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Meta-analysis

AI innovations in anaesthesia: A systematic review of clinical application

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Abstract

Artificial Intelligence (AI) has emerged as a transformative technology with significant potential to enhance the precision and efficiency of anaesthetic treatments. Utilizing AI-driven predictive analytics and machine learning algorithms, healthcare providers may optimize multiple facets of anaesthetic administration, enhancing resource efficiency and superior patient care. AI can markedly enhance the efficiency of anaesthetic workflow optimization. AI algorithms can scrutinize extensive datasets to discern patterns and trends, allowing anaesthesiologists to enhance operation scheduling, resource distribution, and workflow administration. This systematic review, adhering to PRISMA standards, evaluated AI applications in anaesthesiology across critical care and emergency settings, focusing on ultrasound-guided regional anaesthesia (UGRA) and the integration of AI for improved decision-making and patient outcomes, clinical accuracy, operator efficiency, and hemodynamic management. Systematic review findings reveal significant improvements across multiple domains, including clinical decision support systems that enable more accurate event detection, reduced complications, and enhanced hemodynamic management. In ultrasound-guided regional anaesthesia (UGRA), AI systems such as ScanNav demonstrated high accuracy in identifying anatomical structures, reducing complications, and standardizing procedures. While the potential is immense, the review also highlights the need for further validation, standardization, and exploration of deep learning for seamless clinical integration, highlighting AI's transformative potential in modern anaesthetic practices while also acknowledging associated health risks.

Keywords: Anaesthesiology, Systematic review, AI, Clinical decision support systems.

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1. Introduction

In contemporary medicine, traditional healthcare providers have a complex role in patient care. Responsibilities encompass assessing appropriate patient treatment alternatives, verifying accurate prescription dosages, and assuring the operational efficacy of medical devices, including ventilators. Artificial intelligence (AI) complements this process by offering real-time support through the integration of patient data, electronic health records (EHR), medical literature, and expert knowledge.[1] AI is designed to enhance protocols and decision-making rather than serve as a direct replacement for healthcare providers,

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providing timely information, guidance, and processed data to support clinical care.

AI enhances adaptability to individual patient requirements and individualized decision-making by building upon established protocols that offer standardized standards and best practices for healthcare practitioners.[2] However, certain advanced systems can accomplish more than merely producing optimal knowledge. Certain systems are capable of comprehensive data aggregation, imaging support, continuous vital sign monitoring, and enhanced documentation. Therefore, while protocols provide reliable, evidence-based care, AI introduces an advanced dimension of individualized patient information for comprehensive medical management.

An early instance of interactive clinical consultation program documented in the literature occurred in the 1970s, where rule-based choices were augmented by expert knowledge and statistical data. However, due to their perceived resource and time demands, these systems exerted minimal influence throughout that period. In the last fifty years, the advancement of clinical decision support systems (CDSS) has significantly improved and is extensively studied to determine optimal implementation strategies for enhancing patient management. To date, CDSS has been employed in anaesthesia for the regulation of patient-ventilator settings, in the intensive care unit (ICU) for enhanced glycemic control, and in the emergency department (ED) for triage or as a workflow instrument within the electronic health record (EHR).[3] Besides providing diagnostic and management assistance, AI can economically benefit healthcare systems by decreasing prescription expenses, laboratory resources, and costly medical imaging. This is a minor segment of the extensive applications explored and implemented in critical care medicine. AI can reconcile the disparity between the continual advancement of medical knowledge and the efficacy of daily practitioners. This is particularly evident in critical care medicine, where the interplay of intricate diseases, various patient profiles, and an increasing array of factors to oversee fosters an environment conducive to medical errors.

1.1. The future of anesthesia: The revolution of artificial intelligence

AI has significantly advanced across multiple domains, exceeding human ability in numerous fields. AI is being employed in healthcare practices, including regional anaesthesia. Recent breakthroughs in AI have facilitated its incorporation into regional anaesthetics, promising to improve precision, efficiency, and patient outcomes. Utilizing machine learning algorithms and predictive analytics, AI can transform the execution and administration of regional anaesthetic treatments. A significant domain where AI exerts influence is preoperative planning. AI-powered systems, utilizing extensive patient data and diagnostic imaging, can aid anaesthesiologists in formulating individualized anaesthetic protocols based on each patient's anatomical and physiological traits. This degree of personalization can result in more accurate administration of regional anaesthetic, reducing the likelihood of problems and enhancing overall patient safety and happiness. AI can significantly contribute to intraoperative monitoring and decision-making. Through the continuous analysis of real-time patient vital signs, AI algorithms can notify healthcare practitioners of deviations from anticipated norms, facilitating early intervention and proactive treatment of potential issues during regional anaesthetic procedures.

The field of anaesthesiology is progressively shaped by the incorporation of AI (AI), leading to advancements that improve procedure accuracy and boost patient outcomes. Singhal *et al.,* demonstrated that AI's predictive analytics and machine learning functionalities transform preoperative planning and individualized care approaches for regional anesthesia4. Pham FM and colleagues emphasized the revolutionary impact of AI in intraoperative monitoring, where real-time data interpretation is crucial for proactive patient management. Garg and Kapoor emphasized the significance of AI in postoperative recovery, offering a paradigm for risk classification and predictive modelling that aims to enhance post-anaesthesia care.[5] Health care providers must interact with the advancement of AI and utilize its potential to enhance care standards in regional anaesthesia. AI has demonstrated its capacity to improve patient safety and care efficiency.[6] AI enhances anaesthesia procedures, emphasizing the necessity of remaining informed about technology advancements.[7] Studies emphasized the significance of emerging technologies in emergency medicine, correlating them with prospective AI applications for vital, time-sensitive interventions 8. The application of AI in ultrasound-guided regional anaesthesia indicates the potential for its extension into further domains of anaesthetic practice.[9]

1.2. Improving efficiency through AI in anesthesia

Besides raising precision, AI possesses significant potential to augment the efficiency of anaesthetic treatments. Utilizing AI-driven predictive analytics and machine learning algorithms, healthcare providers may optimize multiple facets of anaesthetic administration, enhancing resource efficiency and superior patient care. AI can markedly enhance the efficiency of anaesthetic workflow optimization.[10] AI algorithms can scrutinize extensive datasets to discern patterns and trends, allowing anaesthesiologists to enhance operation scheduling, resource distribution, and workflow administration. This may result in diminished patient waiting times, enhanced utilization of operating room resources, and increased overall efficiency in providing regional anaesthetic treatments. Predictive modelling and risk classification enabled by AI can enhance postoperative care and resource distribution. By identifying patients at elevated risk for postoperative complications, healthcare practitioners can optimize resource allocation, providing focused interventions and proactive monitoring for those most in need. This proactive strategy can result in enhanced outcomes, decreased healthcare expenditures, and increased overall efficiency in providing post-anaesthesia care. As healthcare professionals increasingly incorporate AI into regional anaesthesia techniques, the potential for enhancing efficiency and resource usage is substantial. By becoming aware of AI-driven anaesthesia's newest breakthroughs and opportunities, practitioners can fully leverage these technologies to enhance efficiency, improve patient care, and elevate healthcare delivery standards. To actualize the potential of AI in healthcare, healthcare practitioners, researchers, policymakers, and technology experts need to persist in their collaboration and innovation within the domain of AI-driven anaesthesia.

Collaboration among healthcare practitioners, researchers, policymakers, and technology experts is essential for increasing the incorporation of AI into regional anaesthetic procedures and maintaining alignment with the evolving patient care requirements. Using AI in regional anaesthesia operations offers significant potential for augmenting precision, enhancing efficiency, and promoting education and training within anaesthesiology. As AI technology advances, healthcare professionals must proactively keep informed and adopt new technologies to enhance care standards and benefit patients. Adopting this collaborative and progressive strategy will guarantee that the incorporation of AI in anaesthesia remains focused on patients and consistent with the overarching objectives of improving healthcare delivery.

Despite the widespread adoption of AI in critical care medicine, there is a notable lack of comprehensive literature assessing its overall efficacy, leaving its impact ambiguous. A detailed literature review and statistical analysis can provide valuable insights into AI's influence on patient outcomes and help identify specific subgroups or outcomes requiring further exploration. To address this, a systematic review was undertaken to evaluate AI's effectiveness over the past two decades and compare its performance to the standard of care (SOC) within relevant medical specialties.

2. Materials and Methods

2.1. Study protocol and registration

This systematic review was conducted by the EQUATOR (Enhancing the Quality and Transparency of Health Research) network's Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards. This systematic review was conducted following the guidelines of the EQUATOR (Enhancing the Quality and Transparency of Health Research) network's Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards, ensuring transparency and rigor in the methodology. The review aimed to assess the effectiveness and impact of clinical decision support systems (CDSS) and artificial intelligence (AI) technologies in improving patient outcomes across anaesthesia, critical care, and emergency medicine. It included studies involving hospitalized patients of all ages in acute or specialized care settings who received care with CDSS. Specific exclusion criteria were applied to maintain the study's relevance, removing studies involving primary care, non-randomized research, technical descriptions, non-human models, and case reports. This approach ensured a focused and clinically relevant evaluation of AI's potential in medical practice.

2.2. Search strategy

The research examined randomized controlled trials published from 2000 to 2021, concentrating on the efficacy of decision support systems (DSS) and computer-based decision aids (CDAs) in hospital environments, including emergency departments, intensive care units, and anaesthetic care settings. These technologies were assessed for their capacity to enhance essential components of healthcare, encompassing health status monitoring, healthcare delivery processes, patient data management, clinical evaluations, and the execution of optimal medical strategies. The research methodology entailed a comprehensive evaluation of Decision Support Systems (DSS) and Clinical Decision Aids (CDAs) relative to the conventional standard of care in these critical medical environments. The researchers sought to evaluate whether these technologies may augment clinical decision-making, enhance patient outcomes, and optimize healthcare providers' workflow through outcome comparison. The study aimed to identify areas where Decision Support Systems (DSS) and Clinical Decision Aids (CDAs) could mitigate errors, enhance diagnostic accuracy, and deliver real-time insights to physicians in high-pressure situations. These systems were assessed for their ability to interact with current electronic health record systems, enhance the analysis of extensive patient data, and propose evidence-based therapies.

2.3. Inclusion and exclusion criteria

The inclusion criteria were studies using hospitalized individuals of any age in acute or specialized care settings who received care, including a clinical decision support system. This study focused on the following disciplines: anaesthesia, critical care medicine, and emergency medicine. Exclusion criteria were satisfied if a study involved individuals from primary care, general practice, outpatient populations, or other specialized medical fields. We removed from the identified publications studies that were extraneous to the issue of nonrandomized research, technical descriptions, and presentations of prototypes lacking clinical assessments, performance test studies on nonhuman models, case reports, and case series.

2.4. Data extraction and synthesis

All studies were compiled using the Rayyan intelligent, systematic review tool for deduplication, abstract screening, and preliminary study selection. The identical two independent reviewers conducted the preliminary screening utilizing established criteria outlined in the accompanying process. The retrieved data components include authors, year of publication, journal, study design, department, study population, primary outcomes, kind of decision support system (DSS) and its function, and clinical effect sizes. After the screening, a comprehensive review and evaluation for final inclusion were conducted. Conflicts were settled by conversation and, when necessary, incorporating a third-blinded reviewer.

The chosen papers were assessed utilizing the 3-item, 5-point Oxford Quality Scale. The studies were evaluated according to three methodological criteria. Two points were allocated for descriptions of randomization, two points for a description of the blinding method, and one point for any account of participant withdrawal after randomization. We removed items that did not get a minimum score of 3 from this review. A final sample of 12 papers was chosen for this review, and the risk of bias in each included study was then evaluated using the revised Cochrane risk-of-bias methodology for randomized trials (RoB 2.0) **Figure 1**.

3. Results and Discussions

The studies focused on anaesthesiology and clinical research, perioperative care, intensive care, medical imaging, artificial intelligence (AI) applications in anaesthesiology, and ultrasound-guided regional anaesthesia. The studies also explore gender representation, with some providing specific distributions while others do not report gender data. Key findings highlight the significant reduction in detection and treatment times for critical events with DSS, improved alarm response times, and enhanced compliance with hemodynamic management. AI-based systems demonstrated high accuracy in anatomists.

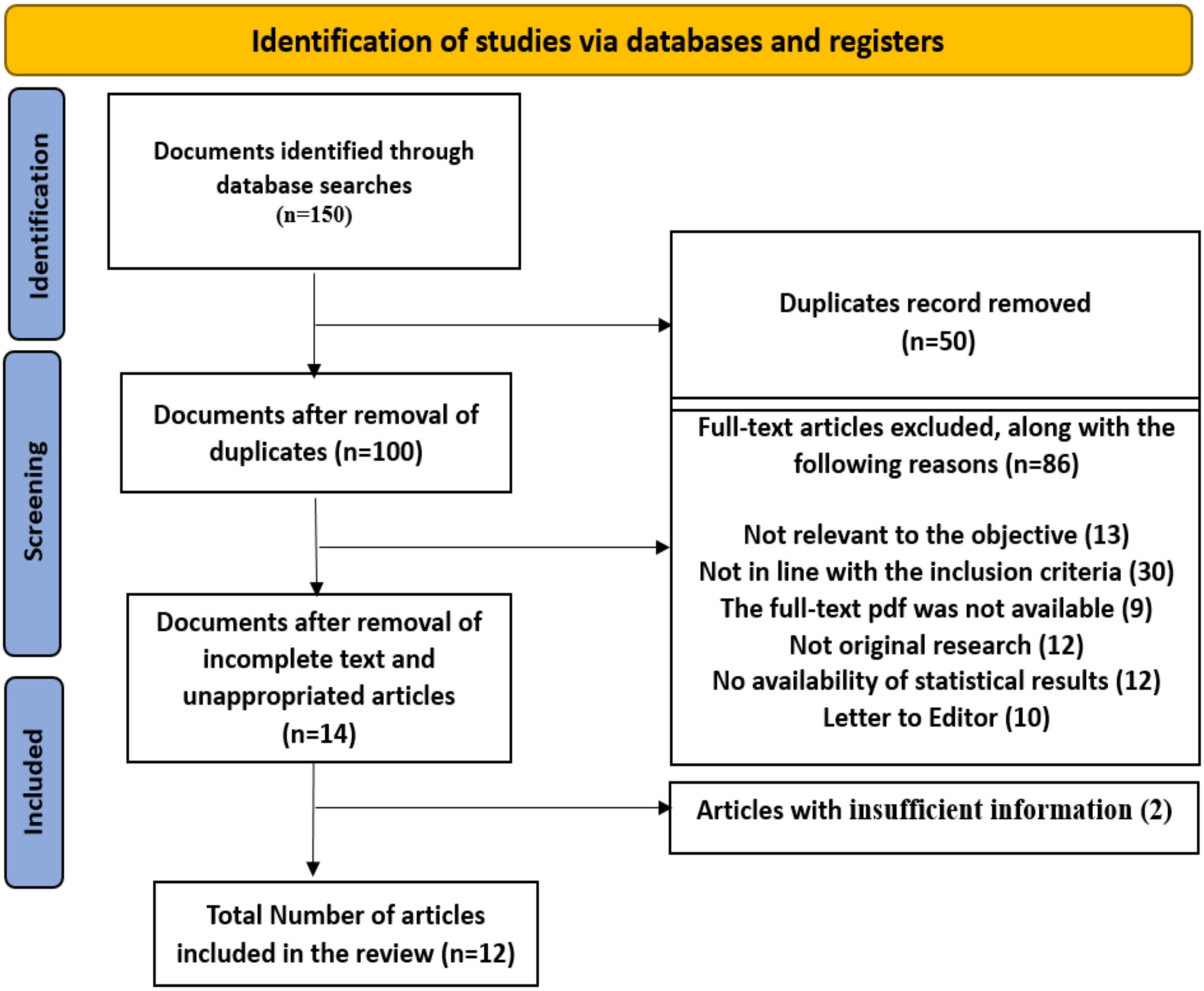

Figure 1: Flow chart

3.1. Description of the studies

Zaouter et al. developed a hybrid sedation system (HSS) for closed-loop propofol delivery in patients under spinal anaesthesia. The HSS outperformed manual administration by maintaining a bispectral index (BIS) of 65 more effectively, with significantly extended periods of "Excellent" sedation and reduced durations of "Poor" sedation, demonstrating superior clinical performance.[11] Similarly, Zaouter et al. designed and evaluated a decision support system (DSS) to assist anaesthesiologists in detecting critical respiratory and hemodynamic events during spinal analgesia with sedation. The DSS group responded significantly faster to these events compared to the control group, enhancing patient safety and vigilance.[12]

Sondergaard et al. evaluated the Navigator™ graphical display decision support system for goal-directed therapy during major abdominal surgery. Although outcomes between graphical and numerical guidance were comparable, the system aligned closely with anaesthetist actions, warranting further comparative studies.[13] Matthew et al. conducted a randomized trial on an electronic decision support tool (eDST) designed to improve adherence to ASRA guidelines for regional anaesthesia in patients on antithrombotic therapy. The eDST group outperformed controls in test performance, demonstrating its clinical utility.[14]

Joosten et al. compared computer-assisted individualized hemodynamic management with manual vasopressor and fluid titration during surgery. The computer-assisted approach significantly reduced intraoperative hypotension and improved stroke volume and cardiac index without increasing postoperative complications.[15] Bowness et al. conducted a scoping review to evaluate AI-supported ultrasound systems for regional anaesthesia, focusing on accuracy, reporting standardization, and guideline adherence, aiming to establish standardized evaluation methods.[16]

Bowness et al. emphasized the challenges of interpreting sono-anatomy in ultrasound-guided regional anaesthesia and highlighted AI's potential to enhance anatomical identification, improving safety, efficacy, and accessibility.[17] A related study by Bowness et al. demonstrated that AI-assisted ultrasound improved image acquisition and anatomical identification for non-experts, though no significant differences in scan time or confidence were noted.[18] Another 2023 study assessed the AI-based ScanNav Anatomy Peripheral Nerve Block device, which identified anatomical structures with 93.5% accuracy, reducing needle trauma and block failure while maintaining low false-positive and negative rates.[19]

Further, Bowness et al. evaluated the variability between human experts and AI (ScanNav™) in identifying anatomical structures in ultrasound-guided regional anaesthesia, finding similar agreement patterns but discrepancies in nerve identification.[20] They proposed a framework for evaluating human and AI performance. A scoping review by Bowness et al. highlighted rapid advancements in AI for ultrasound-guided regional anaesthesia, with deep learning gaining prominence since 2016. The study stressed the importance of standardized assessment frameworks for clinical adoption.[20] McKendrick et al. explored AI and robotics in regional anaesthesia, focusing on AI's application in nerve detection using convolutional neural networks and the role of robotics in precision, decision support, and training innovations, signalling future advancements.[21]

Table 1: Study characteristics of the review

Study Reference	Discipline	Gender	Groups	Primary outcome	Decision Support System
Cedrick Zaouter et al,[11]	Anaesthesia, Clinical Research	The HSS group had 35 males and 40 females, while the control group had 33 males and 42 females.	The study involved two groups: The HSS group and the Control group. Each group consisted of 75 patients.	Primary outcomes included clinical performance, maintaining BIS near 65, control performance, and assessing the system's BIS control over time.	The Hybrid Sedation System (HSS) integrates a Decision Support System (DSS) to detect critical respiratory and hemodynamic events via audio-visual alarms, providing decisional aids to the anaesthesiologist.
Cedrick Zaouter et al,[12]	Anaesthesiology	The study included male and female participants, with a sex ratio in the DSS group of 35 males to 40 females and in the control group of 33 males to 42 females.	DSS Group: Anaesthesiologists used the Decision Support System to monitor respiratory and hemodynamic events. Control Group: Anaesthesiologists followed standard practice without the DSS.	The primary outcome was to determine the efficacy of the DSS in detecting critical events and providing clinical suggestions and treatment options, specifically focusing on patient safety and managing hemodynamic and respiratory events.	The DSS was designed to help clinicians monitor vital signs with smart alarms and provide clinical suggestions to enhance patient safety and reduce human error.

Table 1 Continued…					
Sondergaard et al,[13]	Anaesthesia and Perioperative Care	The study included male and female patients, but specific gender distribution is not mentioned.	The study involved two groups - the intervention group and the control group.	The primary outcome aimed to assess if a graphical decision support system efficiently achieves oxygen delivery targets	Navigator™ (a computerized decision support system developed to assist clinicians in achieving targeted hemodynamic states)
Matthew et al,[14]	Anaesthesiology	Not reported	The study involved a control group and a test group that used the electronic decision support tool (eDST).	The primary outcome was adherence to the American Society of Regional Anaesthesia and Pain Medicine (ASRA) guidelines.	The electronic decision support tool (eDST) was used to assist participants in adhering to the guidelines.
Joosten et al,[15]	Anaesthesiology and Intensive Care	The study included both male and female patients.	The study included two groups: the computer-assisted group and the manually adjusted goal-directed therapy group.	The primary outcome was the percentage of intraoperative case time patients with hypotension, defined as a mean arterial pressure (MAP) less than 90% of their baseline MAP.	The study utilized a computer-assisted individualized hemodynamic management system to provide decision support for anaesthesia providers in delivering interventions.
James Bowness et al.,[16]	Anaesthesia and AI systems for ultrasound scanning	The study included both male and female subjects	Not reported (Review Article)	The primary outcome of the scoping review is to summarize the available evidence on the accuracy and utility of AI systems for ultrasound scanning in regional anaesthesia.	The review highlights AI systems that assist anaesthetists in identifying anatomical structures during ultrasound scanning.
James Bowness et al.,[17]	Anaesthesiology / Regional Anaesthesia	Not reported	The study included three groups: the Pre-operative, Intra-operative, and Postoperative.	The primary outcome is the potential use of AI, particularly machine learning, in improving ultrasound-guided regional anaesthesia by aiding in image interpretation.	The AI system discussed is called Anatomy Guide, which assists in identifying anatomical structures during ultrasound scans.
James Bowness et al,[18]	Anaesthesiology, Medical Imaging, Artificial Intelligence	Not reported	The study involved experts in ultrasound-guided regional anaesthesia (UGRA) acquiring ultrasound scans without using ScanNav and other experts evaluating the performance of the AI models.	The study's primary outcome was to assess the accuracy of the colour overlay produced by the AI technology in identifying key anatomical structures during ultrasound-guided regional anaesthesia.	The ScanNav™ AI model enhances ultrasound imaging by providing a real-time colour overlay, aiding in identifying anatomical structures.
James Bowness et al,[19]	Medical Science, Anaesthesiology	Not reported	Two groups based on whether they used the assistive AI technology (ScanNav) or performed scans without it.	The primary outcome was correctly identifying anatomical structures during ultrasound scanning, which was assessed by expert evaluation.	The decision support system used in the study was the ScanNav Anatomy Peripheral Nerve Block, an assistive AI ultrasound scanning device.

Table 1 Continued…

James Bowness et al,[20]	Clinical Investigation, Anaesthesiology, Ultrasound-Guided Regional Anaesthesia	Not reported	Group 1: Human experts (UGRA experts). Group 2: AI system (ScanNav™)	The primary outcome was to evaluate the consistency of identifying anatomical structures in ultrasound images relevant to UGRA between human experts and the AI system.	The study focused on evaluating the performance of an AI system (ScanNav™) approved for clinical use in Europe and the USA in identifying anatomical structures in ultrasound images relevant to UGRA.
James Bowness et al,[21]	Medical Science, Anaesthesiology	Not reported	The study included four UGRA experts and forty healthy adult subjects who consented to ultrasound scanning.	The primary outcome was to assess the accuracy and potential impact of AI-generated colour overlays on ultrasound images to highlight anatomical structures in ultrasound-guided regional anaesthesia (UGRA).	The decision support system used AI technology, specifically the ScanNav™, to assist in ultrasound image interpretation during UGRA.
McKendrick M et al,[22]	Clinical medicine anaesthesia ultrasound technology	Not reported	The review included various groups, such as clinical trial registries, international learned societies in regional anaesthesia, and commercial organizations involved in ultrasound technology.	The primary outcomes of interest included the accuracy and utility of AI systems in identifying sono-anatomical structures during ultrasound-guided regional anaesthesia (UGRA).	The study discussed the development of a structured framework for validating the accuracy and clinical utility of AI technologies that assist in ultrasound scanning for UGRA, which can be considered a form of a decision support system.

3.2. Discipline and groups in the studies

The referenced studies cover a broad spectrum of disciplines, including anaesthesiology, clinical research, perioperative care, intensive care, medical imaging, and the integration of artificial intelligence (AI) in anaesthesiology and ultrasound-guided regional anaesthesia. Cedrick Zaouter et al. focused on advancing anaesthetic practices and improving patient care through innovations such as hybrid sedation systems.[11,12] Sondergaard et al. emphasized the critical role of anaesthesia in perioperative care, particularly in enhancing safety and post-operative recovery.[13] Matthew et al. explored the effectiveness of electronic decision support tools in anaesthesiology to improve adherence to clinical guidelines.[14] Alexandre Joosten et al. connected anaesthesiology and intensive care by addressing critical care applications,[15] while James Bowness et al. extensively investigated ultrasound-guided regional anesthesia and the integration of AI in medical imaging, reflecting its transformative role in enhancing precision and safety.[16-20]

Gender representation varied across these studies. Zaouter et al. provided specific data, reporting 35 males and 40 females in the HSS group and 33 males and 42 females in the control group for one study. However, in their work, while both male and female participants were included, detailed distribution was not specified. Sondergaard et al. and Alexandre Joosten et al. also included both genders but did not provide specific breakdowns. James Bowness's series of studies generally did not report gender-specific data. This inconsistency in reporting emphasizes the importance of transparent and detailed demographic information to enhance the inclusivity and applicability of medical research. Together, these studies illustrate significant progress in anaesthesiology, highlighting the evolving interplay between technology, AI, and interdisciplinary care (**Table 1**).

3.3. Methodology and key findings of the studies

The studies conducted by Cedrick Zaouter *et al.,* Sondergaard *et al.,* Matthew *et al.,* Alexandre Joosten *et al.,* and James Bowness *et al.,* employed various methodologies to evaluate decision support systems (DSS) and artificial intelligence (AI) in clinical and ultrasound applications. Methodologies included randomized control trials with orthopaedic surgery patients, comparison of DSS groups with controls for critical event detection, assessments of guideline adherence using smartphone-based tools, and evaluations of machine learning algorithms trained on over 120,000 ultrasound images for optimal block site identification. These studies incorporated approaches such as scoping reviews following JBI and PRISMA-ScR guidelines, extensive literature searches, and online evaluations of AI models.[11-20]

Key findings highlighted the significant reduction in detection and treatment times for critical events with DSS, improved alarm response times, and enhanced compliance with hemodynamic management. AI-based systems demonstrated high accuracy in anatomical identification (93.5% success in identifying key structures), reduced cognitive load, and improved confidence and performance in UGRA. Furthermore, these studies emphasized the need for standardized evaluation frameworks and rigorous validation of AI tools for seamless clinical integration, highlighting their potential to improve patient safety and outcomes in anaesthesiology and ultrasound-guided procedures (**Table 2**).[11-20]

3.4. AI used in decision support system

This analysis focuses on the integration of AI-powered decision support systems (DSS) across anaesthesiology, clinical research, and perioperative care, underscoring their impact on safety, precision, and clinical outcomes (**Table 1**).

Cedrick Zaouter et al. introduced a Hybrid Sedation System (HSS) incorporating DSS features, such as audio-visual alarms, to detect critical respiratory and hemodynamic events in real time. This system enabled anaesthesiologists to promptly address potential complications, reducing errors and enhancing situational awareness during sedation.[11,12]

Sondergaard et al. utilized the Navigator™ DSS to assist clinicians in achieving targeted hemodynamic states by analysing real-time patient data. This approach emphasized precision and individualized care in perioperative settings, allowing adaptation to dynamic physiological changes.[13] Similarly, Matthew et al. demonstrated the effectiveness of an electronic DSS (eDST) in improving adherence to clinical guidelines, ensuring standardized, evidence-based care while minimizing variability among practitioners.[14]

Alexandre Joosten et al. implemented a computer-assisted hemodynamic management system that leveraged individualized patient data to optimize anaesthesia interventions, reflecting the growing emphasis on patient-specific strategies to improve outcomes.[15]

James Bowness et al. explored AI-driven DSS designed for ultrasound-guided regional anaesthesia (UGRA), such as Anatomy Guide and ScanNav™. These systems provided real-time overlays and automated anatomical identification, significantly enhancing precision and operator confidence during ultrasound scanning. The ScanNav™ system, in particular, achieved regulatory approval in Europe and the USA, validating its clinical utility in anesthesiology.[18-20]

Additionally, Bowness et al. proposed a structured framework for validating AI technologies in UGRA, addressing reliability concerns and advancing the seamless integration of AI into clinical decision-making systems. This framework aims to foster clinician trust and ensure consistent procedural accuracy, highlighting the transformative potential of AI in improving patient care and standardizing medical practices.[20,21]

Table 2: Methodology and key findings of the studies

Study Reference	Focus Area	Methodology	Key Findings
Cedrick Zaouter et al,[11]	The study aimed to assess the effectiveness of the DSS in detecting and treating critical events more efficiently, enhancing patient safety.	A randomized control trial was conducted with elective orthopaedic lower-limb surgery patients randomly assigned to the DSS or control group.	The DSS group significantly reduced the time to detect and treat critical events, improving patient safety.
Cedrick Zaouter et al,[12]	The focus was on managing hemodynamic and respiratory events in orthopaedic patients under propofol sedation and spinal analgesia.	The randomized trial compared a decision support system group with a control group, measuring detection times and alert effectiveness for critical events	The DSS improved the detection of critical events, reduced alarm delays, and decreased undetected alarms, enhancing anaesthesiologists' response times and patient safety.
Sondergaard et al,[13]	The study focused on the effectiveness of a CDSS in guiding goal-directed therapy during major abdominal surgeries, specifically in achieving hemodynamic targets.	Patients were randomized into two groups, measuring time in target zones and concordance between clinician treatment and CDSS recommendations.	The study found comparable time in the target zone and high concordance between decision support and anaesthetist action.
Matthew et al,[14]	The study focused on improving adherence to clinical practice guidelines in anaesthesiology.	The study included a test based on ASRA guidelines, randomized participants, and a smartphone-based decision support tool was used.	The eDST significantly improved correct responses, indicating the potential to enhance guideline adherence and patient safety in anaesthesiology.

Table 2 Continued…			
Joosten et al,[15]	The study focused on the impact of computer-assisted individualized hemodynamic management on reducing intraoperative hypotension in patients undergoing intermediate- to high-risk abdominal and orthopaedic surgeries.	The study was a prospective randomized trial with 133 screened patients, enrolling 38 for intention-to-treat analysis between two groups.	The computer-assisted group showed lower hypotension, fewer infections, reduced norepinephrine use, and potential for improved hemodynamic management compliance and outcomes.
James Bowness et al.,[16]	The focus area is AI application in ultrasound scanning for regional anaesthesia, emphasizing accuracy and clinical utility.	The methodology employed a scoping review, following JBI and PRISMA-ScR guidelines, focusing on literature search, screening, and data extraction.	The review summarized evidence on AI accuracy in anatomical identification, anaesthetist performance, and patient outcomes and proposes a standardized assessment framework.
James Bowness et al.,[17]	The focus area is the application of AI in enhancing the interpretation of ultrasound images for regional anaesthesia procedures.	The methodology trained machine learning algorithms on over 120,000 labelled ultrasound images to recognize anatomy and identify optimal block sites.	AI enhanced anatomical identification, reduces operator cognitive load, and requires validation; its clinical integration needs further evidence for effectiveness.
James Bowness et al,[18]	The study focused on using AI technology to support ultrasound scanning in ultrasound-guided regional anaesthesia (UGRA) and its potential to mitigate the risk of complications or block failure.	The study acquired and reviewed ultrasound scans from healthy volunteers, evaluating the colour overlay's accuracy and its impact on safety.	ScanNav AI identified essential anatomical structures in 93.5% of cases, potentially reducing the risk of complications in UGRA.
James Bowness et al,[19]	The study focused on evaluating the impact of AI technology on ultrasound scanning for regional anaesthesia, specifically targeting non-expert practitioners.	The exploratory study involved non-expert participants performing ultrasound scans with and without AI and assessing various parameters.	The AI device improved image acquisition and interpretation, anatomical structure identification, participant confidence, and expert rating scores.
James Bowness et al,[20]	The study focused on the evaluation of the variability of human experts and an AI system when identifying structures on ultrasound images relevant to UGRA.	The study evaluated human and AI system variability in identifying ultrasound structures, including qualitative and subjective assessments.	The study found that humans and AI consistently identified arteries, muscles, and nerves.
James Bowness et al,[21]	The study focused on using AI technology to improve the accuracy and safety of ultrasound-guided regional anaesthesia.	Ultrasound scans from healthy adults were evaluated online, and AI models were trained on a large dataset for accuracy.	AI accurately identified structures, showing the potential to reduce risks and marking a shift in UGRA image interpretation.
McKendrick M et al,[22]	The focus area is the application of AI in ultrasound-guided regional anaesthesia, specifically looking at how AI can aid in nerve localization and improve procedural outcomes.	The methodology involved a scoping review, extensive database searches, title and abstract screening, and inclusive data extraction from relevant studies.	The review highlighted six themes: AI methodologies, outputs, evaluation methods, standardization, commercial systems, and a shift to deep learning.

Table 3: Recommendations and challenges of the studies

Study Reference	Main findings	Recommendations	Challenges and Gaps
Cedrick Zaouter et al,[11]	HSS improved sedation control and reduced awake time during surgery	Implement HSS in clinical practice and conduct further research.	Integration into hospital systems, cost implications, and safety. Long-term outcomes, comparative studies, and patient/provider acceptance
Cedrick Zaouter et al,[12]	The DSS reduced detection delays to 9.1 seconds versus 27.5 seconds in the control group, with fewer oxygen desaturation alarms.	Integrate the DSS into anaesthesia practice to improve patient safety and reduce errors; further evaluations are needed to assess treatment efficacy.	Challenges included the need for larger sample sizes and usability analysis. Gaps included long-term clinical evaluations and validation in diverse medical settings.

Table 3 Continued…			
Sondergaard et al,[13]	The study found that the cardiovascular decision support system (CDSS) resulted in a similar time in target and averaged standardized difference compared to conventional care.	The study recommended further investigations into the extended perioperative use of the CDSS and its impact on outcome parameters.	The study highlighted challenges in guiding less sophisticated users and comparing the concordance of clinician-administered treatment with CDSS recommendations. Further research is needed to address these challenges and explore the potential benefits of CDSS in achieving targeted cardiorespiratory indices during surgery.
Matthew et al,[14]	The study demonstrated that using an electronic decision support tool (eDST) significantly improved adherence to clinical practice guidelines in anaesthesiology.	Implementing eDSTs in clinical practice to enhance guideline adherence, alongside local modifications, is recommended to improve usability and clinician engagement with these tools.	Key challenges included clinician familiarity with guidelines and usability of decision support tools. A gap exists in understanding the long-term impact of eDSTs in real clinical practice settings.
Joosten et al,[15]	The study found that computer-assisted hemodynamic management reduced hypotension, improved cardiac and stroke volume index, and lowered lactate concentrations, with a lower net fluid balance.	The study recommends implementing computer-assisted hemodynamic management in abdominal and orthopaedic surgeries to improve patient outcomes.	The study highlighted the need for further research to assess the long-term impact and address financial and logistical challenges associated with implementing computer-assisted hemodynamic management.
James Bowness et al.,[16]	The scoping review aimed to summarize the accuracy and utility of AI systems for ultrasound scanning, focusing on proof-of-concept studies and standardization of reporting.	The review aimed to propose a standardized assessment framework, guiding future research in the rapidly developing field of AI for ultrasound scanning.	The authors predicted challenges such as publication bias, lack of consistency, and limited access to industry data, potentially impacting the review's findings and recommendations.
James Bowness et al.,[17]	The article highlighted AI's potential in improving ultrasound-guided regional anaesthesia by aiding image interpretation, anatomical recognition, risk stratification, monitoring, standardizing approaches, enhancing operator performance, and reducing subjectivity.	The article encouraged embracing AI in healthcare, especially ultrasound-guided regional anaesthesia, to transform service provision and workforce education. It emphasizes anaesthetists' involvement in AI technology development for specialty enhancement.	The article identified challenges in AI applied to medical imaging, including regulatory pitfalls, evidence for performance improvement, equipment requirements, and methodological concerns. Addressing these is crucial for successful AI implementation.
James Bowness et al,[18]	The study revealed that ScanNav showed 93.5% accuracy in identifying essential anatomical structures, aligning with expert consensus. The subjective opinion indicated a potential risk reduction in 62.9-86.2% of scans.	Further research advised to validate AI device effectiveness in UGRA training and clinical practice, requiring additional patient outcome data.	Challenges included the subjective nature of image interpretation, the absence of remote experts during scans, and the need for clinical data.
James Bowness et al,[19]	The AI device improved ultrasound interpretation by non-experts, indicating the potential to enhance regional anaesthesia and expand patient access.	The study recommended further research to assess AI's long-term impact on ultrasound scanning for regional anaesthesia and suggests incorporating blinded and unblended assessors to address potential bias.	The study highlighted the need for larger-scale research to confirm findings and recognize objectivity and sample size limitations.

Table 3 Continued…

James Bowness et al,[20]	The study revealed that human experts and the AI system consistently identified arteries, muscles, and nerves.	Further research recommended to investigate the clinical implications of the observed differences, and greater understanding and clinician engagement are needed to develop and evaluate novel AI devices.	The clinical significance of the differences between human experts and the AI system remained undetermined, stressing the need for further research. The study acknowledged limitations in the evaluation structure and emphasized the importance of a deeper understanding and increased clinician engagement to address these shortcomings.
James Bowness et al,[21]	The study demonstrated the high accuracy of AI-generated colour overlays in identifying anatomical structures during ultrasound-guided regional anaesthesia, with a perceived potential to reduce the risk of adverse events and block failure.	The findings supported the integration of AI technology to augment human interpretation of ultrasound images during UGRA, potentially enhancing safety and efficacy.	The study acknowledged the need for further clinical studies to confirm the predicted benefits and rigorous evaluation of the impact of ultrasound augmentation technology on patient outcomes. Additionally, it recognized the fallibility and subjectivity of medical image interpretation, highlighting the need for objective assessments and measures of performance beyond accuracy.
McKendrick M et al, [22]	The review found heterogeneity and poor reporting in AI literature for ultrasound in regional anaesthesia, hindering effective clinical implementation.	The authors recommended a structured framework for validating AI in ultrasound-guided regional anaesthesia, including standardized accuracy methods and open-access datasets.	The review highlighted challenges such as inconsistent reporting, regulatory variability, and lack of standardized evaluation methods for AI in ultrasound, emphasizing the need for collaboration to address these gaps in regional anaesthesia.

4. Recommendations and Limitations

The studies by Zaouter et al. Bowness et al., Joosten et al, Sondergaard et al. and Matthew et al. focused on integrating advanced decision support systems (DSS), computer-assisted hemodynamic management, and AI into clinical practice. These works recommend implementing DSS to enhance patient safety, adopting AI in ultrasound-guided regional anaesthesia (UGRA) for improved precision and service delivery, and conducting further research to validate AI's long-term impact on patient outcomes and training effectiveness.[11-21]

Key gaps identified include the lack of large-scale clinical studies, usability challenges, and the need for standardized frameworks to evaluate AI's performance and integration into practice. The research underscores the importance of addressing regulatory concerns, publication bias, and logistical barriers, along with engaging clinicians to improve familiarity with AI technologies. Cost-related challenges and the inherent subjectivity of medical imaging further emphasize the necessity for larger, diverse sample sizes and clinician involvement to ensure AI’s successful adoption.

Overall, these studies highlight the transformative potential of AI and DSS in healthcare, contingent on overcoming integration barriers and fostering widespread acceptance. Establishing structured validation frameworks and achieving consistent clinical adoption remain critical to unlocking the full benefits of these technologies (**Table 3**).

5. Conclusion

Artificial intelligence (AI) technologies possess transformative potential in anaesthesiology, critical care, and emergency medicine, offering significant advancements in patient safety, clinical precision, and workflow efficiency. By harnessing advanced algorithms, AI systems enhance decision-making, optimize resource allocation, and improve procedural accuracy, particularly in applications like ultrasound-guided regional anaesthesia (UGRA). Tools such as ScanNav have demonstrated success in identifying critical anatomical structures, reducing complications, and increasing operator confidence. Despite these advancements, further research is essential to validate AI models, establish standardized assessment frameworks, and explore the capabilities of deep learning for broader clinical integration. Addressing challenges such as clinician engagement, usability, and regulatory barriers will be crucial. As artificial intelligence continues to evolve, its adoption is set to revolutionize anaesthetic practices, delivering safer, more precise, and efficient patient care while reshaping the future of healthcare delivery.

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7. Conflict of Interest

None declared.

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