

Recent Evidence of Artificial Intelligence in Ultrasound-Guided Regional Anesthesia: A Review

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ABSTRACT

Ultrasound-guided regional anesthesia (UGRA) is a critical technique in anesthesiology, but its adoption is limited by the need for expert skill. Artificial Intelligence (AI) offers a solution by enhancing the precision, safety, and accessibility of UGRA. This narrative review explores the current evidence supporting AI in UGRA, focusing on ultrasound image acquisition, interpretation, real-time decision-making, and training. A comprehensive literature search using PubMed Central, PubMed, and Google Scholar identified relevant studies on AI-assisted UGRA published between December 2020 and August 2024. From 62 initial searches, 5 studies met the inclusion criteria, detailing clinical trials and research on AI in UGRA. AI technologies have demonstrated significant promise in improving ultrasound image quality, enhancing anatomical landmark identification, and reducing complication risks. AI has also proven beneficial in real-time decision-making, assisting both novice and expert anesthesiologists. Additionally, AI-enhanced training systems have shown potential in reducing complication rates and improving learning outcomes. An automated spinal landmark identification program also showed effectiveness in neuraxial anesthesia, particularly for obese patients. AI integration into UGRA could revolutionize anesthetic practice, making the technique more accessible and safer, especially in regions with limited expert availability. Future research should focus on validating AI as a tool for skill acquisition and refining its application in clinical practice.

Keywords: Ultrasound-Guided, Regional Anesthesia, Artificial Intelligence, AI-Assisted Ultrasound-Guided Regional Anesthesia.



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INTRODUCTION

Ultrasound-guided regional anesthesia (UGRA) is a widely adopted technique in anesthesiology, offering the advantages of real-time visualization of anatomical structures and targeted delivery of anesthetics (Jo et al., 2025; Viderman, Dossov, Seitenov, & Lee, 2022). Despite its benefits, the effectiveness of UGRA is highly dependent on the operator's skill in interpreting ultrasound images and accurately performing nerve blocks (Kretz-Notelle, Johnson, & Mund, 2025; Watson, Taylor, & Bowness, 2025). This reliance on expertise poses challenges in standardizing UGRA and ensuring its broad accessibility, particularly for non-experts or those in training (Gormus, 2024; Holden, 2025).

Recent advancements in Artificial Intelligence (AI) have introduced new possibilities for enhancing UGRA by assisting with ultrasound image acquisition, interpretation, and decision-making (Medeiros, Dabbagh, Vlassakov, & Sabouri, 2025; Yan, Li, Fu, Zhou, & Zhang, 2025). AI technologies, particularly those involving machine learning and convolutional neural networks, are being developed to support anesthesiologists in overcoming the inherent challenges of UGRA (Medeiros et al., 2025; Queiroz et al., 2025). These technologies hold promise for reducing the skill barrier, improving procedural accuracy, and expanding access to regional anesthesia techniques (Giri, Firdhos, & Vida, 2025; Qadrie, Maqbool, Dar, & Qadir, 2025).

In Indonesia, the utilization of UGRA is still relatively limited, largely due to a shortage of trained experts who can effectively operate UGRA technology (Gamboa, Flores, Sarat, & Simmons, 2025; Ramsundra, Mason, & Dobbelsstein, 2025). This challenge is not unique to Indonesia but is a common issue across many low- and middle-income countries (LMICs). Despite this, the trend toward increasing UGRA use is gaining momentum, particularly in Southeast Asia³, as more healthcare centers begin to recognize the value of ultrasound in improving patient outcomes (Muthoka, 2022; Shah & Patel, 2023). Several medical centers in Indonesia have recently adopted ultrasound technology, signaling a gradual shift towards broader acceptance and use of UGRA (Khalid, Fathil, & Karmakar, 2025; Putri & Astuti, 2025).

However, the expansion of UGRA use in Indonesia and similar regions is hindered by the lack of trained professionals (Obeng-Odoom & Haila, 2024; Umar, Rofii, & Purwanto, 2025). The introduction of artificial intelligence (AI) into this field offers a promising solution to this problem. AI-assisted systems have the potential to fill the gap left by the shortage of UGRA experts, making the technique more accessible to a wider range of healthcare providers. Moreover, AI can serve as an invaluable tool in medical education, particularly in training new anesthesiologists in UGRA (Dabbagh & Sabouri, 2025; Sekhavati et al., 2025). By integrating AI into the curriculum, medical schools in Indonesia could accelerate the development of UGRA expertise, ultimately leading to a more widespread and proficient use of this technique in clinical practice (Jannah, Aisyah, Saputri, Sajida, & Parwiyanto, 2025; Rincón et al., 2025).

This narrative review aims to synthesize the recent evidence from four key clinical trials and studies that have investigated the effectiveness of AI in UGRA (Kovalainen et al., 2025; Motevalli, 2025). By examining the findings and implications of these studies, this review seeks to provide a comprehensive understanding of how AI is currently being integrated into UGRA, the benefits it offers, and the challenges that remain. This analysis is crucial for informing future

research and guiding the clinical adoption of AI in regional anesthesia (McKendrick, Yang, & McLeod, 2021; Singh & Nath, 2022).

RESEARCH METHOD

Due to the limited research that specifically discusses AI UGRA, it is not possible to conduct a systematic review that specifically assesses the effectiveness of the security aspects and success of using AI UGRA. However, we conducted a review of data sources on AI-assisted UGRA to answer the aim of the study. An extensive literature search was conducted using PubMed Central, PubMed, and Google Scholar. The following main key search terms were used: “Artificial Intelligence”; “Machine Learning”; “Ultrasound-Guided Regional Anesthesia”; and “Clinical Trials”. We used the PRISMA flow diagram for detailing the database searches. The inclusion criterion was basically data sources that provide information regarding AI-Assisted UGRA and were published between December 2020 and August 2024 while the exclusion criterion was any other data sources that do not provide information regarding AI-Assisted UGRA, a review, and unregistered clinical trials.

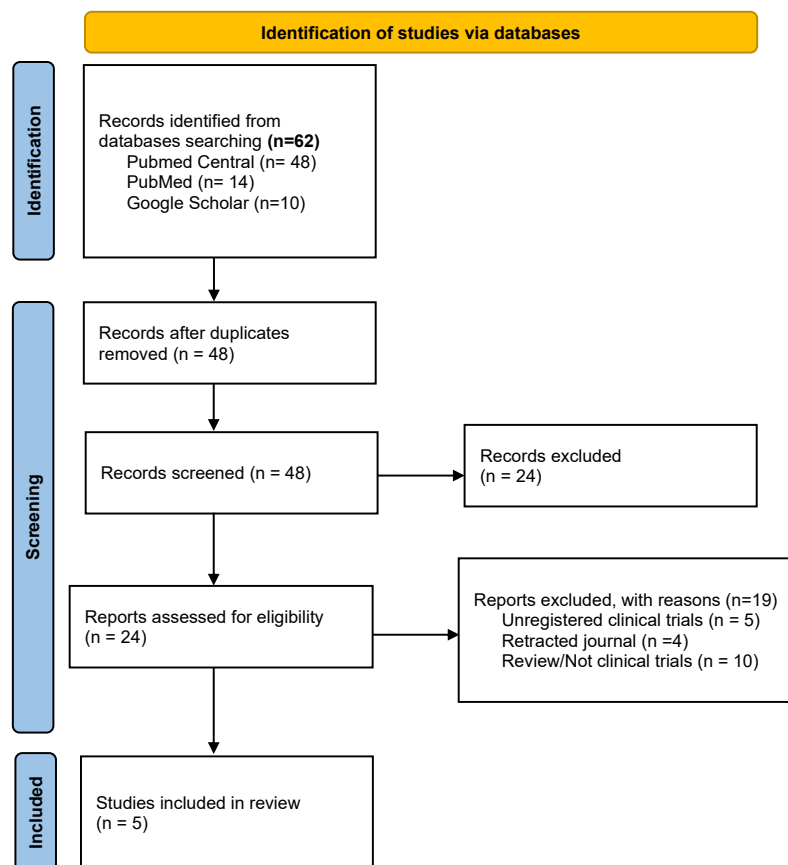


Figure 1 the PRISMA flow diagram for detailing the database searches.

Source: Developed for this research (2025)

RESULTS AND DISCUSSION

From 62 total database searches, 14 were removed due to duplication, 24 were excluded, 19 were excluded due to unregistered clinical trials (n=5), retracted journal (n=4), and review studies / not clinical trials (n=10). We found five study/clinical trials included and eligible for review.

Table 1. Summary of Selected Clinical Trials and Studies

No	Reference	Study	Clinical Trial Registration	Outcomes
1	Bowness et al.	Evaluation of the impact of assistive artificial intelligence on ultrasound scanning for regional anaesthesia	NCT05156099	Use of an assistive AI device was associated with improved ultrasound image acquisition and interpretation.
2	Bowness et al.	Assistive artificial intelligence for ultrasound image interpretation in regional anaesthesia: an external validation study	NCT04906018	Artificial intelligence-based devices can potentially aid image acquisition and interpretation in ultrasound-guided regional anaesthesia.
3	Bowness et al.	Exploring the utility of assistive artificial intelligence for ultrasound scanning in regional anesthesia	NCT04918693	ScanNav shows potential to support non-experts in training and clinical practice, and experts in teaching UGRA.
4	Cai et al.	Examining the impact perceptual learning artificial-intelligence-based on the incidence of paresthesia when performing the ultrasound-guided popliteal sciatic block: simulation-based randomized study	CHiCTR2200055115	The inclusion of an AI-assisted nerve identification system based on convolutional neural network as part of the training program for ultrasound-guided sciatic nerve block via the popliteal approach may reduce the incidence of nerve paresthesia and this might be related to improved perceptual learning.
5	In Chan et al.	Machine learning approach to needle insertion site identification for spinal anesthesia in obese patients.	NCT03687411	The automated spinal landmark identification program is able to provide assistance to needle insertion point

No	Reference	Study	Clinical Trial Registration	Outcomes
				identification in obese patients. There is good correlation between program recorded and clinician measured depth of the skin to posterior complex of dura mater. Future research may involve imaging algorithm improvement to assist with needle insertion guidance during neuraxial anesthesia.

Source: Processed from various sources (Bowness et al., 2023; Cai et al., 2022; etc.)

The integration of artificial intelligence (AI) into ultrasonography-guided regional anesthesia (UGRA) represents a significant advancement in anesthesiology. The studies reviewed in this paper highlight the potential of AI to enhance both the accuracy and accessibility of UGRA, particularly for non-experts.

1. Study 1 demonstrated that AI-assisted devices improve ultrasound image acquisition and interpretation, which can augment the performance of UGRA by non-experts. This finding is crucial in expanding patient access to these techniques, especially in settings where expert practitioners are scarce.
2. Study 2 highlighted that AI-based devices hold promise in supporting image acquisition and interpretation, though further studies are needed to validate their effectiveness in clinical practice and training environments. This underscores the ongoing need for research to establish robust evidence for AI's role in UGRA.
3. Study 3 focused on the potential of ScanNav technology to support both non-experts and experts in UGRA. The technology may help bridge the gap between teaching and practice, facilitating the uptake of UGRA across a broader range of practitioners.
4. Study 4 explored the impact of AI-assisted nerve identification systems on training programs, particularly for sciatic nerve blocks via the popliteal approach. The reduction in nerve paresthesia incidents suggests that AI can improve perceptual learning and patient outcomes in UGRA training.
5. Study 5 introduced an automated spinal landmark identification program, which demonstrated efficacy in assisting with needle insertion point identification in obese patients. The good correlation between program-recorded and clinician-measured depths indicates the potential for AI to assist with neuraxial anesthesia, particularly in

challenging patient populations. Future research could focus on refining imaging algorithms to further support needle insertion guidance during these procedures.

Collectively, these findings underscore the transformative potential of AI in UGRA. While significant progress has been made, there remains a need for ongoing research, particularly randomized controlled trials, to fully establish the role of AI in this field. Additionally, as AI technology continues to evolve, its applications in UGRA are likely to expand, offering new opportunities to enhance patient care and training outcomes.

The application of Artificial Intelligence (AI) in ultrasound-guided regional anesthesia (UGRA) has emerged as a transformative development in anesthesiology. By leveraging advanced machine learning (ML) and deep learning (DL) algorithms, AI technologies are designed to enhance the precision, safety, and accessibility of UGRA. This section provides an overview of how AI is being utilized in UGRA, focusing on its role in improving ultrasound image acquisition, interpretation, and real-time decision-making.

1. AI-Enhanced Image Acquisition and Interpretation

AI has shown significant promise in augmenting the ability of both novice and experienced practitioners to acquire and interpret ultrasound images effectively. Studies have demonstrated that AI-assisted devices can improve the clarity and accuracy of ultrasound images, making it easier to identify anatomical landmarks and guide needle placement during regional anesthesia procedures. For instance, a scoping review by Viderman et al.¹³ has reported that AI solutions could be valuable for identifying anatomical landmarks and minimizing or even preventing potential complications. These AI-guided technologies can enhance the optimization and interpretation of sonographic images, improve the visualization of needle advancement, and aid in the precise injection of local anesthetics. Additionally, AI-guided approaches may enhance the training process for UGRA.

2. AI as a Support Tool for Real-Time Decision-Making

AI technologies are also being developed as assistive tools for real-time decision-making during UGRA. By analyzing ultrasound images in real time, AI can help practitioners make immediate and informed decisions regarding nerve block techniques. The first validation study using AI-based technology in ultrasound-guided femoral nerve blocks highlighted the potential of AI to assist in interpreting sonoanatomy and making precise, on-the-spot decisions based on predefined anatomical landmarks. This capability is particularly beneficial for complex cases or when performing nerve blocks in challenging anatomical regions.

3. AI in Training and Skill Development

Training and skill acquisition are critical components of mastering UGRA, and AI has the potential to play a pivotal role in this area. AI-based systems, such as ScanNav (Figure 2), have been shown to support non-experts in training by providing real-time feedback and guidance, thereby accelerating the learning curve. Additionally, these technologies can assist experts in teaching UGRA, making the training process more efficient and standardized. Artificial intelligence devices could help lower perceived barriers by making ultrasound more accessible. These systems may reduce the reliance on having an appropriate supervisor present.

The feedback provided by AI, such as color-coded identification of relevant structures, could facilitate independent learning, allowing learners to practice without constantly needing

expert guidance. AI devices could serve as an additional resource for revisiting previously taught material, enabling extra practice when supervisors are not available. It is important to provide an appropriate introduction to the topic and orientation to the AI device. Alternatively, the color overlay generated by AI could be shared with a remote supervisor, who could then offer guidance based on that image. However, after using AI to support independent learning, a student's progress should still be evaluated using standard assessment methods. While there is excitement about AI, it has not yet been validated as a tool for skill acquisition, and further research is needed to determine its role.

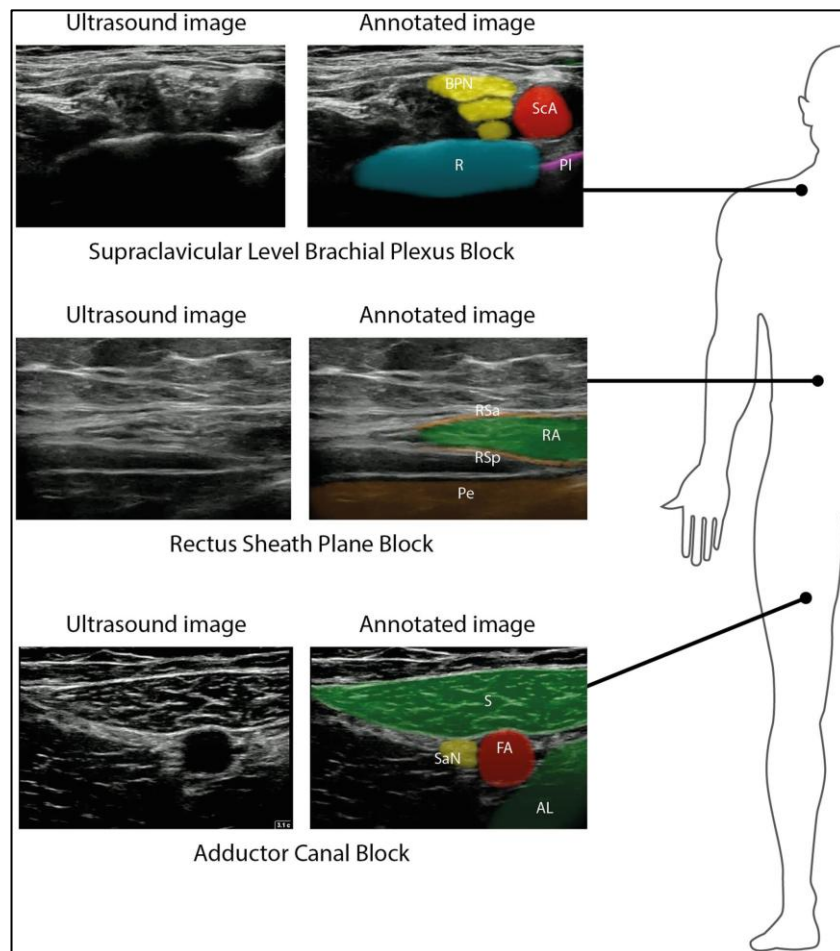


Figure 2 Examples of the real-time ultrasound color overlay generated by ScanNav anatomy peripheral nerve block include images of the supraclavicular fossa (top), rectus abdominis (middle), and anteromedial mid-thigh (bottom). Key anatomical structures identified are: AL, adductor longus; BPN, brachial plexus nerves (divisions); FA, femoral artery; Pe, peritoneum and contents; Pl, pleura; R, first rib; RA, rectus abdominis; RSa, anterior rectus sheath; RSp, posterior rectus sheath; S, sartorius; SaN, saphenous nerve; and ScA, subclavian artery.

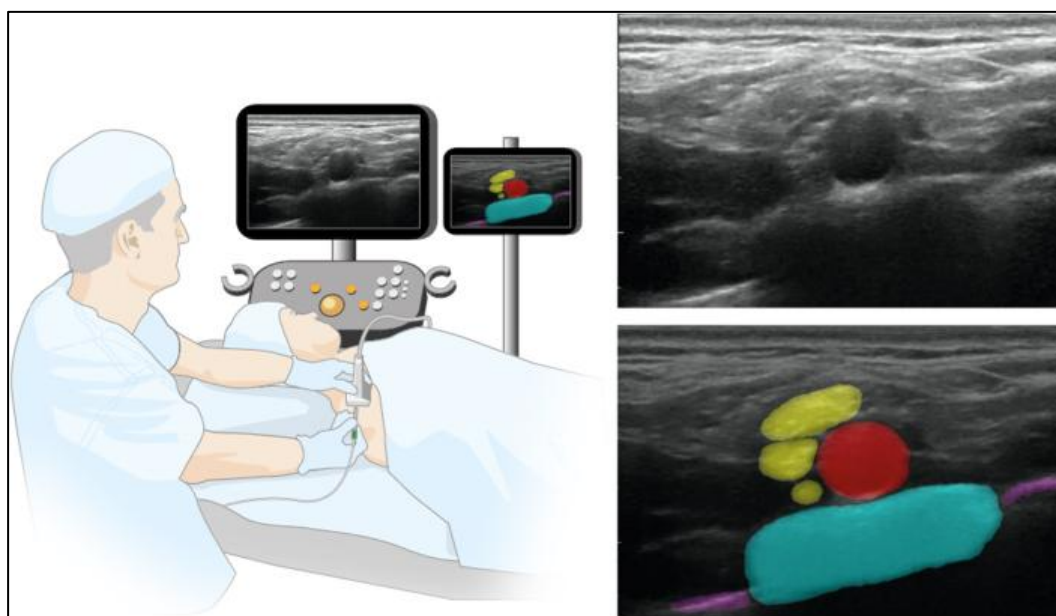


Figure 3 An example of the color overlay produced by ScanNav during a supraclavicular-level brachial plexus block includes the following: the first rib is highlighted in blue, the pleura in purple, the subclavian artery in red, and the supraclavicular-level brachial plexus nerves (trunks/divisions) in yellow.⁸

1. Automated Spinal Landmark Identification

In addition to its application in peripheral nerve blocks, AI is also being explored for use in neuraxial anesthesia, particularly in challenging patient populations. A study by In Chan et al.¹¹ demonstrated the efficacy of an automated spinal landmark identification program in assisting with needle insertion point identification in obese patients. The study found a strong correlation between the program's recorded depth of the skin to the posterior complex of the dura mater and the measurements taken by clinicians. This suggests that AI could be instrumental in improving the accuracy and safety of neuraxial blocks, especially in patients with difficult anatomy. Future research may focus on enhancing imaging algorithms to further support needle insertion guidance during these procedures.

2. Broadening Access to UGRA

One of the most significant implications of AI in UGRA is its potential to broaden access to regional anesthesia techniques. By reducing the dependency on operator expertise and enhancing the accuracy and safety of nerve blocks, AI can enable a wider range of healthcare providers to perform UGRA with confidence. This could lead to more widespread use of UGRA, particularly in settings where access to expert anesthesiologists is limited.

The studies reviewed in this paper highlight the growing impact of Artificial Intelligence (AI) in ultrasound-guided regional anesthesia (UGRA). The evidence suggests that AI can significantly enhance the accuracy and efficiency of UGRA by improving ultrasound image acquisition, interpretation, and real-time decision-making.¹⁷ For example, the integration of AI-assisted devices has been associated with improved image clarity, making it

easier for practitioners, especially non-experts, to identify anatomical landmarks crucial for successful nerve blocks. Furthermore, AI's ability to assist in real-time decision-making has the potential to standardize UGRA procedures and reduce operator dependency, thereby minimizing variability in outcomes.^{7,14} A clinical trial by Bowness et al. compared 21 anesthetists, all non-experts in UGRA, divided into AI-assisted and non-AI-assisted groups. The study reported that participants obtained the correct block view in 56 out of 62 (90.3%) scans with the AI device, compared to 47 out of 62 (75.8%) scans without it ($P = 0.031$, with two data points lost). The correct identification of sonoanatomical structures was achieved in 188 out of 212 (88.8%) instances with the AI device, compared to 161 out of 208 (77.4%) without it ($P = 0.002$). However, there was no significant difference in participant confidence, expert global performance scores, or scan time between the two groups.

The incorporation of AI into UGRA has profound implications for clinical practice. Firstly, AI technologies could democratize access to regional anesthesia by enabling less experienced practitioners to perform UGRA with greater confidence and accuracy.^{8,14} This could be particularly beneficial in resource-limited settings or areas where experienced anesthesiologists are not readily available. Additionally, the use of AI in training programs, as evidenced by the reduction in nerve paresthesia in trainees using AI-assisted nerve identification systems, suggests that AI could play a vital role in enhancing the skill acquisition process. By providing real-time feedback and guidance, AI can help shorten the learning curve and improve the overall proficiency of trainees in UGRA.^{8,14} Another clinical trial by Bowness et al.⁸ compared the outcomes of UGRA performed using AI versus expert guidance. The AI models correctly identified the structure of interest in 93.5% of cases (1519/1624), with a false-negative rate of 3.0% (48/1624) and a false-positive rate of 3.5% (57/1624). The highlighting provided by the AI was judged to reduce the risk of unwanted needle trauma to nerves, arteries, pleura, and peritoneum in 62.9–86.4% of cases (302/480 to 345/400) and to increase the risk in 0.0–1.7% of cases (0/160 to 8/480). Additionally, the risk of block failure was reported to be reduced in 81.3% of scans (585/720) and increased in 1.8% (13/720). This clinical trial has demonstrated that AI assistance could potentially replace the need for an expert anesthesiologist in UGRA, helping to prevent errors in the procedure. Additionally, it suggests that AI could be a valuable tool for less experienced anesthesiologists, aiding them in becoming proficient in the use of UGRA.

When compared to traditional UGRA techniques, AI-assisted methods offer several advantages, particularly in reducing the reliance on operator experience. Traditional UGRA requires a high level of skill in ultrasound interpretation and needle guidance, which can lead to variability in outcomes depending on the practitioner's expertise. In contrast, AI technologies can provide standardized image analysis and decision support, leading to more consistent and accurate nerve block procedures. A simulation-based randomized clinical trial conducted by Cai et al.¹⁰ included a total of 40 residents, who were randomly divided into two groups: a traditional teaching group and an AI-assisted teaching group. The study found that residents trained with AI assistance had significantly lower complication rates of paresthesia during

puncture in the first month of clinical sciatic nerve block practice compared to those in the traditional teaching group [11 (4.12%) vs. 36 (14.06%), $P = 0.000093$]. Similarly, the rates of paresthesia or pain during injection were significantly lower in the AI teaching group than in the traditional group [6 (2.25%) vs. 17 (6.64%), $P = 0.025$]. Additionally, the AI teaching group scored significantly higher on the Assessment Checklist for Ultrasound-Guided Regional Anesthesia (32 ± 3.8 vs. 29.4 ± 3.9 , $P = 0.001$) and on nerve block self-rating scores (7.53 ± 1.62 vs. 6.49 ± 1.85 , $P < 0.001$). Nevertheless, it is important to note that while AI can enhance the performance of non-experts, it is not a replacement for expert judgment and should be used as a complementary tool to support clinical decision-making.

An accuracy study by Gungor et al.¹⁸ which is confirming the accuracy of young anesthesiologists trainee using AI for ultrasound-guided peripheral nerve block procedures has reported that accuracy of an AI-based software supporting ultrasound-guided selected blocks was achieved in male and female subjects by identifying required anatomic landmarks including nerves, arteries, veins, muscles, pleura, peritoneum, and first rib. In a clinical trial by Bowness et al.⁹ involving 30 anesthesiologists—15 non-experts and 15 experts in UGRA—240 ultrasound scans were performed across nine peripheral nerve block regions, with half of the scans utilizing ScanNav. The study found that non-experts were more likely to provide positive feedback and less likely to provide negative feedback than experts ($p = 0.001$). Among non-experts, positive feedback was most frequently given regarding the potential role of ScanNav in training (37/60, 61.7%), while experts most commonly praised its utility in teaching (30/60, 50%). The study demonstrated that non-experts with AI assistance could potentially perform better in UGRA than experts without AI support. The positive feedback from non-experts regarding the role of AI in training, along with the comparable or even lower risk of complications, suggests that AI could significantly enhance the proficiency of less experienced anesthesiologists in performing UGRA.

Artificial intelligence has been extensively researched across various medical fields, particularly in radiology, where it has achieved significant success.² Given the frequent use of sonographic imaging in regional anesthesia, AI could be beneficial for clinicians in identifying anatomical landmarks and minimizing or preventing potential complications, such as nerve, artery, or vein injury, puncturing the peritoneum, pleura, or internal organs, and local anesthetic systemic toxicity. AI-driven solutions have the potential to enhance the optimization and interpretation of sonographic images, as well as improve the visualization of needle advancement and the injection of local anesthetics.

Despite the promising findings, this review has several limitations. Firstly, the scope of the literature search may not have captured all relevant studies, particularly those published in non-English languages or in less accessible journals. Additionally, most studies included in this review were conducted in controlled settings or with healthy volunteers, which may limit the generalizability of the findings to more diverse or clinically complex populations. Furthermore, the studies varied in their methodologies, making direct comparisons challenging.

The integration of AI into UGRA also raises important ethical considerations. Ensuring the safety and reliability of AI-driven systems is paramount, particularly in high-stakes medical procedures like regional anesthesia. The potential for algorithmic bias, where AI systems

trained on non-representative data may perform less effectively in certain populations, must be carefully managed. Additionally, the transparency of AI algorithms and the interpretability of their outputs are critical to maintaining credibility in these technologies. Clinicians must be able to understand and verify the recommendations provided by AI systems to make informed decisions that prioritize patient safety.

Future Directions and Suggestions

The integration of artificial intelligence (AI) in ultrasound-guided regional anesthesia (UGRA) is still in its early stages, but the potential benefits demonstrated in recent studies suggest several promising avenues for future research and development.

Future research should aim to refine AI models, making them more accurate and reliable in identifying complex anatomical structures. Improvements in machine learning algorithms could lead to AI systems that not only assist in image acquisition and interpretation but also provide real-time guidance during needle advancement, further reducing the risk of complications.^{7,10,18}

AI-driven platforms have the potential to revolutionize the training of new anesthesiologists. Future efforts could focus on developing comprehensive training modules that incorporate AI feedback, allowing trainees to practice UGRA techniques independently with real-time guidance. The effectiveness of these AI-based training programs should be evaluated to ensure they meet or exceed traditional training outcomes.⁹

Longitudinal studies are needed to assess the long-term outcomes of AI-assisted UGRA, including patient satisfaction, complication rates, and overall success of the nerve blocks. Additionally, research into the cost-effectiveness of AI systems could help justify their adoption in clinical practice, particularly in resource-constrained settings.

Medical schools and teaching hospitals in Indonesia should invest in AI-assisted training modules that focus on UGRA. These programs can bridge the gap between theoretical knowledge and practical skills, allowing residents and young anesthesiologists to practice UGRA techniques with real-time AI feedback.¹⁴ This approach will help accelerate the development of proficiency in UGRA among new practitioners, ensuring a more consistent and widespread application of the technique across the country.

Healthcare centers that have begun adopting ultrasound technology should take the next step by integrating AI-assisted UGRA systems into their clinical practice. This would not only improve the accuracy and safety of regional anesthesia procedures but also make UGRA more accessible to practitioners who may lack extensive experience. By reducing dependence on expert supervision, AI can democratize the use of UGRA and ensure that more patients benefit from this advanced technique.

While the current evidence supports the potential of AI in UGRA, future research and development are essential to fully realize its benefits. By addressing these key areas, AI could significantly improve the safety, efficiency, and accessibility of UGRA, ultimately enhancing patient outcomes and advancing the field of anesthesiology.

CONCLUSION

The integration of artificial intelligence (AI) in ultrasound-guided regional anesthesia (UGRA) presents a significant opportunity to overcome the current limitations in the availability of trained UGRA experts in Indonesia and similar LMICs. AI not only has the potential to enhance the accessibility and accuracy of UGRA by supporting non-expert practitioners but also serves as a powerful educational tool. By incorporating AI into medical training programs, Indonesia can cultivate a new generation of anesthesiologists who are proficient in UGRA, thereby expanding the use of this technique and improving patient outcomes. Future efforts should focus on further validating AI's role in UGRA through extensive research and developing robust training modules that leverage AI technology. In conclusion, Although AI has shown great promise in enhancing UGRA, its full potential will only be realized through continued research, technological advancements, and thoughtful integration into clinical practice. As AI technologies evolve, they are likely to play an increasingly pivotal role in shaping the future of regional anesthesia, ultimately improving patient outcomes and expanding access to high-quality anesthesia care.

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