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Review Article

Future of Anesthesia: Is Artificial Intelligence Implementation Near?

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Abstract

The implementation of artificial intelligence (AI) becomes increasingly prevalent due to advancements in technology and has the potential to significantly enhance the future of anesthesia and critical care. This article concisely summarizes contemporary AI technology utilized in anesthesia and in the intensive care unit (ICU). The current data indicates that the incorporation of AI could have a substantial impact on areas such as chronic disease management and anesthesia education methods, necessitating the development of specialized studies to investigate these applications. Nevertheless, current AI implementations predominantly function as decision-support tools rather than replacements for clinical judgment, despite the immense potential of AI to enhance the capabilities of anesthesiologists. Additionally, the limitations and ethical considerations of AI implementation in this domain are discussed.

Keywords: ***Artificial Intelligence; prediction algorithms; anesthesia; intensive care unit; critical illness***

Introduction

Artificial intelligence (AI) is often defined as the ability of computers to respond in a manner analogous to human intelligence. It is a multidisciplinary computerized research field that emphasizes the development and creation of intelligent algorithms for problem-solving, object and word recognition, as well as decision-making [1]. Often, it pertains exclusively to computers or robots, but its foundations encompass other fields, including philosophy, psychology, linguistics, and statistics. We have applied AI to various aspects of medicine, from largely diagnostic applications in radiology and pathology to more therapeutic and interventional applications in cardiology and surgery [2,3]. The implementation of AI is becoming more and more prevalent due to technological advancements. This is equally applicable in the domains of anesthesiology and intensive care. It's probable that we are currently employing a type of AI that we are unaware of. Consequently, the introduction of AI is unavoidable, irrespective of individual preferences.

AI is a transformative technology that can greatly enrich the future of anesthesia and critical care. Nevertheless, AI implementation raises several questions: How will AI affect or change clinical decision-making in anesthesiology? Will AI reduce errors in anesthesia practice? Will we as clinicians accept AI anesthesia practice (and on what level) in the future? Will AI ultimately replace anesthesiologists?

Discussion

Where do we stand now with artificial intelligence in anesthesiology?

An anesthesiologist's duties encompass assessing patients before surgery, ensuring their safety throughout the treatment, and securing their comfort thereafter. Even nowadays, AI has many applications in anesthesia, like monitoring vital signs, predicting adverse events, customizing medication doses, and automated record-keeping. AI has engineered robotic devices designed for mechanical tasks, like intubation, ventilation, and the management of nerve blocks, to improve patient care, reduce costs, and improve efficiency, with the potential to fundamentally alter healthcare.

AI systems leverage comprehensive patient data and diagnostic images to assist anesthesiologists in formulating customized anesthesia strategies that align with each patient's distinct anatomical and physiological characteristics. The evaluation of the airway is a critical component of preoperative assessment in anesthesiology. Several AI techniques, in contrast to traditional methods like the Mallampati test, the Cormack-Lehane classification, and thyromental distance, utilize facial and neck features to assess patients, identifying individuals who may present challenges during intubation [4].

Machine learning algorithms have shown significant use in patient risk categorization. Through the examination of patient demographics, medical history, and preoperative evaluations, AI can forecast individual risks and outcomes, including the probability of problems, length of hospital stay, or postoperative pain [5]. AI could accurately predict the probability of intraoperative hypotension nearly 15 minutes prior to its occurrence or a hypotensive episode subsequent to general anesthesia [6]. Similarly, researchers have developed automated models to anticipate Intensive Care Unit (ICU) admissions, aiding clinicians in proactively planning postoperative care, potentially improving outcomes through timely interventions and efficient use of ICU resources [7].

The precise administration of drug doses is crucial for the safety and efficacy of anesthesia. The incorporation of AI offers a new method for forecasting ideal drug dosages. The anesthesia dosage required for each patient varies significantly due to individual factors such as age, body mass index (BMI), and both past and current health conditions. By looking at molecular structures, formulation components, and environmental parameters, machine learning models can guess how stable, soluble, and quickly drugs will be released. This approach enables precise predictions that aid in optimizing drug delivery and therapeutic effectiveness [8].

The procedures by which general anesthetics induce reversible sedation remain a significant issue. AI can determine the dose-effect relationship by analyzing pharmacodynamics and various drug characteristics while also optimizing drug infusion through real-time monitoring data. Target-controlled infusion (TCI) systems, widely used in everyday practice, represent the first generation of open-loop pharmacological robots. Their software has built-in pharmacokinetic models of different drugs, based on which they deliver loading doses to achieve specific plasma drug levels rapidly and then maintain a steady state. They display estimated plasma and effect-site concentrations, which may differ from the actual concentrations [9]. Additionally, researchers specifically developed the Bispectral Index (BIS), an electroencephalogram parameter, to measure the hypnotic effects of anesthesia. Several trials consistently show it to be superior to manually controlled propofol infusions when used in combination with TCI [10].

Pharmacological models utilizing AI, besides aforementioned DiprifusorTM, a TCI pump employing a pharmacological model, include: CLADSTM (closed loop anesthesia delivery systems), drug administration systems designed for precise medication dispensing to achieve specific anesthesia levels; McSleepy, an independent system that simultaneously manages sedation, pain relief, and muscle relaxation with propofol, remifentanil, and rocuronium; SEDASYS®, an AI system for propofol delivery by non-anesthesiologist physicians; goal-directed fluid therapy models, which administer fluid boluses based on patient parameters; and models for vasopressor titration, which adjust vasopressor administration according to non-invasive blood pressure, stroke volume, and stroke volume variation [8,11].

Accurate pain evaluation is crucial for establishing successful treatment, wherein AI has demonstrated potential through objective and established standards. AI evaluates spontaneous facial emotions via image categorization, alongside natural language processing, body posture assessment, and breathing pattern analysis. It uses a neurophysiological approach that relies on biosignals, such as electroencephalography (EEG), electromyography (EMG), and electrodermal activity (EDA), to detect pain [12]. Traditional patient-controlled analgesia (PCA) allows individuals to manage their pain by self-administering additional doses based on their pain levels. The novel AI-PCA algorithm improves the efficacy of acute pain treatments by identifying and alerting medical personnel to probable adverse occurrences, including insufficient analgesia and excessive sedation [13].

The incorporation of AI into ultrasound-guided regional anesthesia is a swiftly advancing domain. Peripheral nerve or central neuraxial blockades employ several commercial AI systems. These systems are essential for the detection and tracking of nerves and other structures, enhancing speed, efficiency, and safety [14].

Artificial intelligence in critical illness and its impact on patient care

Despite this advancement, traditional critical care is limited in its ability to completely grasp and address the complex nature of patients' health, predict deterioration, and provide prompt treatment. The fact that various underlying illnesses can elicit the same symptoms, making it challenging to give individualized therapy, emphasizes the complexity of medical care. Diseases such as digestive disorders, cardiovascular problems, and brain illnesses demonstrate this complexity.

Currently, clinicians make pivotal decisions based on medical knowledge, individual perspectives, and contextual circumstances. These complex characteristics create variability. AI possesses a myriad of varied applications for the management of critically ill patients with one single goal, and that is to personalize medical care.

Diagnosis support is the most essential application of AI. Anticipating disease or its course is essential for critically ill patients, as a delay in identifying clinical instability may lead to permanent injury or mortality. An exemplary use is the detection of epileptic seizures, aimed at improving clinical outcomes or facilitating timely treatment [15]. Furthermore, the prediction of hypotensive events in the ICU has been accomplished by an AI model that examined electronic health records and vital signs data, achieving a sensitivity of 92.7% up to 15 minutes prior to the occurrence of the event [16]. Similarly, numerous AI algorithms have been created that employ diverse clinical and laboratory factors to forecast sepsis many hours prior to its onset [17]. AI could predict ICU mortality and assist with prognosis and early intervention for mechanical ventilation [18], acute kidney injury incidence [19], and treatment outcomes throughout standard scoring systems [20]. Additionally, treatment protocols for electrolyte replacements in an ICU setting have been established to provide recommendations for patient care that can be continuously refined based on individual patient needs [21]. Throughout the epidemic, AI techniques enabled expedited screening and diagnosis of COVID-19, substantially alleviating the loads on healthcare professionals [22]. Future datasets can be enhanced and utilized for subsequent pandemic outbreaks. Pain is frequently under-recognized in critically ill patients, particularly in those unable to self-report, making accurate assessment and management crucial in their care. Pain management in the ICU is an evolving practice that emphasizes accurate and frequent pain assessment. Consequently, in an effort to make pain predictions, machine learning applications are being implemented in the context of pain evaluation [23].

Healthcare worldwide is facing significant challenges, such as increasing patient loads, rising costs, and staff deficiencies. AI enhances the optimization of hospital resources, scheduling, and forecasting patient influx to refine management in emergency environments. It can provide both non-medical and organizational assistance. However, its outcome should not compromise patient health or outcome.

In conclusion, AI encompasses the identification of diseases, the prediction of disease progression, and the identification of distinctive patterns in complex patient data. The use of AI has the potential to significantly enhance the efficacy of clinical diagnostics and can greatly aid clinicians in difficult decision-making processes. To accomplish this, it is essential to guarantee that the rationale for AI-generated recommendations is clear and transparent and that AI systems are engineered to be dependable and resilient in the management of critically ill patients.

Limitations and apprehensions regarding the clinical artificial intelligence implementation

There are still limitations in this field. Currently, there are technical limitations that prevent AI systems from effectively understanding complex medical scenarios or adapting to evolving clinical settings. High-quality data is essential for successful AI implementation, as inconsistencies in data quality might result in errors regarding patient care. AI's intelligence is dependent on the facts and information provided to it, necessitating a correlation between signs and symptoms to formulate a suitable treatment. Therefore, the integration of AI into anesthesiology and intensive care is not solely about technology but about effective implementation to enhance clinical practice. The human aspect of care remains paramount, with AI serving as a tool to augment rather than replace clinician expertise and interaction with patients. Also, many applications remain in the developmental stage and require further validation across diverse clinical settings. Variability in the quality of studies and lack of standardization in AI methodologies pose additional limitations [24].

As always, in research and clinical practice, we need transparency. AI systems must provide clinicians with understandable decision-making rationales to foster trust and facilitate effective collaboration. However, most AI-driven solutions today are partially automated, meaning that human oversight and decision-making are still required. This also raises questions about patient autonomy and informed consent as AI recommendations may not always align with a patient's preferences [25]. However, withholding AI implementation would constitute a global injustice by neglecting advancements that could benefit the general good.

Despite the initial excitement regarding the potential of the new generation of AI models, major shortcomings have to be addressed before these models can be deemed suitable for aiding in critical choices within the anesthesia and critical care.

Further considerations lie in the ethical aspects of AI clinical implementation. There is a need for rigorous measures to protect patient data and ensure privacy. The process of collecting and manipulating data to find patterns in order to ease AI performance, could lead to the leakage of confidential information. This is particularly exerted during the pre-processing stage and if the external validation is warranted. Another ethical concern is the safety of AI models in patient care. Nowadays, clinicians still use both paper and electronic documentation. This may result in incomplete and inconsistent data for the understanding of an AI algorithm. Stated fact could potentially lead to inappropriate interventions leading to patient safety compromise. Similarly, poorly configured AI systems can result in biased decisions, potentially leading to disparities in treatment [26].

In our opinion, future research should focus on assessing AI efficacy in clinical practice with an impact on safety by creating standardized metrics and protocols for AI applications in anesthesia and critical care. These trials should be conducted on a large scale in a multicentric manner. The goal is to provide uniform protocols and standards to minimize worldwide differences in medical care. Additionally, it's crucial to investigate the ethical ramifications of patient data privacy and guarantee that anesthesiologists receive sufficient training on interacting with AI systems.

Conclusion

The current data indicates that the incorporation of AI could have a substantial impact on areas such as chronic disease management and anesthesia education methods, necessitating the development of specialized studies to investigate these applications. Nevertheless, current AI implementations predominantly function as decision-support tools rather than replacements for clinical judgment, despite the immense potential of AI to enhance the capabilities of anesthesiologists. Limitations persist, such as the necessity for AI systems to comply with clinical protocols, data integrity, and model generalizability. However, the human element of care continues to be of the utmost importance, with AI functioning as a tool to complement the expertise and interaction of clinicians with patients, rather than to replace it.

List of abbreviations

AI: Artificial Intelligence
BIS: Bispectral Index
CLADS: Closed Loop Anesthesia Delivery Systems
EDA: Electrodermal Activity
EEG: Electroencephalography
EMG: Electromyography
ICU: Intensive Care Unit
PCA: Patient-Controlled Analgesia
TCI: Target-Controlled Infusion

Declarations

Ethics approval and consent to participate

Not applicable

Informed written Consent

Not applicable

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

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Authors' contributions

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