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Review Article

Novel Regional Nerve Blocks in Clinical Practice: Evolving Techniques for Pain Management

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Abstract

This review examines the use of novel US-guided nerve blocks in clinical practice. Erector spinae block is a regional anesthesia technique doing by injecting a local anesthetic among the erector spinae muscle group and transverse processes. The phrenic nerve is a branch of the cervical plexus, arising from the anterior rami of cervical nerves C3, C4, and C5. The quadratus lumborum muscle is located along the posterior abdominal wall. It originates from the transverse process of the L5 vertebral body, the iliolumbar ligament, and the iliac crest. US-guided peripheral nerve procedures have a considerable scope of use, including treating headaches and hiccups to abdominal surgical pain, cesarean sections, musculoskeletal pathologies. These nerve blocks have been an effective addition to clinical anesthesia practice. The use of peripheral nerve blocks has improved postoperative pain, lessened the use of opioids and their potential side effects, and decreased the incidence of sleep disturbance in patients. More research should be done to further delineate the potential benefits of these blocks.

Keywords: Ultrasound, Nerve Blocks, Phrenic, Quadratus Lumborum, Erector Spinae

1. Context

With recent advances in technology, the development of ultrasound-guided peripheral nerve blocks has revolutionized pain management of surgical patients. Ultrasound (US) as an imaging modality is cost-effective, safe, and efficacious (1, 2). Previously, physicians relied on palpation of anatomical landmarks and other tactical means of delineating the relevant anatomy before injection of anesthetic. Nerve stimulation was also used to be able to tell if one was close to a nerve before injecting anesthetic. The use of US guidance for peripheral nerve procedures allows concurrent visualization of relevant anatomy as the needle passes through anatomical structures leading to increased safety and accuracy. This allows for easier visualization of soft tissues and real-time needle advancement with an added benefit of no radiation exposure (3). There is also a much lower risk for adverse events such as unintentional intravascular injection and other damage to the adjacent tissues when US is used because real-time visualization of the needle allows clinicians to confirm that it is aligned within the intended path (3). There are relatively few contraindications to peripheral nerve blocks (4). These include local infection, comorbid neurological disorders, patients on blood thinners, and patients diagnosed with a coagulopathy (5).

Peripheral nerve blocks are useful, usually well-tolerated, and an effective means of anesthesia when a local block is needed. This modality provides more effective regional anesthesia than others, such as general anesthesia or oral pain medications, because it is targeted to the intended area of interest rather than disseminating to the entire body (5). Using US for peripheral nerve blocks allows visualization of the anesthetic as it spreads to local tissue. Oftentimes the endpoint is a visible "halo" of anesthetic surrounding the nerve of interest (6). The success of nerve blocks is highly dependent on the accurate location and deposition of local anesthetic. For example, in a study of 100 pediatric ilioinguinal-iliohypogastric nerve blocks, when compared to fascial click technique, an US-guided technique resulted in fewer instances of intraoperative anesthesia, post-operative anesthesia and required a lower volume of total local anesthetic.

In the management of several common pain disorders, US-guided perineural injections can offer short to medium-term pain relief (7). When an injection is used for diagnostic purposes or acute pain relief following post-operative/post-traumatic cases, local anesthetic can be used alone. Carpal tunnel syndrome is a common pain disorder that is characterized by entrapment of the median nerve in the carpal tunnel (8). Steroids and anesthetics can be injected surrounding the nerve to offer pain relief. Using ultrasound guidance, the median and radial nerves can be identified and avoided when administering the anesthetic/ steroid treatment. Also, the radial and ulnar nerves may be compressed, or may require local anesthesia, as in median nerve involvement in carpal tunnel syndrome (9, 10). Various other conditions such as chronic shoulder pain, knee pain, headaches, postoperative groin pain, meralgia paresthetica, and others can be successfully treated with US-guided perineural injections (11-16). This manuscript examines the use of numerous US-guided lower extremity nerve blocks in various procedures for pain control.

2. Erector Spinae Blocks

The erector spinae muscle group consists of the spinalis muscle, longissimus muscle, and iliocostalis muscle. The muscles are located posterolaterally to the vertebral column, running between the angle of the ribs laterally and the spinous processes medially. This muscle group is covered by thoracolumbar fascia, along with the serratus posterior inferior, rhomboid, and splenius muscles. The erector spinae group originates from a large tendon attached to the spinous processes of the lumbar and lower thoracic vertebrae, sacrum, and iliac crest. The muscles in the upper back are divided into three columns. The iliocostalis muscle, located most laterally, is associated with the costal elements and has multiple insertions into the angles of the ribs and the transverse processes of the lower cervical vertebrae. The longissimus, located between the iliocostalis and spinalis, is the largest of the group and inserts into the base of the skull. The spinalis is the smallest of the group and located most medially. It connects the spinous processes of adjacent vertebrae. It inserts into the spinous processes of thoracic and cervical vertebrae and into the occipital bone. Each component of the erector spinae muscle group can be further subdivided into regions based on their attachments superiorly (17).

Erector spinae block is a regional anesthesia technique carried out by administrating a local anesthetic among the transverse processes and the erector spinae muscles. This results in a blockade of the dorsal and ventral rami of the thoracic and lumbar spinal nerves (18). The local anesthetic also diffuses to the paravertebral and epidural spaces (19). The spread of anesthetic effectively blocks both somatic and visceral pain (20).

The block can be performed at the lateral decubitus, sitting, or prone positions. Also, may be done under local or general anesthesia. Guidance by ultrasound is preferred, either using a high-frequency linear transducer at the thoracic level or a convex transducer at the lumbar level. The transducer is initially placed in a transverse direction to recognize the spinous process and correct vertebral level. The transducer is then moved 3 cm laterally to identify the transverse process. With the transverse process visualized, the probe is rotated 90 degrees to allow for visualization of the muscles of the back, including the trapezius, rhomboid major, and erector spinae. With proper muscular visualization, the needle is inserted into the plane in a cranio-caudal or caudo-cranial fashion, targeting the transverse process. When the needle reaches the fascial layer among the erector spinae muscles and the transverse process, hydrodissection with saline solution is performed to open the plane for adequate anesthetic deposition. The preferred anesthetic is then injected in large enough volume for spread across multiple spinal levels (19).

Ultrasound-guided erector spinae blocks have been used primarily as a means of postoperative analgesia, including total hip arthroplasty surgery (18), pediatric and adult laparoscopic cholecystectomy (20), pilonidal sinus surgery (21), breast surgery (19), major open abdominal surgery, and cesarean delivery (22). It is also effective in the management of acute and chronic pain, including acute pancreatitis in an emergency department setting (23), cervical neuropathic pain, shoulder pain, zoster, and rib fractures (19).

3. Phrenic Block

The phrenic nerve is a branch of the cervical plexus, arising from the anterior rami of cervical nerves C3, C4, and C5. The phrenic nerve courses around the upper lateral border of the anterior scalene muscle and then continues downwards among the surface of the anterior scalene muscle in the prevertebral layer of cervical fascia (24). As the phrenic nerve continues, it passes between the sternocleidomastoid and omohyoid muscles, along with the subclavian vessels, to enter the thorax. It then continues to the diaphragm, providing its main source of innervation. It also innervates portions of the pericardium, mediastinum, pleura, and peritoneum (25). The phrenic nerve consists of motor, sensory, and sympathetic nerve fibers. It supplies the motor innervation of the diaphragm, resulting in contraction with activation during inspiration. It supplies sensory innervation to the central tendon of the diaphragm, along with touch and pain sensory innervation to the pleura of the mediastinum and pericardium (26).

Phrenic nerve block is a regional anesthesia technique performed by injecting local anesthetic around the phrenic nerve. The block can be performed at the lateral decubitus, sitting, or prone positions. Also, may be done under local or general anesthesia. The US probe is initially placed on the side of the neck, scanning to identify the anterior scalene muscle (27). The phrenic nerve is then identified as it courses along the ventral surface of the muscle near the common carotid artery. With proper phrenic nerve visualization, the needle is conducted by in-plane approach towards the phrenic nerve. When the needle is near to the phrenic nerve, the preferred anesthetic is then injected (27). Another technique involves the identification of the anterior and middle scalene muscles and the inter-scalene groove coursing between the bellies of these muscles. The inter-scalene groove contains nerves of the brachial plexus that can be visualized on ultrasound. The ultrasound probe is then placed supero-laterally to the inter-scalene groove at the level of the fifth cervical nerve root. The course of the fifth cervical nerve is then followed until the phrenic nerve is visualized (28).

Ultrasound-guided phrenic nerve blocks have been used as a treatment method for persistent hiccups refractory to medical management. It has been performed in the surgical setting intraoperatively (27), acute inpatient critical care setting (29), and palliative care setting (28). A hiccup is an unconscious spinal reflex resulting in an involuntary spasmodic contraction of the diaphragm, composed of a thorough reflex arc. The phrenic nerve, vagus nerve, and sympathetic nerves of T6 through T12 are the afferent nerves. Brainstem, phrenic nucleus, medullary reticular formation, and hypothalamus are the responsible for the reflex center. Efferent nerves of the arc include the phrenic nerve and intercostal nerves. The effector muscles consist of the diaphragm, intercostal muscles, and anterior scalene muscles (27). Management of persistent hiccups includes rebreathing of carbon dioxide and pharmacologic treatment, including chlorpromazine (27), proton pump inhibitors, GABA receptor agonists, anticonvulsants, dopamine agonists, and baclofen (28). Blockade of the phrenic nerve through anesthesia can quickly and effectively suppress the hiccup reflex arc and terminate the hiccups. Care should be taken as this could result in paralyzing the patient's diaphragm resulting in the patient not being able to breathe.

4. Quadratus Lumborum Blocks

The quadratus lumborum muscle is located along the posterior abdominal wall. It originates from the transverse process of the L5 vertebral body, the iliolumbar ligament, and the iliac crest. The muscle inserts on the transverse processes of the L1 through L4 vertebrae and the lower edge of 12th rib. The quadratus lumborum fills the space between the iliac crest and rib twelve, flanking the vertebral column. The psoas major muscles overlap the quadratus lumborum muscles medially, while the transverse abdominis muscles are located laterally. The quadratus lumborum muscles function to lower down and fix the 12th ribs and facilitate lateral flexion of the trunk. Innervation to the quadratus lumborum muscles is provided by the anterior rami of T12 and the spinal nerves of L1 to L4 (30). Ultrasound-guided quadratus lumborum blocks have been used primarily as a means of perioperative pain management for abdominal surgery, including gastrotomy, laparoscopy, colostomy, pyeloplasty, and myocutaneous flap surgery (31). The quadratus lumborum block has also been used to provide postoperative analgesia in hip surgery and cesarean section (32-35).

Quadratus lumborum block is a regional anesthesia technique performed by injecting local anesthetic either anteriorly, posteriorly, or laterally to the quadratus lumborum muscle or intramuscularly (31). Spread of local anesthetic into the thoracic paravertebral space facilitates blockade of both somatic nerves and the lower thoracic sympathetic trunk, providing analgesia for both somatic and visceral pain (35).

The block can be performed with the patient lying supine or lying on their side. It can be done under local or general anesthesia. Ultrasound guidance (USG) is provided by a curved (low frequency) or a linear (high frequency) transducer. For the anterior quadratus lumborum block, the patient is in the lateral decubitus with the curved transducer placed perpendicularly upper the iliac crest. A needle is conducted by in-plane approach from the posterior side of the transducer through the quadratus lumborum in an anteromedial orientation, with the tip among the psoas major and quadratus lumborum muscles. The preferred injectate is then administered into the fascial level (31). For the lateral quadratus lumborum block, the patient is lying on back with the linear transducer placed in the zone of the Petit triangle to visualize the quadratus lumborum muscle. A needle is inserted with the tip placed at the anterolateral margin of the quadratus lumborum along the border of the transversalis fascia, where the preferred anesthetic is then injected (31). For the posterior quadratus lumborum block, the patient is lying supine with the linear introducer placed in the Petit triangle to visualize the quadratus lumborum muscle. A needle is inserted into the posterior view of the quadratus lumborum muscle with the tip in the lumbar interfascial triangle, where the preferred anesthetic is then injected (31). For the intramuscular quadratus lumborum block, the patient is lying supine with the high-frequency linear probe placed above the iliac crest. A needle is inserted into the quadratus lumborum muscle, where the preferred anesthetic is then injected (31).

5. Clinical Studies: Safety and Efficacy

Several reviews and randomized control trials have been conducted evaluating the effectiveness of various ultrasound-guided neve block techniques for postoperative analgesia. Although new techniques are being explored, many of these studies placed focus on erector spinae plane blocks (ESPB), pectoral nerve blocks (PECS), phrenic nerve block (PNB), intercostal nerve blocks (ICNB), transverse abdominus plane blocks (TAPB), rectus sheath blocks (RSB) and quadratus lumborum block (36-39). The primary endpoint of the majority of these studies was overall postoperative pain and amount of opioid requirement.

In Altiparmak et al. (40), effects of a modified pectoral nerve (PECS) block and erector spinae plane (ESP) block were compared postoperatively following unilateral radical mastectomy. The patient's pain was monitored utilizing numerical rating pain scale (NRS). Over a 24-hour period, the pain was assessed by comparing fentanyl or tramadol requirements and pain scale at different points. In the first 24 h, modified PECS block decreased analgesic using up and NRS significantly more than ESP block (40). Although either block was not compared to a control or placebo group, this study showed efficacy of PECS block for the use of postoperative analgesia of mastectomy or pectoral surgeries due to the coverage of the block. The effects of modified PECS block are on the following nerves (40):

1) Lateral and medial pectoral nerves;

2) Thoracic intercostal nerves;

3) Intercostobrachial nerve;

4) Long thoracic nerves.

These nerves that are blocked provide a favorable distribution since it provides coverage for both the chest wall and axillary area.

Macaire et al. (41) studied patients undergoing open cardiac operation with cardiac bypass comparing continuous erector spinae plane block with IV pain medication. The RSPB group received a loading dose of ropivacaine 0.2% postoperatively and was connected to a pump receiving intermittent boluses. The control group received i.v. morphine, and nefopam. The primary endpoint of this study was overall morphine consumption and determining early outcome factors compared to standard perioperative and postoperative management. Opioid consumption in the first 48 hours was significantly reduced in the ESPB group as was intraoperative sufentanil (41). Macaire et al. (41) also compared time to removal of the chest tube and logged pain scores using the visual analog scale (VAS). Not only did the ESPB decrease postoperative sternotomy pain, but it also reduced the time to chest tube removal and mobilization compared to the control group. Their research displayed that the utilization of an USG continuous ESPB caused a considerable reduction in postoperative opioid administration, rapid patient ambulation, drain removal, and pain relief (41).

Chen et al. (42) compared the analgesic effect of three different nerve block techniques for postoperative analgesia in thoracoscopic surgery. The three techniques studied in this randomized, double-blinded clinical trial were ultrasound-guided intercostal nerve block (ICNB), single ESPB, and multiple paravertebral nerve block (PVB). This study included seventy-five patients scheduled for elective thoracoscopic partial pulmonary resection surgery and were assigned into three groups receiving each of the nerve blocks using 20 mL of 0.375% ropivacaine. The primary endpoint for this study was to reduce postoperative morphine consumption and reduced postoperative pain, which was measured using the VAS pain scale. This study showed a decrease in morphine consumption 24 hours postoperatively with all three blocks (42). Although PVB was shown to be superior to both ICNB and ESPB, it was recommended future studies be performed to determine optimal doses for each of the nerve block techniques as it may have contributed to the insufficient analgesia in the ICNB and ESPB groups.

Wu et al. (43) performed a study comparing TAPB and local anesthetic infiltration (LAI) for postoperative analgesia in laparoscopic cholecystectomies. This study included one hundred eighty patients separated into three groups: LAI group using ropivacaine plus dexmedetomidine all over the trocar site before the surgery, TL group using posterior TAPB plus LAI, and the TR group using TAPB plus RSB. The main goal of this study was to assess the efficacy of analgesia with each of the techniques, and the primary endpoint of this study was to compare early ambulation. This study also utilized the VAS pain scale at different time points to determine and compare analgesia between the groups. Results showed the differences were not considerable between the three groups (43). It was concluded in this study that pain relief with TAPB was equivalent to LAI but provided little benefit in patients undergoing laparoscopic cholecystectomies.

Yi et al. (44) performed a study exploring the use of phrenic nerve blocks for post laparoscopic cholecystectomy shoulder pain as the primary cause is thought to be irritation or injury of the phrenic nerve from CO_2 pneumoperitoneum causing referred pain to the C4 dermatome. The patients were randomly allocated into phrenic nerve block and control group. The pain score, delivered PCA boluses, rescue analgesic requested, and side effects were documented (44). This study also utilized the VAS pain scale and made sure patients were aware this scale was to be exclusively used for shoulder pain rather than incisional or visceral pain. The primary endpoint for this study was overall incidence and VAS scores of postoperative laparoscopic shoulder pain at 2 hours. In the study group, the overall incidence and severity of shoulder pain was decreased significantly but had no effect on incisional or visceral pain and analgesic requirements between groups. This study also performed postoperative pulmonary function tests to assess the effects of respiratory discomfort and diaphragmatic paresis following PNB and were in normal ranges within 24 hours of PNB. In conclusion, USG phrenic nerve block, can lessen and hamper shoulder pain and does not cause clinically notable respiratory problems (44).

Blichfeldt-Eckhardt et al. (45) conducted a study exploring the analgesic effect of PNB for shoulder pain following thoracic surgery. In this study, 76 patients scheduled for lobectomy or pneumonectomy were randomized, and one group received 10 mL of ropivacaine while the other received a placebo dose (saline). The initial goal of was to examine the incidence of postoperative early (6 h) shoulder pain, and the next goal was late (3 days) shoulder pain. Spirometry was also performed to determine the impact of phrenic nerve block on patients pre and postoperatively. The early shoulder pain was significantly lower in the phrenic group than the control group (45). Results of spirometry tested also showed no evidence of respiratory compromise or change in respiratory parameters, specifically FEV1 and FVC. In conclusion, this study demonstrated that a PNB is a safe and useful method of reducing the ipsilateral shoulder pain following thoracic surgeries and recommend future studies focus on the use of newer long-acting liposomal formulations to explore the duration of effects and outcomes versus current amide local anesthetics used today.

Blanco et al. (46) performed a study comparing the quadratus lumborum block versus a TAPB after cesarean delivery, hypothesizing that the novel quadratus lumborum nerve block technique would be equal to or better than TAPB and improve early recovery, ambulation, and breastfeeding. This study randomized 76 patients into two groups that were scheduled for elective cesarean delivery under spinal anesthesia, one group receiving a quadratus lumborum block and the other receiving a TAPB postoperatively. The primary outcome was morphine consumption over a 48-hour period. Results showed, morphine consumption in the quadratus lumborum block group at the late hours was considerably reduced compared to the transverse abdominus plane block group but not at the early hours (46). They concluded that quadratus lumborum block was more effective in decreasing postoperative analgesic administration compared to TAPB and improved analgesia at rest and with movement.

Irwin et al. (47) performed a study exploring the analgesic effects of a quadratus lumborum block after cesarean section performed under neuraxial analgesia. This study highlighted that the quadratus lumborum block was a relatively novel technique and was inspired by previous studies showing the superiority of this approach compared to a TAPB. This was a prospective, double-blind, placebo-controlled trial in which 86 women were randomly assigned to two groups, one receiving a bilateral quadratus lumborum block with 40 ml of 0.25% levobupivacaine, and the control group receiving a sham block. The initial goal was to measure total 24-hour morphine consumption. The secondary outcome of this study was the opioid PCA requirements (24 h); total opioid administration (48 h); pain scales (47). Although morphine consumption was similar between both groups throughout the study, patients showed a reduction in VAS scales only at 6 h with the quadratus lumborum block compared with the control group at rest and during movement. They concluded that adding the quadratus lumborum block to spinal morphine in cesarean not only did not decrease postoperative morphine administration but also did not any more pain relief after 6 h (47).

Yoshida et al. (48) also performed a study for cesarean patient receiving an intramuscular quadratus lumborum block versus placebo with a primary outcome of elapsed time to first postoperative analgesic use between and secondary outcome of dose of postoperative analgesic use. Results showed that the first time for postoperative analgesic request were no significant differences among the two groups (48). It is important to note that this study used ropivacaine that was injected on the right and left side quadratus lumborum muscle rather than utilizing hydro dissection prior to insertion of the local anesthetic. Although many studies have concluded the quadratus lumborum block to enhance analgesia, this study hypothesized that the analgesic effect of quadratus lumborum block in previous studies utilizing the hydro dissection method is demonstrated analgesia because of the distribution of local anesthetic to the paravertebral space.

Several studies have concluded that these blocks improve analgesia and post-operative outcomes from various surgical procedures. These studies primarily focused on decreased use of opioid consumption and proved to be effective not only in that area but able to improve surgical outcomes in terms of patient functionality. With this information, future studies can focus on the most effective dosages for each of these nerve block techniques and may eventually become an integral part of recovery protocols.

6. Conclusions

In most cases, ultrasound-guided peripheral nerve procedures are a safe and effective alternative to general procedural anesthesia and sedation. Peripheral nerve blocks typically last longer than regional anesthesia and have a faster onset (7). Ultrasound guidance allows the advantage of visually monitoring the needle advancement, amount of injected anesthetic, and distribution of the anesthetic. It allows for real-time visualization of relevant anatomy and the added benefit of needle adjustment while in the soft tissue if needed. The ease of use and low cost of ultrasound guidance spurred the technological advancements and engineering that led to its use as a diagnostic, imaging, and now therapeutic modality (49). Indications for peripheral nerve procedures include patients at risk of respiratory depression from general anesthesia, patients refractory to oral medications, and patients who want to avoid potential side effects of oral medications like opioids (5). Although rare, complications and potential side effects of peripheral nerve blocks are nerve injury, hematoma, local anesthetic toxicity, infection, and allergic reaction (5).

US-guided peripheral nerve procedures have a very large scope of use, including treating headaches and hiccups to abdominal surgical pain, cesarean sections, musculoskeletal pathologies. These nerve blocks have been an effective addition to clinical anesthesia practice. PNB, with precise injection using ultrasound guidance, can help alleviate shoulder pain without resulting in respiratory compromise. The use of peripheral nerve blocks has improved post-operative pain, lessened the use of opioids and their potential side effects, and decreased the incidence of sleep disturbance in patients (50). The use of quadratus lumborum blocks have shown mixed results in studies, but that could have been owed to the difference in the amount of local anesthetic used (51). The studies also noted that hydrodissection was not used in some studies examining the quadratus lumborum block so the block may not have spread enough to have appropriate effect. Opioids are frequently used in the post-operative period following shoulder arthroscopy surgery and other common orthopedic procedures (52). More research is warranted to further delineate the potential benefits of these blocks and best practice strategies.

Footnotes

Authors' Contribution: Study concept and design: ANE, BG, AJK, EMC, AK, and ADK. Analysis and interpretation of data: ANE, BG, KAT, CCH, AJK, EMC, AK, and ADK. Drafting of the manuscript: ANE, BG, KAT, CCH, AJK, EMC, FI, and EB. Critical revision of the manuscript for important intellectual content: ANE, BG, KAT, CCH, AJK, EMC, FI, EB, AK, and ADK.

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