefits	Challenges
Clinical decision support[11]	Real-time perioperative risk assessment, drug interaction alerts	Reduces decision latency and improves protocol adherence	Limited contextual awareness in complex cases
Patient education[12-14]	Multilingual preoperative instructions, anxiety-reducing explanations	Improves health literacy, reduces clinician workload	Potential mistranslation of medical jargon
Documentation optimization[11,15]	Automated quality reporting and billing compliance Detailed anaesthesia records, rigorous incident reporting	Reduces administrative burden by 30-40% Saves 45-60 minutes daily per clinician	Integration challenges with EHR systems
Predictive analytics[11,16]	Postoperative pain prediction Postoperative nausea/vomiting (PONV) risk stratification	Enhances personalized pain management strategies Achieves 89% specificity in high-risk identification	Requires continuous model validation Requires continuous calibration with local data
Research synthesis[17]	Systematic review search string generation	Achieves low to moderate retrieval rate with specialized models	Underperforms manual methods
Multimodal integration[16,18]	Combining vital sign analysis with clinical notes	Enables real-time decision support	Computational resource requirements
Medical translation[14,19,20]	Patient information localization	Expands access to non-English speakers	Loss of clinical nuance in translations
Risk stratification[16,18]	ASA physical status classification	Ensures high agreement with expert anaesthesiologists	Limited to structured data inputs
Clinical reasoning[14]	Differential diagnosis generation	Reduces cognitive load during emergencies	Hallucination rate of 8-12%
Closed-loop systems[11,16]	Anaesthesia depth monitoring	Reduces human error in titration	Regulatory approval challenges
Educational Tooling[21]	Simulated patient scenarios for trainee anaesthesiologists	Accelerates skill acquisition	Lacks tactile feedback integration
Resource Optimization[23]	Operating room scheduling, drug inventory forecasting	Reduces case delays by 15-20% in trials	Sensitive to input data quality
Crisis Management	Differential diagnosis during intraoperative emergencies	Provides higher accuracy in common crisis protocols	Slow response times in critical moments
Pain Management[24]	Personalized postoperative analgesia plans	Reduces opioid over prescription by 33%	Ethical concerns about algorithmic bias
Quality Assurance[13]	Automated compliance auditing for anaesthesia protocols	Identifies 98% of documentation discrepancies	Limited understanding of contextual exceptions
Research Acceleration[25]	Literature synthesis for rare anaesthesia complications	Cuts literature review time by 70%	Hallucination rate of 9-14% in niche topics
Regulatory Compliance[26]	Real-time monitoring of anaesthesia duration limits	Prevents protocol violations	Adaption lag during guideline updates
Tele-anaesthesia Support[27]	Remote pre-operative assessments via conversational AI	Expands access to rural populations (moderate increase in screenings)	Connectivity dependencies and latency issues

6.2. Transformative potential of LLMs

Large language models (LLMs) show transformative potential in anaesthesiology and recent advancements. Studies reveal that AI systems can produce multilingual preoperative instructions to enhance patient understanding and can also automate the ASA physical status classification with up to 95% accuracy compared to experts.[19] Other applications include reducing postoperative opioid over prescription by 33% by integrating pain management protocols and achieving 92% diagnostic accuracy in identifying common intraoperative emergencies using intraoperative crisis support tools.[24] Paperwork automation improves workflows, enabling clinicians to reduce charting time by 50%, and virtual simulation reduces the time required for acquisition of necessary skills. Despite these benefits, there are certain challenges such as the occasional mistranslation of medical terms, latency in critical decision support, and integration into legacy electronic health record systems. The ethical concern is that algorithmic bias in treatment recommendations is unacceptable, and the need for hybrid human-AI workflows all rely on the indispensability of clinician oversight. This highlights a potential future where LLMs enhance anaesthesia efficiency and decision-making, but their widespread adoption depends on scalability and robust safety validation.[28] While LLMs improve risk prediction, documentation and patient education, they still have reliability gaps during complex decision making. Safe adoption requires hybrid human-AI workflows and rigorous validation frameworks. Establishing standardized benchmarks and ensuring strict regulatory oversight are needed in order to utilize full potential of LLMs while preventing risks in high stakes clinical settings.

7. Challenges in Implementing LLMs

7.1 Operational challenges

LLMs still need to go through the process of operationalization. Research shows that their model performance is inconsistent in different subgroups of patients and across various outcome metrics.[29] LLMs work well on binary classification modules, but less so when predicting continuous variables such as PACU scores.[10] Moreover, demographic biases in training data raise concerns regarding fairness and equity in AI driven decision making.

7.2. Conversational capabilities

The conversational capabilities of LLMs present both opportunities and challenges in patient-clinician interactions. Comparisons between ChatGPT and Bard reveal that ChatGPT achieves higher accuracy (0% hallucination rate vs. Bard’s 30.3%) but struggles with readability, often producing dense, technical responses.[30] To maximize their utility, hybrid models could combine LLM knowledge retrieval with controlled natural language generation, ensuring clinical precision while tailoring explanations to individual patients’ comprehension levels.

7.3. Challenges in AI-assisted drug delivery

There are also challenges in deployment of AI assisted closed loop systems for anaesthetic drug delivery. For example, McSleepy is an automated propofol and remifentanil infusion system based on EEG and hemodynamic monitoring, but it faces difficulty in managing real world patients’ physiological variability.[31] Hybrid models that combine LLM predictions with reinforcement learning for dynamic protocol adaptation may offer a solution, although such approaches remain experimental at present. An example of future perioperative risk prediction is via the use of multimodal AI models that integrate text, imaging, and waveform data, allowing assessment across a wide spectrum of disease states. Studies integrating preoperative notes with intraoperative telemetry demonstrate improved detection of hemodynamic instability. With IoT (Internet of Things) enabled real-time analytics, the operating rooms become more digitized, and with advanced AI driven assessments of situations, they can even replace clinical decision making while ensuring enhanced patient safety.[32]

7.4. Ethical considerations and transparency

Ethical issues continue to affect AI transparency and accountability. The majority of commercial LLMs are “black boxes”, making it difficult for clinicians to understand how AI generates its recommendations.[33] Some proposed solutions, like explainable AI framework, including attention weight visualization and counterfactual reasoning, aim to increase the model’s interpretability.[34] Furthermore, liability issues need to be addressed if AI produces harmful recommendations. To address these considerations, a continuous evaluation model, that incorporates robust policy frameworks, is needed for the successful adoption of AI in anaesthesiology (**Figure 1**).

8. Hybrid Human-AI Models and Future Directions

Although LLMs are open sourced, the development of domain-specific LLMs, like the Hypnos model for Chinese anaesthesiology, suggests that AI systems can be fine-tuned for specific medical fields.[35] These models outperform general purpose LLMs in medication dosing recommendations and complication prediction by employing out of the box training using anaesthesia textbooks, procedural guidelines, and anonymised clinical narratives. However, their implementation remains limited by resource constraints, especially in underfunded healthcare systems.

9. Integrating AI into Anaesthesiology

To successfully integrate AI into anaesthesiology, institutions must establish continuous evaluation mechanisms to monitor model drift and retrain AI systems as needed. A promising approach to enable data sharing across institutions, without compromising patient privacy, is federated learning, which allows collaborative model training without directly sharing patient data.[36]

Trust in AI systems centres on transparency, reliability, and user-friendly interfaces. Anaesthesiologists must receive training in AI literacy to interpret model outputs effectively while maintaining therapeutic associations with patients. Medical education programs should evolve to incorporate AI competencies, preparing future clinicians for a technologically advanced healthcare landscape (**Figure 2**).[37]

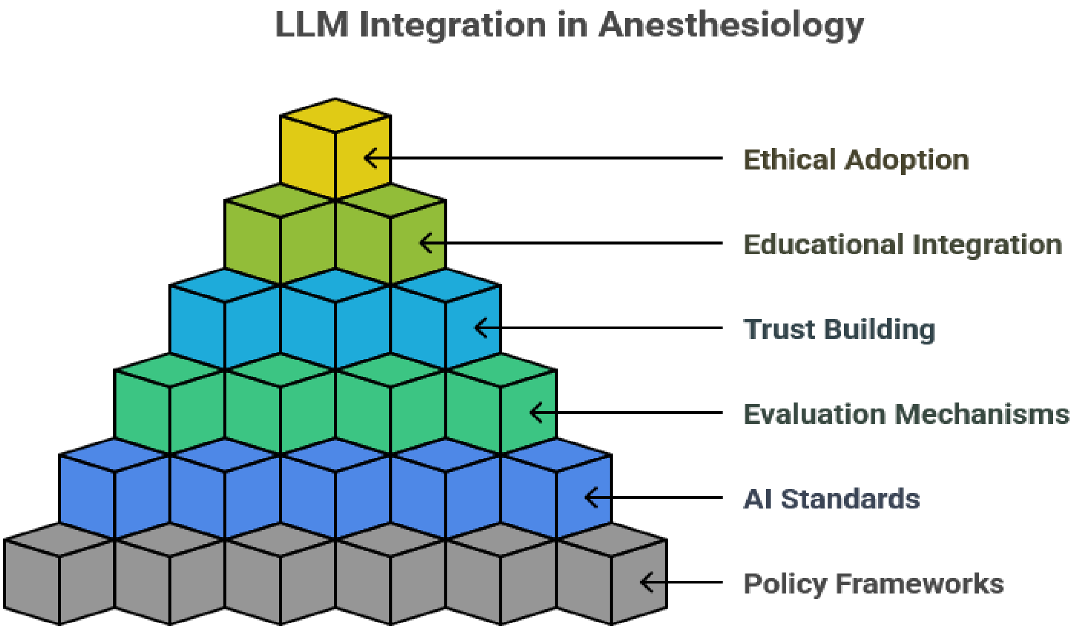

Figure 1: Continuous evaluation model

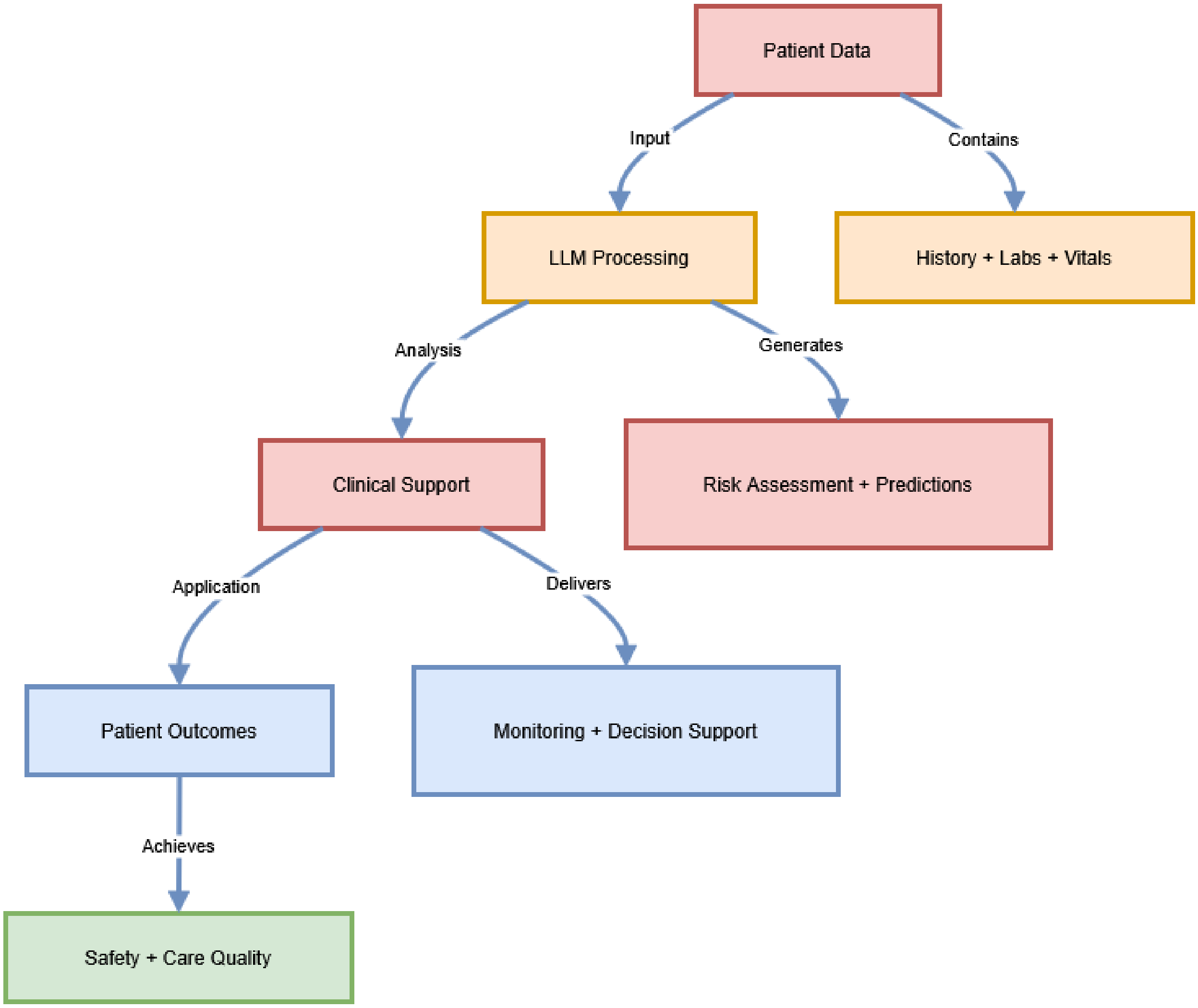

Figure 2: Integrating AI into anaesthesiology

10. Medicolegal Concerns and Policy Frameworks

In terms of medicolegal concerns, policy frameworks need to evolve to accommodate AI driven decision making. Since current malpractice laws do not consider AI involvement, new regulations are required to ensure explain ability and human oversight, particularly for high-risk recommendations. Additionally, standards must be established for AI validation criteria, demographic bias audits, and transparency in training data sources to facilitate responsible AI integration.[38,39]

11. The Future of AI in Anaesthesiology

Professional societies must drive the development of the specialty specific AI guidelines, as seen in radiology and cardiology. Establishing assessment criteria beyond predictive accuracy, such as fairness, usability, and real-world clinical effectiveness, will be critical for ensuring ethical and safe AI adoption in anesthesiology.[40,41] Through the confluence between innovation and ethics, the specialty has the opportunity to harness AI's transformative power, yet maintain the humanistic elements of patient care. With investments in education, infrastructure, and policy, LLMs can enhance perioperative safety and efficiency while preserving the essential role of anaesthesiologists in clinical decision-making.

12. Conclusion

Large Language Models hold great potential to revolutionize anaesthesiology by enhancing patient safety, devising efficient workflows, and transforming education and training. LLMs can be used for predicting post-operative complications, automating administrative tasks, real time monitoring and for much more, that can indirectly augment the anaesthesiologists. But their integration is not without challenges. Ethical concerns, regarding accountability and data privacy, need to be addressed. Over-reliance on AI, potential biases in algorithms, and the need for robust infrastructure and resources pose significant hurdles. Successful implementation necessitates continuous evaluation, comprehensive training, and collaborative efforts between AI developers, healthcare practitioners, and policymakers. Harnessing the full potential of LLMs, while ensuring human oversight in patient care, requires placing transparency and reliability at the very core.

13. Authors' Contributions

Study design: LG, DB; Initial screening: DB, ST; Literature search: DB, ST; Full-text review and data extraction: DB, ST, LG; Drafting of the initial manuscript: LG, DB; Contribution to and review of the final version of the manuscript: LG, DB.

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Nil.

15. Conflicts of Interest

There are no conflicts of interest.

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