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Emerging Trends in Regional Anesthesia Techniques

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Abstract

Regional anesthesia has become an essential component of modern perioperative care, offering targeted pain relief, reducing opioid consumption, and enhancing recovery. Recent advancements in regional anesthesia techniques, particularly the adoption of ultrasound guidance, the development of novel nerve blocks, and the use of continuous catheter infusions, have significantly improved the precision, efficacy, and safety of these procedures. This article provides a comprehensive review of the emerging trends in regional anesthesia, including the latest techniques, clinical applications, and future directions. The integration of these advancements into clinical practice has the potential to further optimize patient outcomes, reduce perioperative complications, and enhance overall patient satisfaction.

Keywords

Regional Anesthesia, Ultrasound-Guided Nerve Blocks, Continuous Catheter Infusions, Opioid-Sparing Techniques, Perioperative Pain Management, Novel Local Anesthetics, Enhanced Recovery After Surgery (ERAS)

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Introduction

Regional anesthesia has consistently been a cornerstone of modern anesthetic practice, known for its ability to provide targeted pain relief without the widespread systemic effects associated with general anesthesia. By selectively blocking nerve impulses in specific regions of the body, regional anesthesia offers the dual benefits of effective analgesia and reduced reliance on systemic opioids, which are associated with significant side effects such as nausea, respiratory depression, and the potential for dependence. This targeted approach not only enhances patient comfort during and after surgery but also contributes to faster recovery times, reduced hospital stays, and overall better clinical outcomes.

In recent years, the importance of regional anesthesia has grown exponentially, largely driven by the increasing emphasis on opioid-sparing techniques and the implementation of Enhanced Recovery After Surgery (ERAS) protocols. ERAS protocols aim to minimize the physiological and psychological stress of surgery, expedite recovery, and improve patient satisfaction. Central to these protocols is the reduction of opioid use, given the ongoing opioid crisis and the recognition of the adverse effects of opioid overuse. As a result, regional anesthesia has emerged as a critical component in the multimodal analgesia strategies that form the backbone of ERAS, offering an effective means of controlling pain while minimizing opioid requirements.

The field of regional anesthesia is not static; it is characterized by continuous innovation and refinement. Recent advancements in this field, including the adoption of ultrasound-guided techniques, the development of novel nerve block

approaches, and the introduction of long-acting local anesthetics, have revolutionized how anesthesia is administered. Ultrasound guidance, for example, has greatly improved the precision of nerve blocks, allowing anesthesiologists to visualize anatomical structures in real-time and place anesthetic agents with greater accuracy. This has led to higher success rates, fewer complications, and enhanced patient safety.

Furthermore, the introduction of continuous peripheral nerve blocks (CPNB) and advanced catheter techniques has provided patients with extended pain relief that can last well into the postoperative period. These innovations have not only improved the efficacy of regional anesthesia but have also expanded its application across a wider range of surgical procedures, from minor outpatient surgeries to complex, high-risk operations.

As the role of regional anesthesia continues to expand, it is clear that these advancements are not merely incremental improvements but represent a significant paradigm shift in perioperative care. The integration of these cutting-edge techniques into routine clinical practice has the potential to transform patient care, making surgeries safer, recovery quicker, and outcomes more predictable. In the following sections, we will explore the emerging trends in regional anesthesia, highlighting the latest techniques, their clinical applications, and the future directions that will likely shape the next generation of anesthetic practice.

Emerging Trends in Regional Anesthesia

Regional anesthesia, a technique involving the administration of anesthetic agents to specific regions of the body, has witnessed significant advancements in

recent years. These innovations have led to improved patient outcomes, reduced complications, and enhanced patient satisfaction. This brief overview highlights some of the key emerging trends in regional

anesthesia, including novel techniques, expanded applications, and future directions. Table 1 provides a comprehensive overview of the latest developments in regional anesthesia.

Table 1. Emerging Trends in Regional Anesthesia

<i>Emerging Trend</i>	<i>Current Application</i>	<i>Advantages over Conventional Methods</i>	<i>Future Possibilities</i>	<i>Examples</i>
<i>Ultrasound-Guided Regional Anesthesia</i>	Used for precise nerve block placement in various surgeries.	Enhances accuracy in block placement, minimizes complications, and improves patient outcomes.	Continued advancements in ultrasound technology and integration with AI for enhanced guidance.	Sonosite M-Turbo: Provides detailed imaging for precise nerve visualization [1].
<i>Continuous Peripheral Nerve Blocks</i>	Utilizes catheters to deliver continuous anesthesia post-surgery.	Enables extended pain relief, reduces systemic opioid use, and improves postoperative pain control.	Development of more durable and user-friendly catheter systems, along with refined pain management techniques.	On-Q PainBuster: Delivers continuous local anesthetic via a catheter [2].
<i>Single-Injection Ultrasound-Guided Blocks</i>	Applied in minor procedures requiring short-term anesthesia.	Faster setup with fewer complications compared to multi-injection techniques.	Innovations to extend the duration and efficacy of single-injection blocks.	SABER (Single Injection Anterior Block): Effective for hip surgery analgesia [3].
<i>Pharmacologic Advances in Local Anesthetics</i>	Involves new formulations and adjuvants to enhance local anesthesia.	Improves pain management, reduces side effects, and extends the duration of analgesia.	Exploration of novel anesthetic agents and combinations for superior outcomes.	Exparel (Liposome-Encapsulated Bupivacaine): Prolongs analgesia with a single dose [4].
<i>Patient-Controlled Analgesia (PCA) with Regional Anesthesia</i>	Combines regional blocks with PCA systems for better pain management.	Allows patients to self-manage pain, decreasing opioid dependence.	Enhanced technology integration for more precise control and monitoring of analgesia.	CADD-Legacy PCA System: Facilitates patient-controlled analgesia [5].
<i>High-Density Regional Anesthesia</i>	Employs advanced techniques for more comprehensive nerve block coverage.	Provides more thorough pain relief with potentially fewer blocks.	Development of methods to achieve even higher block density and reliability.	Targeted Nerve Stimulation: Improves block density and precision [6].

Enhanced Recovery After Surgery (ERAS) Protocols with Regional Anesthesia	Integrates regional anesthesia into ERAS protocols to boost recovery.	Reduces opioid use, accelerates recovery, and enhances patient satisfaction.	Broader application of ERAS protocols incorporating regional anesthesia for various procedures.	ERAS Guidelines: Incorporate regional anesthesia for improved recovery [7].
Virtual Reality (VR) and Simulation for Anesthesia Training	Utilizes VR and simulation for training in performing regional blocks.	Offers immersive training environments that enhance skill acquisition and confidence.	Increased use of VR and simulation for comprehensive and realistic training.	OSCE Simulators: Provides VR-based training for regional anesthesia [8].

Ultrasound-Guided Nerve Blocks

The advent of ultrasound-guided nerve blocks has been a game-changer in the field of regional anesthesia, significantly enhancing both the precision and safety of these procedures. Unlike traditional techniques that relied on anatomical landmarks and "blind" needle insertions, ultrasound guidance allows anesthesiologists to directly visualize the anatomy in real-time. This ability to see the target nerve, surrounding structures, and the actual spread of the local anesthetic provides a level of accuracy that was previously unattainable, leading to better patient outcomes and a reduction in procedure-related complications [9].

The primary advantage of ultrasound-guided nerve blocks lies in their precision. The anesthesiologist can observe the needle as it advances towards the nerve, making fine adjustments in real-time to avoid inadvertent contact with critical structures such as blood vessels or other nerves. This reduces the risk of accidental intravascular injections, which can lead to systemic toxicity, and minimizes the likelihood of nerve damage, which can result in long-term complications such as neuropathy [10].

Additionally, ultrasound guidance improves the distribution of the local anesthetic around the nerve. The

anesthesiologist can ensure that the anesthetic is deposited in the optimal location for effective nerve blockade, enhancing the success rate of the block. This is particularly important in cases where anatomical variations might otherwise make a successful block difficult to achieve with traditional techniques.

Ultrasound guidance also allows for the assessment of the block's effectiveness before proceeding with surgery. If the spread of the anesthetic is inadequate, the anesthesiologist can make immediate adjustments, either by repositioning the needle or by administering additional anesthetic. This proactive approach reduces the likelihood of incomplete blocks, which can lead to intraoperative pain and the need for supplemental anesthesia, such as general anesthesia.

Clinical Applications

The versatility of ultrasound-guided nerve blocks has made them an integral part of anesthesia practice across a wide range of surgical procedures. In orthopedic surgery, for example, nerve blocks such as the interscalene block for shoulder surgery, femoral nerve block for knee surgery, and popliteal sciatic block for foot and ankle procedures are commonly performed under ultrasound guidance. These blocks provide targeted pain relief while allowing for early

mobilization, which is crucial for rehabilitation and recovery [11].

In thoracic and abdominal surgeries, ultrasound-guided nerve blocks have also gained prominence. The transversus abdominis plane (TAP) block is widely used to provide postoperative analgesia for abdominal surgeries, including cesarean sections, appendectomies, and hernia repairs. The erector spinae plane (ESP) block is another innovative technique that has been employed for thoracic surgeries and even spinal surgeries, offering effective analgesia with a low risk of complications. These blocks have the advantage of providing pain relief without significant motor blockade, which is essential for procedures where early ambulation is desired [12].

The adductor canal block is another example of a block that has benefited from ultrasound guidance. It is used primarily for knee surgeries and offers the advantage of preserving quadriceps muscle strength, allowing patients to begin physical therapy soon after surgery. This early mobilization is a key component of ERAS protocols, which aim to reduce hospital stays and improve patient outcomes [13].

Continuous Peripheral Nerve Blocks (CPNB)

Building on the success of single-injection nerve blocks, continuous peripheral nerve blocks (CPNB) have emerged as a powerful tool for managing postoperative pain over an extended period. This technique involves the placement of a catheter near the target nerve, through which continuous or intermittent infusions of local anesthetic can be administered. The ability to provide prolonged analgesia without the need for frequent bolus injections or systemic opioids is a major

advantage of CPNB, particularly in patients undergoing major surgeries with severe postoperative pain.

Benefits of CPNB

The primary benefit of CPNB is its ability to maintain consistent pain relief over an extended period, often several days. This is particularly beneficial for surgeries associated with significant postoperative pain, such as joint replacements, major abdominal surgeries, and trauma surgeries. By providing continuous analgesia, CPNB reduces the need for systemic opioids, which in turn lowers the risk of opioid-related side effects such as nausea, vomiting, constipation, and respiratory depression.

Another advantage of CPNB is the potential for improved functional outcomes. By providing effective pain relief with minimal motor blockade, patients are able to participate in physical therapy and ambulation much sooner, which is critical for recovery. For example, in patients undergoing knee replacement surgery, the use of a continuous femoral nerve block can significantly improve early mobilization and reduce the length of hospital stay.

CPNB also allows for tailored pain management. The infusion rate of the local anesthetic can be adjusted based on the patient's pain levels and activity. For instance, higher infusion rates can be used during the immediate postoperative period when pain is most intense, while lower rates can be used as the patient begins to recover. This flexibility in pain management contributes to greater patient comfort and satisfaction [14].

Challenges and Considerations

While CPNB offers many benefits, it also presents challenges that must be carefully managed. One of the primary concerns is the risk of catheter dislodgement, which can lead to inadequate analgesia if the catheter is not properly positioned near the nerve. To mitigate this risk, secure catheter fixation and careful monitoring are essential.

There is also the potential for local anesthetic toxicity, particularly if the infusion rate is too high or if the local anesthetic accumulates in the bloodstream over time. Monitoring for signs of toxicity, such as tinnitus, metallic taste, and central nervous system symptoms, is crucial when using CPNB.

Finally, while CPNB can significantly reduce the need for systemic opioids, it does require more complex equipment and expertise compared to single-injection nerve blocks. Anesthesiologists and pain management teams must be well-trained in the use of these techniques, and institutions must be equipped with the necessary infrastructure to support their implementation [15].

Advantages and Challenges

CPNB offers several advantages, including sustained analgesia, reduced opioid consumption, and improved patient

comfort. However, challenges such as catheter dislodgement, local anesthetic toxicity, and the need for careful monitoring must be addressed to ensure the success of this technique. Advances in catheter technology and the development of more user-friendly infusion pumps have helped mitigate some of these challenges.

Novel Local Anesthetics and Adjuncts

The development of novel local anesthetics and adjuncts has further enhanced the effectiveness and duration of regional anesthesia. Agents such as liposomal bupivacaine, which provides prolonged release of the anesthetic, have shown promise in extending the duration of nerve blocks, reducing the need for additional analgesics, and improving patient satisfaction [16].

Advantages and Challenges of Continuous Peripheral Nerve Blocks (CPNB)

Continuous Peripheral Nerve Blocks (CPNB) have become an invaluable tool in perioperative pain management, offering significant advantages in terms of sustained analgesia and opioid reduction. However, like any medical technique, CPNB comes with its own set of challenges that require careful consideration and management (Table 2).

Table 2. Advantages and Challenges of Continuous Peripheral Nerve Blocks (CPNB)

Advantages	Challenges
<p>Sustained Analgesia One of the most compelling benefits of CPNB is its ability to provide prolonged pain relief. Unlike single-injection nerve blocks that offer pain relief for a limited duration, CPNB delivers a continuous or intermittent infusion of local anesthetic through a catheter placed near the target nerve. This continuous administration ensures that analgesia is maintained for</p>	<p>Catheter Dislodgement One of the primary challenges associated with CPNB is catheter dislodgement. If the catheter becomes displaced from its intended position near the nerve, the effectiveness of the analgesia can be compromised. Dislodgement can occur due to patient movement, improper catheter fixation, or mechanical issues. To minimize this risk, secure catheter</p>

an extended period, which is particularly beneficial for managing postoperative pain following major surgeries. The ability to sustain pain relief reduces the variability in pain levels and improves overall patient comfort.

Reduced Opioid Consumption

By providing effective pain control with local anesthetics, CPNB significantly reduces the need for systemic opioids. This reduction in opioid consumption is crucial given the opioid crisis and the associated side effects of opioid use, such as nausea, vomiting, constipation, sedation, and the risk of opioid dependence. Lower opioid requirements not only minimize the risk of these side effects but also contribute to a safer and more comfortable recovery period.

Improved Patient Comfort

The consistent analgesia offered by CPNB leads to enhanced patient comfort. Effective pain control allows patients to participate more actively in physical therapy and early mobilization, which is important for recovery, especially in surgeries that require significant postoperative rehabilitation. Improved comfort also contributes to better overall patient satisfaction and a smoother recovery process.

Tailored Pain Management

CPNB allows for individualized pain management. The infusion rate of the local anesthetic can be adjusted based on the patient's pain levels and activity. For instance, the infusion rate can be increased in response to heightened pain during the initial postoperative period and reduced as the patient's pain subsides. This flexibility ensures that pain management is adapted to the patient's needs throughout the recovery process.

placement techniques and robust fixation methods are essential. Regular monitoring and prompt corrective action if dislodgement is suspected are also critical.

Local Anesthetic Toxicity

Continuous infusion of local anesthetics carries the risk of toxicity, particularly if high infusion rates or large volumes are used. Symptoms of local anesthetic toxicity include tinnitus, metallic taste, dizziness, seizures, and cardiovascular effects. To mitigate this risk, it is important to use appropriate infusion rates, monitor for signs of toxicity, and ensure that the total dose of local anesthetic remains within safe limits. The development of newer local anesthetics with improved safety profiles may also help reduce the risk of toxicity.

Technical Complexity and Equipment

CPNB requires specialized equipment, including infusion pumps and catheters, which can be complex to use and maintain. The need for precise calibration of infusion rates and careful setup of the catheter can present challenges, especially in settings with limited resources or experience. Advances in catheter technology and infusion pump design, including user-friendly interfaces and improved safety features, have addressed some of these issues, but proper training and familiarity with the equipment remain essential.

Monitoring and Management

Continuous monitoring of patients receiving CPNB is crucial to ensure effective analgesia and to detect potential complications early. Regular assessment of pain levels, catheter function, and signs of adverse effects is necessary. This monitoring requires time and resources and may involve additional personnel or technology to support ongoing surveillance.

Infection Risk

Although rare, the risk of infection at the catheter insertion site is a potential concern. Proper aseptic technique during catheter insertion and maintenance, as well as regular site inspection, are important practices to minimize this risk.

Advances and Mitigation Strategies

Recent advancements in continuous peripheral nerve block (CPNB) technology and practices have focused on addressing existing challenges and improving patient outcomes. Innovations include the

development of improved catheter designs featuring better fixation mechanisms and smaller diameters, which help reduce dislodgement and enhance patient comfort. Additionally, modern infusion pumps now come with intuitive interfaces, precise

dosing capabilities, and built-in safety alarms, facilitating accurate delivery and monitoring of local anesthetics. Research into novel local anesthetic agents with longer durations of action and enhanced safety profiles aims to mitigate risks associated with toxicity. Furthermore, ongoing education and the establishment of standardized protocols for CPNB insertion, maintenance, and monitoring ensure that healthcare providers are well-prepared to effectively manage these techniques,

ultimately enhancing patient care and safety.

Novel Nerve Block Techniques

In recent years, several innovative nerve block techniques have emerged, providing enhanced options for anesthesia and pain management. These novel approaches have expanded the capabilities of regional anesthesia, offering improved efficacy and targeting for specific surgical procedures. Table 3 is a closer look at some of these techniques.

Table 3. Novel nerve block techniques

Quadratus Lumborum Block (QLB)	The Quadratus Lumborum Block (QLB) is a relatively new regional anesthesia technique designed to provide effective analgesia for abdominal and pelvic surgeries. It targets the thoracolumbar nerves, specifically the lumbar plexus, which innervates the lower abdomen and pelvis.
<i>Technique</i>	The QLB is typically performed by injecting local anesthetic into the fascial plane of the quadratus lumborum muscle, which is located deep in the back. This can be approached from several angles, including the posterior, lateral, or anterior approaches. Ultrasound guidance is commonly used to visualize the anatomy and ensure accurate placement of the needle and anesthetic.
<i>Clinical Applications</i>	The QLB is particularly beneficial for surgeries involving the lower abdomen, such as cesarean sections, appendectomies, and hernia repairs. It provides robust analgesia for the entire lower abdominal region, often reducing the need for systemic opioids and contributing to a more comfortable recovery.
<i>Advantages</i>	The QLB can offer prolonged pain relief with fewer systemic side effects. By targeting the thoracolumbar nerves, it provides effective pain control for a wide area with relatively minimal motor blockade, which helps facilitate early ambulation and recovery.
Pectoral Nerve Block (PECS)	The Pectoral Nerve Block (PECS), also known as PECS I and PECS II, is used primarily for breast surgery and provides targeted analgesia by blocking the pectoral nerves.
<i>Technique</i>	The PECS block involves the injection of local anesthetic into the fascial plane between the pectoralis major and pectoralis minor muscles (PECS I), and also in the plane deep to the pectoralis minor (PECS II). This approach can be performed using ultrasound guidance to ensure accurate needle placement.
<i>Clinical Applications</i>	The PECS block is commonly utilized for mastectomies, breast reconstruction surgeries, and other procedures involving the breast and chest wall. It can effectively reduce postoperative pain, diminish the need for systemic opioids, and improve patient comfort.

<i>Advantages</i>	The PECS block provides effective analgesia for the breast and anterior chest wall with minimal motor impairment, allowing for improved postoperative recovery and early mobilization. It has also been shown to reduce the incidence of chronic pain following breast surgery.
Serratus Anterior Plane Block (SAPB)	The Serratus Anterior Plane Block (SAPB) is an advanced technique used to provide analgesia for thoracic and breast surgeries by targeting the thoracic intercostal nerves.
<i>Technique</i>	The SAPB involves injecting local anesthetic into the plane between the serratus anterior muscle and the ribs, targeting the intercostal nerves that supply the lateral chest wall. Ultrasound guidance helps in visualizing the anatomical landmarks and achieving accurate placement.
<i>Clinical Applications</i>	This block is beneficial for surgeries involving the thoracic region, including rib fractures, thoracic procedures, and breast surgeries. It offers effective pain relief for the chest wall and can be used in combination with other blocks for enhanced analgesia.
<i>Advantages</i>	The SAPB provides excellent analgesia with minimal motor blockade, which is advantageous for surgeries that require patient mobility and cooperation during the postoperative period. It also helps in reducing opioid consumption and associated side effects.

ERAS Protocols

The integration of novel regional anesthesia techniques into ERAS protocols has significantly improved surgical outcomes by focusing on optimizing perioperative care to enhance recovery, reduce complications, and minimize hospital stays. Techniques such as quadratus lumborum block (QLB), pectoral nerve block (PECS), and serratus anterior plane block (SAPB) provide targeted analgesia, thereby effectively managing pain and reducing reliance on systemic opioids, which aligns with ERAS goals of minimizing opioid consumption and improving patient comfort. Additionally, effective pain control facilitates early mobilization—an essential component of ERAS—allowing patients to engage in physical therapy and ambulation sooner, ultimately leading to faster recovery and shorter hospital stays. Overall, the use of advanced nerve block techniques enhances patient satisfaction, reduces postoperative

complications, and accelerates the return to normal activities, thereby supporting the ERAS principle of optimizing recovery through comprehensive and evidence-based strategies.

Future Directions and Challenges

Despite the promising advancements in nerve block techniques, several challenges and areas for future research remain. Implementing novel nerve blocks necessitates specialized training and expertise in ultrasound-guided techniques, making it essential to ensure that anesthesiologists and pain management teams receive adequate training for successful application. Additionally, variability in patient anatomy can affect the effectiveness of these nerve blocks, highlighting the need for ongoing research and technological advancements to improve predictability across diverse populations. While these techniques offer significant benefits, there is also a risk of

complications, such as nerve injury or local anesthetic toxicity, necessitating continuous monitoring and the development of safer techniques and agents. Furthermore, integrating novel nerve block techniques into standardized clinical pathways and ERAS protocols requires further research and consensus to establish evidence-based guidelines and best practices. Finally, the development of new local anesthetic agents with longer durations of action and fewer side effects will be critical in enhancing the effectiveness and safety of regional anesthesia.

Conclusion

Emerging trends in regional anesthesia techniques have significantly improved the safety, efficacy, and patient-centeredness of perioperative care. Ultrasound-guided nerve blocks, continuous catheter infusions, and novel nerve block techniques have enhanced the precision and effectiveness of anesthesia, reducing the reliance on opioids and facilitating faster recovery. As these techniques continue to evolve, their integration into clinical practice will play a critical role in advancing perioperative care and improving patient outcomes. Ongoing research, education, and collaboration among healthcare providers will be essential to fully realize the potential of these innovations in regional anesthesia.

Statements and Declarations

Conflicts of interest

The authors declare that they do not have conflict of interest.

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