Narrative Review

Artificial intelligence in regional anaesthesia

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ABSTRACT

Ultrasound-guided regional anaesthesia is used to facilitate the real-time performance of the regional block, increase the block success and reduce the complication rate. Artificial intelligence (AI) has been studied in many medical disciplines with high success rates, especially radiology. The purpose of this article was to review the evolution of AI in regional anaesthesia. The role of AI is to identify and optimise the sonography image, display the target, guide the practitioner to advance the needle tip to the intended target and inject the local anaesthetic. AI supports non-experts in training and clinical practice and experts in teaching ultrasound-guided regional anaesthesia.

Key words: Artificial intelligence, regional anaesthesia, sonoanatomy, training, ultrasound

INTRODUCTION

Ultrasound-guided regional anaesthesia (USG-RA) involves the optimal acquisition and interpretation of ultrasound (USG) images to delineate sonoanatomy and apply a colour overlay on real-time USG image to highlight key anatomical structures and for guided needle insertion and deposition of local anaesthetic around the nerve elements.[1] Anatomical knowledge and the ability to interpret sonoanatomy are difficult, different and imperfect in trainees and no-voice anaesthesiologists.

Artificial intelligence (AI) is the development of computer systems capable of performing tasks that usually require human intelligence, such as decision-making, object detection and solving complex problems. Machine learning (ML) allows computers to learn by exposing them to an algorithm. Deep learning (DL) is a subset of ML that uses artificial networks imitating human brains' neural networks.[2]

AI is currently used in various healthcare fields like medical imaging and diagnosis, medical education, drug development, treatment and monitoring, managing medical data, digital consultation, individual health monitoring, disease diagnosis, analysis of health plans and medical audits.

AI can recognise structures and objects with high sensitivity and specificity, provide fast reports attributed to programmed algorithms and achieve high consistency in results. The use of AI in USG-RA has been addressed in various ways, including increasing the success rate of regional anaesthesia (RA), increasing the safety and decreasing the complication rate. AI is also an educational tool to train novice anaesthesiologists and trainees. AI is innovative in identifying sonoanatomy for USG-RA and motivates them to learn RA quickly.

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REGIONAL ANAESTHESIA

RA is increasingly used in various surgical procedures. USG-guided nerve block/regional block has increased the percentage of success and reduced the complication rate. USG gained popularity among practitioners because of its portability, absence of radiation, real-time visualisation of needles and injection of local anaesthetics.[3]

USG-RA involves the optimal acquisition and interpretation of USG images to delineate sonoanatomy and apply a colour overlay on real-time USG images to highlight key anatomical structures and for guided needle insertion and deposition of a local anaesthetic around the nerve elements, thereby reducing complications. USG avoids painful muscular contraction during nerve stimulation and helps improve the block's quality.[4]

Anatomical knowledge and the ability to interpret sonoanatomy are difficult and imperfect for trainees and novice anaesthesiologists. The loss of reflective signal between the needle and the probe can complicate USG-guided nerve block. Visibility of the needle is challenging when performed on an obese patient and while performing deeper blocks.[5]

AI IN RA

AI is helpful in RA for practitioners in correctly identifying anatomical landmarks and reducing complications. AI-guided models improve the optimisation and interpretation of sonographic images and improve needle visibility. AI-assisted USG-RA can facilitate the identification of anatomical structures and help non-experts locate the correct USG anatomy to perform regional blocks. Previous studies highlighted the apparent deficiencies in anatomical knowledge, which the assistance of USG image interpretation may support. Therefore, such assistive AI approaches could improve the probability of a successful block and reduce complications. Thus, AI USG-RA target identification was used to identify the following anatomical structures: nerves, blood vessels and muscles.[6-8] Real-time anatomy identification AI models have been developed for trainees to interpret better interscalene, supraclavicular, infraclavicular, transverse abdominis and femoral nerve block. AI can rapidly peruse big data, including patient-, performer-, procedure- and drug-related details, formulate strategic steps to perform a given nerve block correctly, act as a supervisor or assistant to a trainee and rapidly identify scenarios to improve block success.

USG MACHINE AND AI ALGORITHMS

AI aims to accurately identify the target region (nerve) on USG images in real-time. Therefore, some ML methods have been proposed, and their essential techniques can be divided into

(1) Anatomic region differentiation,
(2) Target detection (localisation of nerve and blood vessels) and
(3) Tracking algorithms.[7,8]

AI-assisted medical image interpretation is a prevalent research direction in healthcare setup. AI has been used in RA to detect the correct needle insertion site, track the needle insertion and facilitate localisation of the needle tip and length. Tracking is one of the most widely used tasks in computer vision, with applications such as video medical imaging, compression and robotics. Several AI models have been reported to improve the quality of monographic anatomical target detection. Thus, a multiple-model data association has been used to detect the nerves, vessels, bones and soft tissues.[9,10]

AI was reported to be helpful in 99.7% of the cases. Identification of specific anatomical structures by USG and confirmation of correct structures are essential components of USG-RA.

There is a statistically significant difference between the performances of blocks using USG in different regions. The rectus sheath, interscalene and supraclavicular level brachial plexus regions yielded the lowest results, whereas the adductor canal block and the axillary brachial plexus yielded the highest results. The highest-ranked anatomical regions were the bones and vessels. This demonstrates the potential for AI's clinical utility in USG-RA, especially its usage by non-experts.[11]

Developing the AI algorithms to identify all anatomical features using USG is challenging due to the diversity, complexity and operator dependence, such as inter-and intra-individual variation. Therefore, automated image interpretation technologies can be trained to identify various structures using ML to show the difference between nerves, blood vessels, bones and soft tissues.

This technology could improve the interpretation of USG anatomy by identifying targets (such as peripheral nerves and fascial planes) and mapping optimal insertion sites by detecting the relevant landmarks and guidance structures (such as muscles and bones). The safety profile can be improved by highlighting the anatomical structures (blood vessels) to reduce or avoid unwanted injury. Although AI-assisted techniques appear promising, few applications are currently introduced in clinical practice. Therefore, the potential for its utilisation is yet to be proven. The AI model ScanNav system uses deep convolutional neural networks (CNNs) to perform semantic segmentation of the USG images provided.

Understanding the sonographic anatomy and image interpretation represents critical importance in USG-RA. Robust AI-assisted technologies could help clinicians improve performance and training in USG-guided nerve blocks. AI-assisted technologies can change the practice of USG-RA and its education. Anaesthesia practitioners should contribute to the transformation of USG-RA. Although training can be performed in non-clinical settings, such as educational courses, clinical practice training is fundamental.

AI-assisted USG-RA is a novel medical device that many clinicians might not be familiar with. Therefore, its initial use may be associated with lower confidence, which will improve with time of training and practice.

AI-GENERATED AUTOMATIC TARGET DETECTION

In this technique, automatic detection and tracking of nerve structure followed by assistance in successfully recognising nerves, blood vessels and anatomical structures and confirmation of the correct placement of needles leads to overall good performance in providing precise RA. Furthermore, features like a USG view for anaesthetists, standardisation of clinical procedures, and a real-time interpretation of anatomical structures for immediate decision-making during blocks allow automated nerve block techniques to be performed using a remote control system.

The automated USG spinal landmark identification model uses an intelligent image processing system that allows improved spinal USG interpretation and successful detection of vertebral anatomy at real-time speed.[11,12] It was reported that AI can assist trainees and experienced anaesthesiologists unfamiliar with USG techniques. The automated USG-guided neuraxial technique takes less than a minute to identify the correct interspace and needle pathway. The automated approach results in a high first-attempt success rate that could reduce the complications from multiple attempts.

RISKS AND FAILURES OF AI-ASSISTED USG-RA

Although automated solutions have several benefits, there are risks and failures. The most critical limitations are detection and tracking failure. This may be due to nerve appearance similar to surrounding areas. Another limitation of this technology is the failure to distinguish osseous images. Although real-time tracking allows proper scanning of block regions, it does not always result in the detection of the whole needle, which can occur at a steep insertion angle. The evidence for applying AI-assisted technologies in RA is still in its initial stage. There is limited evidence of its accuracy in paediatric and geriatric patients. Over-reliance on an expert to detect the exact tip localisation is a limitation, especially if the tip is completely invisible. The algorithm is highly specific only if all landmarks are detected. AI algorithms are not designed or validated for complex spinal anatomy, geriatric patients, obese patients and paediatric patients. The risk of image misinterpretation could be high in case of abnormal anatomy (e.g. fusion or reduced interspinous distance).[11,12]

The following risks were assessed and reported in the studies:

- Increased risk of block failure and
- The risk of needle trauma to the surrounding structure.

The assessed complications included:

- Nerve injury and postoperative neurological manifestations,
- Local anaesthetic systemic toxicity,
- Pleural injury (pneumothorax) and
- Peritoneal injury.

Generally, the included studies reported a low perception of increased risk associated with AI assistance, although complications may be clinically important (e.g., nerve injury/local anaesthetic systemic toxicity, LAST). Possible causes of error are related to technological performance, for example, improper highlighting, which may result in misinterpretation of USG images. Block failure and undesirable trauma to critical structures may be more likely if the colour on the screen misleadingly reassures the practitioner. Other risks may be related to the usage of the device, for example, highlighting resulting in distraction or focusing on one object and neglecting another structure. AI-assisted technology, therefore, should be used as a source of additional information (image augmentation system) rather than a decision-maker. Furthermore, correct anatomical structure identification can be helpful to anaesthesiologists, although it does not ensure safe USG-RA or guide needle placement. Therefore, it is the performer's responsibility to consider the hazards.

DIFFICULTIES IN AI USG-RA

Tracking anatomical targets in USG-guided procedures can be challenging due to illumination changes, occlusion, noise and deformation of the target, which can result in tracking failure.[13] Moreover, the object's motion may exhibit abrupt changes; the images may be corrupted by multiplicative noise, leading to false alarms and misinterpretation, and some detected features may not belong to the object. It is essential to highlight that the tracker should neglect the wrongly detected features because they may mislead medical professionals and jeopardise the performance of the procedure. Finally, the object's shape might change during tracking. This can lead to failures.

AI UPCOMING DEVELOPMENT

USG has become an integral part of RA and has significantly contributed to its development in medical practice. It is challenging to develop excellent skills to interpret USG images and achieve the necessary level of proficiency to perform RA safely and reduce the block failure rate, especially for beginners.[14,15]

Therefore, applying AI in USG-RA might maximise the benefits of USG guidance, improve efficacy and safety and reduce the failure rate. Computer vision is one of the most promising areas of application of AI in medicine. DL may hold the highest potential to advance image interpretation in USG-RA, but an increased number of images would be required for its training; clinicians should play a more active role in these collaborations since they are instrumental in image acquisition, conducting clinical trials, advising and overall moving this field forward. AI-guided mechanical robots can provide better precision and dexterity, and cognitive robots can help as decision-support systems. In the future, these models might function as autopilots for anaesthesia. Technical robots incorporate visual and motion metrics to develop sensors for training.

AI, as in the case of RA education, will break new ground in education with innovation and contemporary concerns. Despite AI's growing benefits and advantages, ethical and legal concerns remain. Practitioners are best to anticipate these benefits and potential problems.

CONCLUSION

AI can restructure RA practice, provide better patient care and improve accuracy in pain management. AI-guided USG-RA can enhance the optimisation and interpretation of the sonographic image, visualisation of needle advancement and local anaesthetic injection. AI-guided USG RA models might improve the training process among young anaesthesiologists and postgraduates. Although significant progress has been made in applying AI-guided USG-RA, randomised control trials are still missing. More high-quality studies are warranted to generate evidence of the application of AI-guided USG-RA in different patient populations, anatomical regions and nerve blocks for various surgeries. Practitioners should be aware of the accountability of errors while using AI.

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Conflicts of interest
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