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SCIENTIFIC ARTICLE - REVIEW ARTICLE

# ANESTHESIA AND ARTIFICIAL INTELLIGENCE: WHERE ARE WE AND WHERE ARE WE GOING?

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**ABSTRACT**

Technology based on Artificial Intelligence (AI) and its subfields such as Machine Learning and Deep Learning applied to the healthcare sector is undergoing rapid evolution. In the field of anesthesiology, its applications can be observed in the areas of preoperative assessment, monitoring of anesthetic depth, automated drug administration, ultrasound-guided regional anesthesia, and surgical room management with promising results.

**Objective:** The objective of this narrative literature review is to understand the technological landscape in which anesthesiology currently exists and explore future perspectives. It aims to comprehend the results, barriers, and challenges within this field.

**Methodology:** This study consists of a literature review, conducted through the analysis of articles on the PubMed platform from the years 2010 to 2023, using the terms: Anesthesiology, Artificial Intelligence, Machine Learning, and Deep Learning. Results:

**Results:** 65 articles related to the searched terms were identified, of which 25 articles were selected. After excluding 3 articles unrelated to the theme, 22 articles were deemed eligible, and 15 articles were chosen for the present study.

**Conclusion:** Artificial Intelligence and its subfields are undergoing progressive development and expansion. The ability to create algorithms that perform tasks and solve problems similarly to human intelligence is present in various areas of anesthesiology. They assist experts in delivering quality, safety, and efficiency in care; however, ethical, moral, and social barriers must be overcome. Despite showing promising results, future studies regarding their applicability should be conducted, and the presence of the anesthesiologist is still indispensable in clinical practice.

**Keywords:** Anesthesiology; Artificial Intelligence; Machine Learning; Deep Learning.

## INTRODUCTION

Artificial intelligence (AI) represents a dynamic area of computer science that seeks to empower machines to perform tasks that are executed based on human action and intelligence. At the heart of AI is the idea of developing algorithms and systems capable of learning, reasoning, and making decisions autonomously, potentially imitating, matching, or even surpassing the performance of experts in various fields [1-4].

Machine Learning (ML) is a subfield of AI that enables computers to make decisions and solve problems, improving future actions without explicit programming. Algorithms are formed by analyzing data that can include numbers, text, images, sounds, and speech [2-4].

Deep Learning (DL) is a subfield of ML that relies on complex computational architectures called artificial neural networks (ANNs) that mimic the human brain. It aims to create models capable of learning and performing complex tasks without prior programming by analyzing data, enabling them to achieve the best answer or result for a given task [4].

In the field of anesthesiology, AI shows positive trends, being present in various sectors of the field, with its main clinical applications currently in: 1- Preoperative evaluation; 2- Monitoring of anesthetic depth and automated drug administration; 3- Ultrasound-guided regional anesthesia (USGRA); 4- Operating room management and logistics [1-4].

The present study aims to discuss the existing forms of AI that currently assist anesthesiologists, investigate potential advances in the field, and relate the benefits achieved in patient care outcomes.

## METHODOLOGY

This study consists of a narrative review of the literature, conducted through the analysis of articles searched on the PubMed platform, between the years 2010 and 2023, applying the following keywords in its selections: Anesthesiology, Artificial Intelligence (AI), Machine Learning, Deep Learning.

The inclusion criteria were articles presenting previous studies related to the fields of anesthesiology and AI algorithms currently validated in clinical practice.

Articles with the terms ML and DL related to the development of algorithms applied to anesthesiology were also included, although the details of their development by the field of Computer Science were not described in detail here.

## RESULTS

Figure 01 shows the flowchart for the selection of studies included in this review. The search resulted in 65 articles. After critical reading, 25 were selected for addressing the relationship of the topic with anesthesiology. Three articles were excluded for being off-topic. Of the total, 22 were evaluated for eligibility, and 10 articles contained similar descriptions with redundancy in how the topic was described in its context. Therefore, 16 articles were included for the present study. Table 01 describes the authors of the various studies, objectives, and conclusions discussing the analyzed topic, presented in a summarized manner.

AI is present in various fields of anesthesiology, with validated applicability in preoperative evaluation, blood pressure monitoring, automated drug administration, ultrasound-guided regional anesthesia, and surgical room management.

Figure 1. Flowchart for selection and inclusion of articles in the present study.

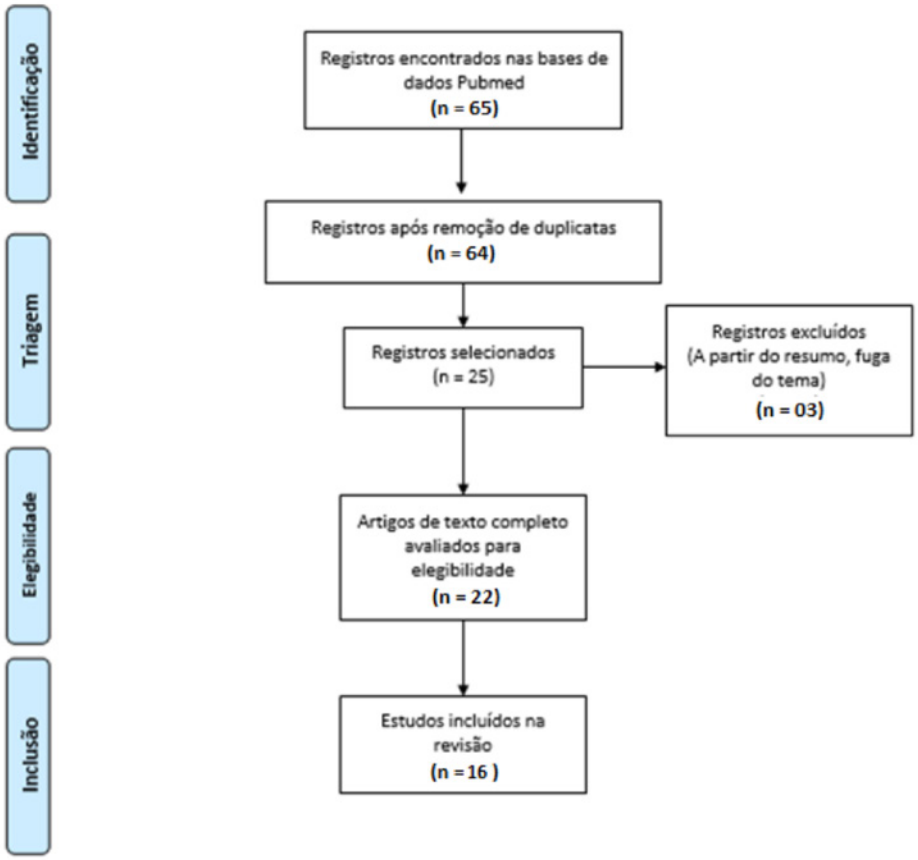


Table 1 - Results of the literature search, presented in summary form, including articles, authors, objectives, and conclusions.

| ARTIGO | *AUTOR* | OBJETIVO | CONCLUSÃO |
|---|---|---|---|
| **1- Necessity and Importance of Developing AI in Anesthesia from the Perspective of Clinical Safety and Information Security** | *Song .B. et al* | Esclarecer a situação atual e os desafios da aplicação de IA em anestesiologia, fornecendo referências clínicas e orientando o desenvolvimento futuro da IA na área. | Os algoritmos de IA são ferramentas clínicas que analisam com rapidez e precisão grandes quantidades de dados, descobrindo correlações e padrões imperceptíveis para a cognição humana. Anestesistas auxiliam a identificar possibilidade de novas tecnologias e fornecer *insigths* que garantem suas aplicabilidades na área. |
| **2- A Comprehensive Analysis and Review of Artificial Intelligence in Anaesthesia.** | *Singal M. et al* | Explorar o uso, os desafios e as aplicações prospectivas de IA na anestesiologia. | IA pode melhorar os cuidados de saúde, aprimorar produtividade e treinar futuros anestesiologistas. Tem aplicações na monitorização de sinais vitais, predição de eventos adversos e administração automatizada de drogas. Apresenta como desafios a qualidade e quantidade dos dados analisados, limitações técnicas e problemas éticos e morais. |

| ARTIGO | *AUTOR* | OBJETIVO | CONCLUSÃO |
|---|---|---|---|
| **3- Artificial Intelligence in Anesthesiology: Current Techniques, Clinical Applications, and Limitations** | *Hashimoto D. et al* | Revisar sobre a implicação da IA na anestesia, discutir sobre suas limitações e sobre o papel dos médicos no desenvolvimento de novas tecnologias. | IA pode impactar a prática anestésica dando suporte perioperatório, nos cuidados críticos e no manejo da dor ambulatorial. Com o avanço tecnológico é de grande importância que os anestesiologistas fornecem insights baseados na prática clínica para verificar a aplicabilidades de futuras tecnologias de IA. |
| **4- Anesthesia Monitoring using Artificial Intelligence Techniques** | *Grath H. et al* | Demonstrar as evoluções tecnológicas que atuam na área da anestesiologia. | O avanço da tecnologia permitiu criar robôs com sistemas farmacológicos capazes de titular as doses e manter o estado de analgesia, hipnose e relaxamento neuromuscular. Em anestesia demonstram a vantagem de eliminar a parte repetitiva de "*workload*" permitindo aos anestesistas focarem mais no cuidado do paciente. |
| **5- Artificial intelligence and telemedicine in anesthesia: potential and problems** | *Bellini V. et al* | Discutir sobre a atual aplicação de telemedicina na anestesia e cuidados perioperatórios. | IA tem benefícios nas fases do cuidado perioperatório, previsão de riscos e organização das salas operatórias. Reduz custos e melhora os resultados da assistência. Telemedicina tem sucesso na avaliação pré-operatória, monitoramento dos cuidados e acompanhamento pós cirúrgico. |
| **6- Preadmission Anesthesia Consultation Using Telemedicine Technology: A Pilot Study** | *Wong D. et al* | Relatar sobre os aspectos e implementação da telemedicina em consultas anestésicas. | Telemedicina pode reduzir os custos com deslocamento dos pacientes e melhorar a acessibilidade do cuidado à saúde. |
| **7- Patient preferences on telemedicine for preanesthesia evaluation** | *Fishman M. et al* | Investigar a preferência dos pacientes quanto ao uso da telemedicina para avaliação pré anestésica | Telemedicina permite realizar consultas e avaliações pré-anestésicas, alcançando satisfação do examinador e do paciente. |
| **8- McSleepy, da Vinci, Kepler Intubation System et al** | *Shah S.* | Pontuar sobre Mc Sleepy e Keppler Intubation System (KIS). | IA pode auxiliar na prática anestésica com segurança e precisão. |
| **9- Recent advances in the technology of anesthesia** | *Seger C. et al* | Dicorrer sobre a presença da tecnologia na prática anestésica. | A tecnologia de monitorização e entrega de medicamentos permitiu segurança e eficiência dos anestésicos. A telemedicina permite avaliações perioperatórias e a geração de dados de saúde. Automação é iminente no futuro da anestesiologia. As inovações precisarão considerar os fatores humanos, garantir a privacidade, segurança, e validade dos dados gerados. |
| **10- Artificial intelligence, nano-technology and genomic medicine: The future of anaesthesia** | *Naaz S. et al* | Concentrar nas associações e oportunidades de IA criadas com anestesia. | IA poderia ser usada para desenvolver ferramentas avançadas de apoio à decisão clínica aumentando a precisão e eficiência da prática anestésica. A anestesia é uma especialidade complexa sendo irrealista a hipótese de substituição por IA. |
| **11- Monitoring the depth of anesthesia using entropy features and an artificial neural network** | *Shalbaf R.et al* | Propor um novo modelo automatizado de avaliação de profundidade anestésica. | Um novo modelo de sistema de monitorização de EEC poderia auxiliar anestesistas a estimar a profundidade anestésica com rapidez e precisão. |

| | | | |
|---|---|---|---|
| **12- Artificial intelligence in ultrasound-guided regional anesthesia: A scoping review** | *Viderman D. et al* | Revisar as aplicações de IA no uso de USG em anestesia regional. | IA pode ser útil para identificar estruturas anatômicas durante anestesia guiada por USG reduzindo ou evitando complicações. |
| **13- The Advances and Utility of Artificial Intelligence and Robotics in Regional Anesthesia: An Overview of Recent Developments** | *Karmakar A. et al* | Explorar o cenário e aplicações de IA e robótica na anestesia regional, delineando benefícios, desafios e considerações éticas. | IA e a robótica têm o potencial de remodelar a prática da anestesia regional, melhorando o atendimento ao paciente e o manejo da dor. |
| **14- Machine learning approach to needle insertion site identification for spinal anesthesia in obese patients** | *Chan J. et al* | Discorrer sobre o uso de USG em anestesia de neuroeixo. | O uso de USG em anestesia de neuroeixo identifica o local de punção em pacientes obesos reduzindo o desconforto e complicações. |
| **15- Ultrasound Images Guided under Deep Learning in the Anesthesia Effect of the Regional Nerve Block on Scapular Fracture Surgery** | *Liu Y. et al* | Avaliar os desfechos de bloqueios guiados por USG em fratura escapular. | O USG apresenta precisão para identificar estruturas resultando em efeitos anestésicos adequados com baixas complicações. Modelos de DL podem melhorar efetivamente a conduta em pacientes com fratura de escapula. |
| **16- Artificial Intelligence: A New Tool in Operating Room Management** | *Bellini V. et al* | Entender o papel das novas tecnologias no período perioperatório, com foco particular em manejo e gestão de salas operatórias. | ML é capaz de dar suporte a modelos que coordenam múltiplos espaços simultaneamente como SRPA e salas cirúrgicas. Podem limitar problemas organizacionais com importante repercussão econômica. Tem potencial na gestão de centros cirúrgicos, capacidade de melhorar os serviços hospitalar, avaliar os riscos perioperatórios e atentar às necessidades da recuperação de cada paciente. |

Below, still as results, we developed four sub-themes according to the scope of the study: Application of artificial intelligence in preoperative medicine; Application of artificial intelligence in monitoring anesthetic depth and automated drug administration; Application of artificial intelligence in regional anesthesia; and Application of artificial intelligence in operating room management.

APPLICATION OF ARTIFICIAL INTELLIGENCE IN PREOPERATIVE MEDICINE.

Perioperative assessment allows the anesthesiologist to examine the patient and identify risk factors, enabling adequate anesthetic and operative planning, reducing complications, and mortality [5].

Defined by the World Health Organization (WHO) as the provision of health services through communication technologies, telemedicine allows anesthesiologists to conduct consultations, pre-anesthetic evaluations, and patient follow-up in regions where distance is a limiting factor [5-7].

Wong (2004) demonstrated the success of telemedicine during pre-anesthetic assessment, making it possible to achieve patient satisfaction and identify clinical conditions that could postpone the surgical procedure [6].

Computerized evaluation of photographs and facial analysis help identify predictive indicators of difficult airway (DA), and algorithms that use measures such as body mass index (BMI) and mento-thyroid distance allow anesthesiologists to decide on the best strategy for orotracheal intubation (OTI) [7].

ML models identify high-risk patients based on data analysis such as vital signs, ASA physical status classification, and comorbidities. These data are correlated, and the algorithms are programmed to predict possible postoperative outcomes such as severe operative pain and the need for ICU admission, assisting in proper bed management, shortening hospital stay, and reducing costs [5-7].

According to Fishman (2014) and Song (2022), AI has shown positive results. Advanced technology such as airway cameras and electronic stethoscopes assists in pre-anesthetic assessment; however, the doctor-patient relationship and the specialist's intuition in decision-making should be preserved.

APPLICATION OF ARTIFICIAL INTELLIGENCE IN ANESTHETIC DEPTH MONITORING AND AUTOMATED DRUG ADMINISTRATION

Anesthetic depth (AD) corresponds to the central nervous system response between the period of the effect of anesthetic drugs and the nociceptive perception of surgical stimuli.

The excessive use of hypnotics is correlated with increased postoperative mortality, and superficial anesthesia is related to emotional trauma and physiological changes that can compromise the surgical procedure and the postoperative outcome. Adequate monitoring of AD allows for safe surgical procedures, reduced doses of hypnotics, and favorable post-anesthetic recovery. Currently, the bispectral index (BIS) is the most used monitor, but interference in the capture of electroencephalographic signals and the poor nociception relationship predispose to subjective assessments of AD.

The electroencephalogram (EEG) records the brain's electrical activity and provides information about the different physiological states of the brain. Models based on ANNs identify the different characteristics of the waves captured and correlate them with the depth of anesthesia.

Mathematical models constructed from data analysis and deep learning determine the dose-response relationship of an anesthetic based on its pharmacokinetic and pharmacodynamic characteristics. Using monitoring data such as heart rate, blood pressure, and BIS, algorithms prevent fluctuations in AD by controlling and adjusting the target dose of hypnotics. [10-11].

Automation is the ability of a machine to change its function without human intervention, but in pursuit of a goal defined by it. The interdependence of these factors defines closed-loop anesthesia delivery systems (CLADS) [11].

The McSleepy, developed by McGill University Health, is an example of automation in anesthesia administration. Designed to monitor and maintain anesthetic depth, it uses parameters such as blood pressure, pain, and muscle relaxation to calculate the appropriate dose of anesthetics. It acts as a humanoid anesthesiologist capable of analyzing information and adapting its behavior, monitoring and recognizing malfunction [8].

Another example where AI was present in anesthesiology was in April 2011, when the Kepler Intubation System (KIS), a robotic intubation system developed by Dr. Thomas M. Hemmerling, performed the first remote intubation on a patient at the Montreal General Hospital. The KIS was developed with the goal of facilitating the intubation procedure, reducing complications associated with airway management [8].

Monitoring blood pressure using machine learning models that analyze EEG wave characteristics has allowed for a more precise evaluation of the anesthetic state compared to BIS [11].

The integration of AI and BP monitoring contributes to safer, personalized, and more effective anesthesia. Brain electrical activity, heart rate, blood pressure, and oxygen saturation make up the data

analyzed by the algorithm, allowing for real-time blood pressure assessment, reducing complications, and optimizing the doses of hypnotics used.

APPLICATION OF ARTIFICIAL INTELLIGENCE IN REGIONAL ANESTHESIA

Visual Computing is a subfield of AI in which machines recognize images, videos, and other visual data such as tomographies and x-rays. It has great applicability in anesthesiology with the automated analysis of ultrasound images that assist in the identification of structures during sonographically guided peripheral nerve blocks [12-13].

Ultrasound (USG) is commonly used in anesthesiology to perform regional blocks. Capable of identifying structures such as blood vessels, muscles, bones, and nerves, it allows for real-time monitoring of needle insertion and local anesthetic dispersion, minimizing or avoiding puncture accidents. Experts in the learning curve, overweight patients, and overlapping images with similar echogenicity are challenges that increase the risk of complications such as intravascular injections, nerve injury, and pleural or peritoneal puncture [12].

Hashimoto (2020) and Viderman (2022) demonstrated the applicability of artificial neural networks to identify anatomical structures from ultrasound images, successfully assisting in anesthetic practices [3,12].

The use of USG with automatic target detection assists anesthesiologists in identifying specific anatomical structures and ensuring the correct positioning of the needle and administration of local anesthetic, reducing complications and increasing the success of the anesthetic technique [12,14].

Chan (2021) presented, after evaluating 48 patients, that machine learning algorithms and image processing help identify the best needle insertion site and angle in neuroaxis blocks in obese patients with a body mass index (BMI) > 30 kg/m², reducing discomfort and complications from multiple punctures [14].

Liu (2021) concluded that the use of deep learning in ultrasound images assists in the regional blockade of patients undergoing scapular fracture surgery, reducing complications and the execution time of the blockade [15].

Despite being a promising technique, the applicability of AI in regional anesthesia presents risks and limitations. Failure to identify nerves with densities similar to nearby structures or failure to recognize structures with anatomical alterations predisposes to puncture trauma or systemic toxicity due to intravascular administration of local anesthetic. The identification of richly vascularized structures is also a challenge [13-14].

APPLICATION OF ARTIFICIAL INTELLIGENCE IN OPERATING ROOM MANAGEMENT

Surgical centers can be considered the "financial center" of hospital units, representing approximately 30 to 45% of revenue. They present a complex space where the high expectations of patients are confronted with the interaction of various professionals and unpredictable surgical schedules [4].

With the ability to generate numerous data points such as the type of surgery, surgical team, patient's medical history, as well as the type of anesthesia and surgical team experience, machine learning algorithms and artificial neural networks are fed, creating surgical center management systems [4,16].

This way, AI can optimize costs and reduce expenses by predicting the occupancy time of operating rooms and the stay in the Post-Anesthesia Care Unit (PACU), increasing the efficiency and safety of the service [16].

## DISCUSSION

AI has the ability to quickly and accurately analyze large data sets and identify patterns that are imperceptible to human cognition, making it a greatly helpful tool. However, it should be implemented in the right situation to address a specific question or solve an applicable problem.

With various applications in the field of anesthesiology, AI presents promising results, especially in the areas of preoperative assessment, monitoring of anesthetic depth, automated drug administration, regional anesthesia, and operating room management.

In preoperative assessment, the advent of telemedicine has enabled remote anesthetic consultations. With the aid of algorithms for facial recognition and analysis of data such as vital signs, comorbidities, BMI, and ASA physical status, it has been possible to assess and monitor patients in remote areas. Thus, AI has contributed to the success of assessments, stratifying surgical risks, VAD, and minimizing possible complications. However, due to cultural aspects, medical-patient contact is still necessary to achieve complete patient satisfaction.

ANNs identify different EEG wave patterns and correlate them with data obtained from blood pressure monitors, heart rate, and muscle relaxation, determining the brain's physiological state and predicting the level of blood pressure. Together with mathematical models built from the pharmacokinetic and pharmacodynamic characteristics of drugs, they determine the dose-effect relationship of anesthetics, preventing excessive blood pressure or superficial consciousness, ensuring safety during the surgical procedure, better anesthetic recovery, and cost reduction.

However, due to the human ability to extrapolate the known and deal with unexpected and emergent situations, the clinical judgment of the anesthesiologist is essential during patient care. The specialist is indispensable for evaluating the usefulness and validity of the data collected for algorithm training and ensuring that the developed technology is clinically applicable [3].

Visual computing recognizes patterns of anatomical structures that, in association with ML-based algorithms, compose software currently used in ultrasound devices, assisting anesthesiologists during sonographically guided regional and neuraxial blocks. With the assistance of AI, the risks of nerve injury, technique failure, puncture of nearby structures, and local anesthetic intoxication administered in the intravascular space are significantly reduced. Despite its success, this technology needs to improve the quality and quantity of images analyzed in its database, as structures with similar densities and anatomical changes can compromise the reliability of its use.

Surgical centers have significant economic importance within hospital institutions. Operating room occupancy, length of stay in the Post-Anesthesia Care Unit (PACU), inconsistency in surgical schedules, procedure complexity, and team experience are data directly related to productivity and efficiency. This information feeds AI algorithms that allow predicting the occupancy time of operating rooms and PACU, increasing efficiency, and reducing costs in these units.

While AI is a promising technology for the healthcare system, it is not exempt from challenges to be overcome, such as ethical and moral issues, quality and quantity of recorded data, and technical limitations. Future qualitative research will be necessary to better understand the ethical, social, and cultural implications of the integration between AI and clinical care.

Although effective in demonstrating correlations and identifying patterns, AI is still unable to determine causal relationships necessary for its clinical implementation without the participation of the anesthesiologist. Therefore, specialists in the field must critically evaluate new findings before their use.

## CONCLUSION

At the end of this review, it is concluded that in the current scenario, AI can assist anesthesiologists in preoperative consultations, allowing for remote assessment and monitoring of patients. In automated drug administration and monitoring of anesthetic depth, it can evaluate consciousness accurately through the correlation between EEG waves, vital signs, and the level of muscle relaxation. In regional anesthesia, software developed with visual computing data integrates new ultrasound devices, facilitating the identification of anatomical structures and reducing technique complications. Surgical centers increase productivity and efficiency when AI algorithms assist in managing these units. The interaction between AI and anesthesiology ensures quality and safety of care, and efficiency in hospital units. The data generated in the units feed the algorithms and allow the progression of AI, however, the quality and quantity of existing data is a barrier to this, as well as ethical and sociocultural challenges. Despite its constant evolution and great applicability in the field, AI is still not able to handle complications and emergent situations, making the presence of the specialist essential in delivering care.

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Conflict of Interest

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## REFERENCES

1- Song B, Zhou M, Zhu J.Necessity and importance of developing AI in anesthesia from the perspective of clinical safety and information security . Med Sci Monit. 2023; 29:e938835. Available from: https://medscimonit.com/abstract/full/idArt/938835 doi: 10.12659/MSM.938835

2- Singhal M, Gupta L, Hirani K (September 11, 2023). A comprehensive analysis and review of artificial intelligence in anesthesia. Cureus. 2023 Sep 11;15(9):e45038. Available from: https://doi.org/10.7759/cureus.45038 doi: 10.7759/cureus.45038

3-Hashimoto DA, Witkowski E, Gao L, Meireles O, Rosman G. Artificial intelligence in anesthesiology: current techniques, clinical applications, and limitations. Anesthesiology. 2020 Feb;132(2):379–94. Available from: https://doi.org/10.1097/ALN.0000000000002960 doi: 10.1097/ALN.0000000000002960

4- Grath MH, Flanagan C, Zeng L, Lei Y. Anaesthesia monitoring using artificial intelligence techniques. Int J Anesth. 2019;6(4):098. https://doi.org/10.23937/2377-4630/1410098 doi: 10.23937/2377-4630/1410098

5- Bellini V, Valente M, Gaddi AV, Pelosi P, Bignami E. Artificial intelligence and telemedicine in anesthesia: potential and problems. Minerva Anestesiol. 2022 Sep;88(9):729-34. Available from: https://doi.org/10.23736/S0375-9393.21.16241-8 doi: 10.23736/S0375-9393.21.16241-8

6- Wong DT, Kamming D, Salenieks ME, Go K, Kohm C, Chung F. Preadmission anesthesia consultation using telemedicine technology: a pilot study. Anesthesiology. 2004 Jun; 100(6):1605-7. Available from: https://doi.org/10.1097/00000542-200406000-00038 doi: 10.1097/00000542-200406000-00038

7- Fishman M, Mirante B, Dai F, Kurup V. Patient preferences on telemedicine for preanesthesia evaluation. Can J Anesth. 2015;62:433-4. Available from: https://doi.org/10.1007/s12630-014-0280-0 doi: 10.1007/s12630-014-0280-0

8- Sha SB. McSleepy, da Vinci, Kepler Intubation System et al. Indian J Anaesth. 2013 Jan-Feb;57(1):101-2. Available from: https://doi.org/10.4103/0019-5049.108597 doi: 10.4103/0019-5049.108597

9- Seger C, Cannesson M. Recent advances in the technology of anesthesia. 2020 May 18, 9:1-7. [version 1; peer review: 2 approved] Available from: https://doi.org/10.12688/f1000research.24059.1 doi: 10.12688/f1000research.24059.1

10- Naaz S, Asghar A. Artificial intelligence, nano-technology and genomic medicine: the future of anaesthesia. J Anaesthesiol Clin Pharmacol. 2022 Jan 28;38(1):11-7. Available from: https://doi.org/10.4103/joacp.JOACP_139_20 doi: 10.4103/joacp.JOACP_139_20

11- Shalbaf R, Behnam H, Sleigh JW, Steyn-Ross A, Voss LJ. Monitoring the depth of anesthesia using entropy features and an artificial neural network. J Neurosci Methods. 2013 Aug 15;218(1):17-24. Available from: https://doi.org/10.1016/j.jneumeth.2013.03.008 doi: 10.1016/j.jneumeth.2013.03.008

12-Viderman D, Dossov M, Seitenov S, Lee M-H. Artificial intelligence in ultrasound-guided regional anesthesia: a scoping review. Front Med. 2022 Oct 25; 9:994805. Available from: https://doi.org/10.3389/fmed.2022.994805 doi: 10.3389/fmed.2022.994805

13- Karmakar A, Khan MJ, Abdul-Rahman M, Shahid U. The advances and utility of artificial intelligence and robotics in regional anesthesia: an overview of recent developments. Cureus. 2023 Aug 29;15(8): e44306. Available from: https://doi.org/10.7759/cureus.44306 doi: 10.7759/cureus.44306

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