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OTHER PAIN (A KAYE AND N VADIVELU, SECTION EDITORS)

Novel Regional Anesthesia for Outpatient Surgery

Jinlei Li[1] · David Lam[1] · Hanna King[1] · Ellesse Credaroli[1] · Emily Harmon[1] · Nalini Vadivelu[1]

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Abstract

Purpose of Review Peripheral nerve blocks are effective and safe modalities for perioperative analgesia. But it remains unclear what blocks are adequate for ambulatory surgeries, as well as the proper patient management before and after discharge.

Recent Findings Emerging nerve blocks have sparked interests due to ease to perform under ultrasound guidance and lower risks of adverse events. Some of these novel blocks are particularly suitable for ambulatory procedures, including but not limited to motor-sparing lower extremity nerve blocks and phrenic-sparing nerve blocks for shoulder surgeries.

Summary The adoption of peripheral nerve block into outpatient surgery is a multidisciplinary effort that encompasses appropriate patient choice, careful selection of nerve blocks that minimize potential adverse events after discharge, and proper patient follow-up until block effects resolve.

Keywords Outpatient surgery · Novel peripheral nerve block · Ultrasound guidance

Introduction

The transition of surgical procedures from the hospitals to the ambulatory surgery setting has been increasing each year, thanks to the adoption of minimum invasive surgery and advancement in anesthesia techniques. The recent advancements in regional anesthesia in the lower extremity such as the motor-sparing peripheral nerve blocks are key factors to make major joint surgeries such as total knee arthroplasty and total hip arthroplasty same-day ambulatory procedures. The advancements in newer truncal peripheral nerve blocks have offered additional advantages as compared with neuraxial anesthesia such as no need for urinary catheter and more hemodynamic stability. New blocks on the horizon include the phrenic nerve–sparing suprascapular nerve block and axillary nerve block.

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✉ Jinlei Li
Jinlei.li@yale.edu

David Lam
David.Lam@yale.edu

Hanna King
hanna.rahman@yale.edu

Ellesse Credaroli
Ellesse.Credaroli@yale.edu

Emily Harmon
Emily.harmon@yale.edu

Nalini Vadivelu
Nalini.Vadivelu@yale.edu

[1] Department of Anesthesiology, Yale University, New Haven, CT, USA

Established Novel Blocks

Adductor Canal Block

History Adductor canal block (ACB) was originally described as a “subsartorial approach” to the saphenous nerve (the terminal sensory branch of the femoral nerve) block, by van der Wal in Canada in 1993. The development of this regional anesthetic technique was intended to find an alternative anesthetic approach to saphenous blocks for foot and ankle surgeries [1]. It was found that the single-shot injection approach both in and out of the plane would demonstrate similar results as a saphenous nerve block. This development leads to the continued incorporation of saphenous nerve blocks for lower extremity procedures.

Indications The ACB is a sensory nerve block for the majority of the part, involving the saphenous nerve, nerve to the vastus medialis, and articular branches of the obturator nerve. When successfully done, the block produces analgesia similarly as a femoral nerve block, but without significant loss of motor control to the thigh [1]. Its use is primarily for lower leg surgeries including total knee replacements, ACL reconstruction, and meniscal repair. It is also an alternative to the femoral nerve block and can be used in conjunction with sciatic nerve blocks to provide complete analgesia below the knee, such as ankle procedures.

Outcomes The advantage of this block is the sparing of most of the motor fibers to the quadriceps muscles after knee surgery which encourages earlier ambulation, recovery, and rehabilitation compared with femoral nerve blocks [1]. In 2016, Jiang developed a meta-analysis of randomized controlled trials to determine the efficacy of adductor canal blocks, to evaluate postoperative pain management in patients undergoing total knee arthroplasties. Several considerations were involved including analgesic consumption postoperatively, pain at rest/during movement, ability to ambulate, quadriceps strength, and additional complications (nausea, vomiting, sedation): with the accumulation of information, there were substantial differences in patients receiving adductor canal blocks within a multimodal blockade set, relative to the traditional usage of femoral nerve blocks. In comparing ACB with saline to femoral nerve blocks, it was found that despite similar results in postoperative analgesic consumptions, variations in the ability to ambulate, as well as quadriceps strength, were statistically significant. This difference was most noticeable in the recovery period and strength of quadriceps muscles after surgery, with noted decreases in pain medication consumption as well [1]. Accumulating literature has indicated that by blocking the saphenous nerve at the adductor canal location, the nerve to the vastus medialis and articular branches of the obturator nerve are also blocked, demonstrating the efficacy of ACB in knee surgeries [1]. Nonetheless, similar to most other regional blocks, blood vessel needle puncture, infection, and failure are potential risks.

Anatomy/Techniques The adductor canal itself is bordered by the sartorius muscle, the quadriceps muscle, and the adductor longus muscle. The adductor canal contains the femoral vessels, saphenous nerve, nerve of the vastus medialis, and posterior division of the obturator nerve. At the proximal end of the adductor canal, the medial border of the sartorius muscle intersects the medial border of the adductor longus muscle. The distal end of the adductor canal is the adductor hiatus. The saphenous nerve is the large cutaneous branch of the femoral nerve and lies anterior to the femoral artery as it passes underneath the sartorius muscle, remaining behind the aponeurosis which covers the adductor canal. As the saphenous nerve itself travels distally, it goes through the fascia lata between the tendons of the sartorius and gracilis muscles, with continued progression down into the ankle as a subcutaneous vein. When scanning with ultrasound for landmarks, it may help to start finding the sartorius muscle first, in which the adductor longus muscle will be medial, and the quadriceps muscle will be lateral to the findings of the canal.

The best location to perform ACB continues to be controversial when it comes to the balance between analgesia efficacy and motor-sparing effect. Given the variation in injection points for ACB, Wong and colleagues specifically studied one of the most common injection locations, the midpoint between the anterior superior iliac spine and the base of the patella. They found that injection at the mid-thigh is much more a femoral triangle block than an adductor canal block per se. Consequently, a more accurate ACB would require a more distal approach [2].

In order to properly perform an ACB, the local anesthetic should sufficiently fill the canal while avoiding adjacent vasculature and structures. Jaeger and colleagues found that 20 cc of local anesthetic was the minimal effective volume to fill the adductor canal without significant proximal spread to femoral triangle [3]. Interestingly, it was noted that there was no statistical significance between local anesthetic volume used and proximal spread to the femoral triangle. Moreover, it was found that the amount of injected local anesthetic would not have an effect on muscle strength which would alter postoperative management either [2].

To perform the block, supplemental oxygen and ASA standard monitors should be placed first, especially if sedation is required, followed by standard safety protocols. A patient can be placed in a supine or semi-recumbent position with the hip laterally rotated to expose the medial thigh and undergo aseptic technique. The use of an ultrasound is recommended over purely performing a landmark-based technique as relevant structures are easily viewed. Using a linear probe with depth set to 3–4 cm, it should begin at the midpoint of the patella and inguinal crease, on the medial side of the thigh roughly where the sartorius muscle would be. Adjust to have a short axis view of the pulsating distal femoral artery: the superficial femoral vein should be compressible. After verification of the femoral artery, view the adductor canal with the distal femoral artery still in the short axis field: the sartorius and adductor longus muscles should be visible. The needle can then be inserted into the fascial plane between the sartorius and vastus medialis muscles under direct visualization. Advance a short bevel; blunt block needle underneath the femoral artery toward the adductor canal from a superior-lateral aspect. The final end point of the needle should be the lateral aspect of the superficial femoral artery. Be sure to aspirate for blood intermittently throughout injection of local anesthetic. The saphenous nerve may be difficult to visualize but appropriate deposition of the LA into the plane to fill the adductor canal will appropriately anesthetize the nerve. Alternatively, the adductor canal can be located by placing probe at the inguinal crease, scan caudally and watch the femoral artery becomes the superficial femoral artery, and the sartorius muscle comes in view.

Summary Unlike other traditional techniques, the use of an ACB can spare most of the motor nerve distributions to the quadriceps muscles while providing adequate analgesia. Strength preservation in a patient's lower extremity is instrumental in helping patients ambulate, recover, and consequently initiate postoperative physical therapy earlier. It is an entry level of peripheral nerve block that is relatively easy to perform, with lower failure rates and relatively low adverse event profiles.

iPACK

History Infiltration between the popliteal artery and capsule of the knee (iPACK) block was developed by Dr. Sanja Sinha from his clinical trials in 2011 and the aim for the block is to provide adequate analgesia to the posterior aspect of the knee and avoid foot drop after total knee arthroplasty (TKA). It blocks the articular branches of tibial, common peroneal, and obturator nerves in the popliteal region. Though similar to a posterior capsule injection often implemented by the surgery service, the advantage of this technique through the use of ultrasound minimizes the risk for popliteal artery puncture and a sciatic nerve block. By targeting the terminal branches of the sciatic nerve only, the iPACK block provides an alternative to controlling posterior knee pain following total knee arthroplasty as well as reducing the risk of foot drop [4].

Indications The iPACK block provides the ability to anesthetize the posterior part of the knee without significant sciatic motor nerve involvement, primarily utilized in knee surgeries, such as total knee replacement, anterior cruciate ligament repair, and knee arthroscopy. This technique is often used in combination with an anterior knee block such as femoral nerve block or adductor canal block, and spinal/epidural anesthesia [5].

Outcomes The implementation of the iPACK block into the practice for major knee surgeries has been extremely successful especially when used in conjunction with other peripheral nerve blocks. Oschner et al. did a study comparing a combination of ACB and iPACK blocks with the traditional femoral nerve block for total knee arthroplasty. It was found that patients who underwent iPACK blocks, when used in conjunction with other regional blocks relative to the femoral nerve block only technique, had substantially reduced opiate consumption, decreased recovery times, and increased capacity for baseline strength [6]. Another study by Sankineani et al. also demonstrated the success of iPACK blocks when used in conjunction with ACBs for TKA [7]. Nevertheless, given nearby anatomical structures, there is always the risk for popliteal artery puncture as well as causing a motor block through local anesthetics spreading to the sciatic nerve.

Anatomy/Techniques Anatomy surrounding the capsule is the vastus medialis muscle, sartorius, femur, popliteal vessels, and sciatic nerve. The sciatic nerve is located superficial to the popliteal vein, popliteal artery, and femur. The target of injection is the space between the popliteal artery and the femur, where small branches of the sciatic nerve toward the joint capsule are located. Care should be taken to avoid excessive local anesthetic spread to the sciatic nerve itself and therefore avoid foot drop.

Supplemental oxygen and standard ASA monitors should be started, especially if sedation is required followed by standard safety protocols. Patients can be placed supine, prone, and lateral decubitus. Placing the transducer in the popliteal fossa, identify the femoral condyle and the popliteal artery and move about 1 cm cephalad to pass the curvy condyle into the straight part of the femur. The space between the popliteal artery and the femur is easily identified. The popliteal vein located between the sciatic nerve and popliteal artery is often not visible.

The utilization of Doppler can be helpful in locating the popliteal artery which is often quite deep relative to the skin's surface. The insertion angle is often steep if a patient is in a supine position without leg support. A lateral decubitus, prone, or supine position with a secure leg up position allows for an in plane, less steep needle angle and easier needle visualization. Tibial and common peroneal nerves are not usually seen in a medial approach with the patient in supine position, but can be visualized superficial to the popliteal artery and vein in a prone, supine lateral approach, or lateral decubitus position. The goal is to deposit the anesthetic in the interspace between the posterior capsule of the knee and the popliteal artery. Inject local anesthetic incrementally after negative aspiration and visualize the space between the femur and popliteal artery that get expanded.

Summary The iPACK block is a newly developed motor-sparing block that targets the small branches of the sciatic nerve before they enter the posterior joint capsule of the knee. It has been proven to be an effective analgesic in knee procedures without lower extremity weakness or foot drop. It is particularly useful when used in combination with femoral or adductor canal block for lower extremity analgesia. It is an intermediate level of peripheral nerve block that is relatively easy to perform and is associated with low adverse event profile as long as the popliteal artery is always kept in view.

Obturator Nerve Block

History Obturator nerve block (ONB) was first described in the early days of regional anesthesia back in 1922 when Labat identified the clinical efficacy of selective obturator nerve blocks. Several years later, Pauchet, Sourdat, and Labat stated that a "obturator nerve block combined with blocks for the sciatic, femoro-cutaneous nerves, [was a useful method to] anesthetize the entire lower limb." However, the block yielded inconsistent results; given unclear anatomical landmarks and as such, the block remained generally unused. In 1967, Parks modified the block and, with its revival, was further changed and improved by Wassef through an inter-adductor approach, followed by Pinnock in 1996 [8]. In 1973, Winnie introduced the "3-in-1" concept as an anterior approach: using a paravascular inguinal injection, the femoral nerve, lateral cutaneous nerve of the thigh, and obturator nerve were able to be anesthetized [9]. Despite its success, multiple studies refuted this method's ability to block the obturator nerve. With the advancement in technologies including ultrasounds and nerve stimulators, selective blockade of the obturator nerve has become much more reliable and, as such, has increased its use in common practice to provide complete analgesia for lower extremity when used together with sciatic and femoral nerve blocks.

Indications The obturator nerve block (ONB) has great utility as its use is not simply for orthopedic surgeries.

- Transurethral resection of bladder tumor: prevents sudden thigh adduction during transurethral resection of bladder tumors. The obturator nerve is located directly adjacent to the lateral wall of the bladder in which any electrical stimulation has been found to cause sudden adductor contraction [10].
- Knee surgery: knee joint capsule has obturator knee innervation and is crucial for gracilis tendon harvest in ACL repair as the anterior branch of the obturator nerve innervates the gracilis muscle [11].

- Analgesia after major knee surgery: distal and lower leg to prevent tourniquet pain during lower leg surgery
- Often used in combination with femoral, lateral femoral cutaneous nerve (LFCN), and sciatic blocks

- Hip surgery: The obturator nerve contributes to the sensory innervation of the hip joint with the articular branch providing sensory to the anteromedial hip joint capsule: these considerations involve multimodal regional blocks for effective postoperative pain management
- Pain therapy and hip adductor spasticity: Persistent groin and hip pain with spasticity is often managed with ONB blocks on an outpatient basis
- Chronic leg pain

Outcomes Given its varied use, ONBs have become a staple in regional anesthesia and pain management. Multiple studies have demonstrated the efficacy of ONBs when used within a multimodal nerve block treatment plan. Per McNamee in 2002, total knee replacement patients who had a ONB in conjunction with femoral and sciatic nerve blocks demonstrated a significant increase in the time until their first request for breakthrough pain control, correlating with a reduction in total morphine usage as well. The participants of the study also did not experience any systemic or neurological sequelae [12]. In a 2010 study by Sakura et al. evaluating the value of ONB for anterior cruciate ligament reconstruction, they described the nerve block as crucial for intraoperative analgesia [13]. The ONB has an extensive history in which its techniques have been modified to yield high success rates. Pladzyk analyzed over 500 patients who underwent ONB for transurethral resections of bladder tumors, continuing the notion that this method is extremely efficacious with low risks of complications [14].

Anatomy and Technique Arising from the anterior rami of L2–L4, the obturator nerve passes through the psoas major and comes through the medial border of the muscle, extending laterally to the anterior thigh to the obturator canal dividing into anterior and posterior branches. The anterior portion is located between the pectineus and adductor brevis muscles, and varies greatly in the extent of its sensory innervation to the medial thigh and hip joint. The posterior branch lies within the fascial planes of the adductor brevis and longus muscles and primarily provides motor functions to the thigh adductors. However, the posterior branch may also provide articular branches of the medial aspect of the knee joint. With the diffuse variability in the cutaneous innervation to the medial thigh, the best method to evaluate the success of the block is demonstrated by weakness or absence of adductor muscle strength, rather than decreased skin sensation. Despite a successfully placed injection, the innervation from the femoral nerve and sciatic nerve to the adductor muscles may inhibit complete loss of adductor muscle strength [8].

For ultrasound-guided distal approach, with ASA standard monitors, place the patient supine with the thigh slightly abducted and externally rotated. Using a linear or curved transducer (depending on patient body habitus), begin with a transverse orientation on the inguinal (femoral) crease, over the femoral artery. If the femoral artery is not seen, consider utilizing color Doppler or adjusting depth (4–6 cm). Upon visualizing the artery, slide the transducer medially to visualize the three adductor muscles: adductor longus, brevis and magnus. Between the adductor longus/brevis, the anterior branch of the obturator nerve can be visualized in the fascial plane. From here, advance a block needle after a heme-negative aspiration, into the fascial plane between the adductor brevis and magnus for the posterior branch [8]. Even if the nerve itself is frequently not directly visualized, it is appropriate to inject the local anesthetic as long as the fascial plane between the two muscles is identified. Local anesthetic spread into the interfascial plane will ensure that the innervation surrounding the anterior and posterior portion of the obturator nerve is well anesthetized. There are multiple ultrasound-guided proximal approaches of obturator nerve block being described where the obturator nerve can be blocked before it bifurcates into the anterior and posterior branches, between the pectineus muscle and the obturator externus muscle [8].

Summary With ultrasound guidance, the ONB has regained popularity due to higher success rates and minimum, if any, lower extremity weakness/risk of fall. It is particularly useful when used in conjunction with femoral and sciatic nerve blocks, which significantly improve patient comfort and reduce opioid consumption. In addition, the use of ultrasound has improved the efficacy and consistency of this block while making the procedure itself easier. This is an intermediate to high level of peripheral nerve block.

Lateral Femoral Cutaneous Nerve Block

History Painful mononeuropathy in the distribution of Lateral Femoral Cutaneous Nerve (LFCN) led to the meralgia paresthetica association with the compression of the LFCN, which was first described by Hager in 1885. The naming of this nerve entrapment occurred later by Roth in 1895, which would be called Bernhardt-Roth syndrome. With the clinical description of LFCN entrapment, the ability to specifically address this pathology led to the development of this block. Anesthetic nerve blocks as a nonsurgical intervention for this pathology encouraged people including Hopkins in 1991 to evaluate the efficacy of the block as a standard technique [15]. Although not for postsurgical use, individuals such as Kim also provided some valuable information about the specific blockage of the LFCN along with Lang in 1995 [16]. With the advancements in ultrasound, the understanding and appreciation of this block has only substantially increased its use in modern anesthesia.

Indications Meralgia paresthetica, postoperative analgesia for hip surgery, regional blocking for skin grafts/muscle biopsy of the proximal lateral thigh, supplemental block for anterior cruciate ligament repair, or tourniquet pain control when used together with femoral, sciatic, and obturator nerve blocks. This regional block has always been utilized as a diagnostic tool to differentiate between spinal radiculopathy with local LFCN entrapment.

Outcomes Prior to the utilization of ultrasound, landmark-based injections were extremely unreliable. However, the incorporation of ultrasound-guided blocks has consistently demonstrated appropriate perineural spread of local anesthetic, and thus ensured the efficacy and consistency of the injection [17]. Though varied in its use, it has remained consistent in acting as a component in a multimodal regional block group. It has merits as a stand-alone anesthetic in skin grafting as demonstrated by Shteynberg et al. in 2013 [17]. Complications of this procedure are similar to most others including bruising, infection, hematoma, and reaction to injectates. Paresthesias and numbness have been noted but are rare.

Anatomy and Techniques LFCN is a small subcutaneous nerve providing sensory innervation to the lateral thigh. Anatomically, it sits between the fascia lata and fascia iliaca. It is derived from the dorsal divisions of L2-L3 that comes out at the lateral border of the psoas muscle and moves inferior laterally toward ASIS. The nerve passes below the inguinal ligament but over the sartorius muscle, dividing into anterior and posterior branches into the thigh with a width of approximately 3 mm. The course of the nerve is variable but it is helpful to locate the LFCN distally than trace it proximally toward the ASIS. On ultrasound visualization, it will appear as a hyperechoic nerve structure in the proximal thigh within a fat-filled hypoechoic space.

The patient is placed supine with the leg extended in a neutral position. Clean site and prepare patient after supplemental oxygen, and standard ASA monitors are placed: place a U/S transducer inferior to the ASIS, parallel to the inguinal ligament. Identify the tensor fascia lata and sartorius muscle with the nerve appearing as a hyperechoic structure between the two structures. Insert needle in a lateral to medial orientation through the subcutaneous tissue in plane: passing through the tensor fascia lata and sartorius muscle, the provider may feel a popping sensation as the needle goes through the fascia. Inject a small volume of 1–2 cc of LA to verify the tip of needle position. Hydro-dissection with normal saline in the plane below the fascia lata may allow improved visibility of the LFCN. Upon verifying correct location of needle, spread of the local anesthetic in the plane should demonstrate correct position. Similar to most regional blocks, the blockade of the sensory innervation of lateral thigh does not depend on deposition of local anesthesia: it is the spreading through the fascial plane that leads to successful anesthesia.

Summary Lateral femoral cutaneous nerve block is a superficial fascia layer block that could be categorized as an entry-level block that is easy to perform. It is associated with low risks and supplements many other regional blockades such as femoral, obturator, and sciatic nerve blocks to provide improved analgesia, especially when the incision is on the lateral thigh.

Quadratus Lumborum

History Quadratus lumborum (QL) block was originally introduced during a presentation by Dr. Rafael Blanco in 2007 at the European Society of Regional Anesthesia, in which the QL block was described as a variant to the classic transverse abdominis plane (TAP) block. In the spring of 2013, Dr. Borglum from Copenhagen officially published a detailed description of this block technique coining the "Shamrock sign" term, which described the end point of needle insertion for local anesthetic injection. Since then, there has been continued interest in the use of truncal blocks and evaluation of its efficacy in the field of anesthesia perioperative pain management. The QL block was found to create a wider sensory blockage relative to TAP blocks when using similar volumes of local anesthetic (T6–L1 for QL blocks vs T10–T12 for the classic TAP blocks), with the potential of visceral pain control in addition to somatic pain control. Given the distribution of the innervation, the block could also involve the lateral cutaneous branches of the thoracoabdominal nerves (T6–L1).

Indications It has been used in almost all upper and lower abdominal procedures. such as exploratory laparotomy, large bowel resection, ileostomy, open/laparoscopic appendectomy, cholecystectomy, cesarean section, total abdominal hysterectomy, open prostatectomy, renal transplant surgery, and nephrectomy, abdominoplasty, and iliac crest bone graft. Recently, there has been an interest of using this block in hip procedures [18–21].

Outcomes The mechanism of action for quadratus lumborum muscle (QLM) blocks is focused in the thoracolumbar fascia (TLF), which is a complex connective tissue structure made by aponeuroses and fascia layer that envelope the back muscles and connect the anterolateral wall with the lumbar paravertebral region. Given the intricate nature of this anatomy, the true mechanism of analgesia has yet to be fully clarified. However, there have been continued efforts in research supporting the value of this method. Blanco et al. undertook a randomized controlled trial of QL blocks that demonstrated when used in a multimodal regimen (no use of intrathecal catheters), patients undergoing elective c sections had substantially reduced opioid requirements and pain scores [22]. Murouchi et al. developed a prospective cohort for laparoscopic gynecological surgeries with QL blocks versus TAP blocks. It was found that patients with QL blocks had sensory anesthesia from T8–L1 compared with the TAP group having anesthesia from T10–L1: the former group of patients also took longer to request rescue analgesics. The findings from this particular study demonstrate that QL blocks may have utility beyond truncal anesthesia. As the transversalis fascia overlying the QLM extends caudally over the psoas major, iliacus, as well as the lumbar plexus, QL blocks may show to have use for hip surgeries. On the other hand, its extending effects should raise concerns about unanticipated quadriceps weakness and consequently falls when giving QL blocks for abdominal surgery. Literature on QL blocks as a stand-alone intervention remains sparse but the collection of data has continued to grow to evaluate its efficacy into general practice in anesthesia. An isolated QL block cannot generate surgical anesthesia or complete analgesia. As such, studies about the efficacy of this block can be challenged given its use as a supplemental addition to other regional blocks. Moreover, variable volumes of LA in regard to each QL block have been utilized in which in some studies, more than 20 cc of LA at one site was required [23]. The lower pole of the kidney lies anterior to the QL muscle and is separated only by peripheral fat and posterior renal fascia, and anterior thoracolumbar fascia, in which great caution must be utilized during this injection. In addition, there are four lumbar arteries that arise from the aorta that course posterior to the psoas muscle which should be avoided during insertion of the LA needle.

Anatomy and Techniques The quadratus lumborum is a muscle of the posterior abdominal wall dorsal to the iliopsoas muscle. It originates from the medial half of the iliac crest and inserts into the lower medial portion of the 12th rib. The muscle has four additional tendinous insertions to the top portions of the transverse processes of the upper four lumbar vertebrae. The ventral rami of the spinal nerve roots travel between the QLM and its anterior fascia. The QLM, with the tough thoracolumbar fascia that surrounds it, is considered the anatomical bridge between the anterolateral muscles of the abdominal wall and the lumbar paravertebral region.

Place the patient in a lateral decubitus position, with hip abducted and laterally flexed toward the same side of the block (contract the QL muscle). The angle from this position provides more exposure to neuraxial structures and encourages stability in handling the ultrasound probe and needle. A curved ultrasound transducer is utilized to visualize the three lateral abdominal muscle layers, the QLM, and adjoining anatomy. Begin scanning at the mid-axillary line between the iliac crest and subcostal margin moving posteriorly until all three abdominal muscle layers and QL muscle are visualized. The fascia transversalis can be seen during an initial scan, appearing as a hyperechoic layer: this marker acts as a safeguard as it separates the muscle from perinephric fat and abdominal contents. Scanning can also be performed posteriorly at the L3–L4 level approximately 4–5 cm to the lumbar spinous process or higher while a patient is in a lateral decubitus or prone position. At this level, the QLM with the transverse process of lumbar vertebrae, erector spinae muscle, and psoas major muscle can be identified: coined as the Shamrock sign described by Borglumet al. The L4 vertebra transverse process is viewed as the stem, with the erector spinae muscles as the posterior leaf, the psoas muscle as the anterior leaf, and the QLM as the lateral leaf [24•].

Needle Component The location of the QLM allows for several different approaches to needle insertion, all which have found to yield similar results. There are currently four different types that are performed.

1. QL1: Lateral approach: This primary method is actually identical to the fascia transversalis plane block. Using a linear transducer, scan the mid-axillary line until the posterior aponeurosis of the transverses abdominis muscle becomes visible. The needle track (lateral to medial direction) should aim to reach just deep to the aponeurosis but superficial to the fascia transversalis at the lateral margin of the QL muscle. The LA is injected between the aponeurosis and the fascia transversalis at the lateral margin showing a visible spread through the anterior (ventral surface of the QLM). The anesthetic should affect the lateral cutaneous branches of the iliohypogastric, ilioinguinal, and subcostal nerves [25].
2. QL2: The positioning of the needle is aimed to inject into the posterior (dorsal) surface of the QLM in the space between the QLM and medial lamina of thoracolumbar fascia that separates it from the latissimus dorsi and paraspinal muscles. The approach is similar (lateral to medial) through the oblique muscles with a shallower trajectory. Once between, the local anesthetic can be deposited out the anterior layer of the thoracolumbar fascia while remaining superficial to the fascia transversalis: the local anesthetic should be seen pooling along the posterior aspect of the QLM.
3. QL3: Described by Borglumet et al., also known as the transmuscular QL block. The QLM is defined by its borders of the psoas major with attachment to the transverse process at the L4 vertebra. From a posterior to anterior direction, the needle should move through the QLM until the tip reaches the plane between the anterior surface of the QLM and psoas major. Upon injection of the LA, there will be evident spread. The use of the Shamrock sign is utilized as a landmark for this method.
4. QL4: refers to the injection of the local anesthetic directly into the QLM itself.

Summary QL blocks, as fascia layer blocks, have been increasingly accepted and utilized in truncal procedures, with potential extension into hip surgeries. QL blocks provide mostly somatic pain control with minor visceral pain control when paravertebral spread occurs. It is an intermediate to high level of block that requires a relatively higher level of ultrasound technique and a good understanding of sono-anatomy. Ultimately, spread of the local anesthetic to any area between the fascia and the muscle results in a successful block [23]. The risk of intrafascicular spread may be increased when placing anterior and lateral QL blocks given that the nerves are located anterior to the QLM where the needle is placed. The use of a pressure monitor may help avoid this complication. The oblique approach is thought to prevent accidental needle entry into the peritoneum, as the psoas muscle may provide a protective barrier [25]. Over the past decade, this technique has evolved significantly, even though there remains great controversy regarding the best approach for block placement. Some studies suggest that different approaches provide varying analgesic profiles. The anterior approach covers T10 to L4, with the subcostal variant covering T6–T7 to L1–L2 [26], the posterior and lateral approaches cover T7 to L1 [22], and the intramuscular approach covers T7 to T12 [27]. Ultimately, the specific approach of any QL block should be tailored to the given surgical procedure and the expected pain profile.

Paravertebral Block

History The concept of paravertebral block (PVB) was brought up by Hugo Sellheim of Germany in 1905, modified by Lawen (1911) and Kappis (1919), and popularized by Eason and Wyatt in the late 1970s when a renewed interest developed [28]. There are many names associated with this block based on the segment of the spine that the block is to be placed, such as "cervical paravertebral" vs. "posterior approach" in cervical region, "psoas compartment" vs. "lumbar plexus block" vs. "lumbar paravertebral block" in the lumbar region. Nonetheless, in general, all paravertebral blocks are performed on the level of the nerve/plexus roots, which are covered by the dura mater, and all can be performed with a similar technique, provide similar features in terms of analgesia effects, and are associated with similar adverse events and potential complications [29].

Indications Cervical paravertebral block can be used in shoulder procedures; thoracic paravertebral block can be used in most truncal procedures such as thoracotomy, rib fractures, nephrectomy, hepatectomy, cholecystectomy, Whipple procedure, gastrectomy, and G-tube placement; lumbar paravertebral block can be used for lower abdominal procedures such as inguinal hernia repair and in lower extremity procedures such as hip and knee surgeries.

Outcomes The spinal nerve root leaves the intervertebral foramen and divides into dorsal and ventral rami. The sympathetic chain lies in the same fascia plane but anterior to the intercostal nerve, and also communicates with it via the rami communicates. Therefore, in theory and in practice, paravertebral block has the capacity to produce unilateral sensory, motor, and variable sympathetic blockade. The paravertebral space is a triangular anatomical section just lateral to the vertebral bodies. This triangle is composed of the parietal pleura anterolaterally, superior costotransverse ligament posteriorly, vertebral body and intervertebral foramina medially, and rib heads superiorly and inferiorly. Thoracic paravertebral blocks (TPVBs) are the best known and most commonly used among all paravertebral blocks, likely due to the reliable and wide longitudinal spread along rib heads [30, 31]. TPVBs may be used for anesthesia or analgesia in thoracic procedures, chest wall, and upper abdominal surgeries such as those requiring sternotomy, breast surgery, and major upper abdominal surgery, as well as for analgesia in the setting of rib fracture, thoracic neuralgia, G-tube placement, and regional pain syndromes. The use of PVBs for breast surgery has been shown to lower pain scores and reduce nausea and vomiting for up to 48 h when compared with general anesthesia alone [32]. Other advantages of PVBs may include shorter hospital stays, decreased development of chronic pain, and reduced breast cancer recurrence rates when performed in conjunction with general anesthesia [32]. Like epidurals, PVBs cover all branches (posterior, lateral, and anterior) of the intercostal nerves. As PVBs may be thought of as a nerve block of the ipsilateral spinal nerve, this technique may involve a single level, or several levels, along the spinous processes, and may also be performed as single-shot injections or as a continuous catheter technique. Multiple studies have shown that paravertebral block provides comparable analgesia as epidural analgesia, with similar length of hospital study and similar or less adverse events [33, 34].

Anatomy and Techniques The block involves injection of local anesthetic into the paravertebral space, which is bordered by the transverse process (identified about 2.5 cm lateral to the spinous process in most adult patients), the parietal pleura, and the costotransverse ligament. This triangle contains thoracic spinal nerves and the sympathetic trunk. This space also communicates with the epidural space, which can lead to a bilateral block in some cases [35].

Using an ultrasound-guided technique, the paravertebral space is located and local anesthetic is injected using a blunt-tipped needle advanced from lateral to medial (when using a transverse scan) or superior to inferior or inferior to superior (when using a sagittal scan). In TPVB, the pleura is frequently seen moving during local anesthetic injection, which is a positive sign for a successful block. This block can also be placed using a landmark technique by marking the tips of the target spinous processes. An 18-G graduated epidural needle is inserted in a caudal to cranial direction about 2.5 cm lateral to the target spinous process until making direct contact with the corresponding transverse process. The needle is then "walked off" of the transverse process downwardly until a "change in resistance" is felt, indicating that the needle has passed beyond the costotransverse ligament, typically about 1 cm beyond the transverse process. If a full "loss of resistance" is felt, it is likely that the needle has entered the pleural space [32]. A drop of fluid can be placed at the needle hub. If the needle has punctured the pleura, the drop of fluid will be sucked in by the negative intrapleural pressure. With either ultrasound guidance or blind technique, if the needle tip is successfully placed in the paravertebral space, local anesthetic will spread over the parietal pleura or the anterior border, indicating correct placement. It is possible for the local anesthetic to spread for a few level within the paravertebral space, generally speaking 5–8 levels in the thoracic area [30, 31]. Therefore, surgical site/target pathology must be taken into account with determining where/which levels to place the PVBs.

Coagulation status must be taken into account before placing a PVB due to the inability to provide direct pressure. Given the location of the injection into the paravertebral space, which is similar to an intercostal nerve injection, there is an increased risk of local anesthetic uptake into the systemic circulation, so some recommend lesser concentrations (0.5% equivalent or less) of local anesthetic. Other side effects or risks include a failed block (6–12%), epidural spread, brachial plexus spread, hematoma, hypotension, and vascular puncture [30, 31]. The most feared adverse events such as pleural puncture (less than 1%) and pneumothorax (less than 0.5%) are rare in experienced hands [32, 36].

Summary Paravertebral blocks are a group of versatile blocks that can be placed at all levels of the spine for acute and chronic pain management, widely utilized in operating rooms, ICU, and office procedures. Perioperatively, they are mostly used as a less invasive alternative to neuraxial analgesia that provides similar analgesia, less modality-related adverse events, and better hemodynamic stability. The most severe complications such as pneumothorax are rare.

Pectoralis Blocks and Serratus Plane Block

History Pectoralis (Pecs) blocks and serratus plane block are newly developed fascia plane blocks as alternatives or supplements to thoracic epidural, paravertebral block, intercostal block, and interpleural block, for unilateral or bilateral hemithorax analgesia. The growth of these blocks is largely due to the direct visualization of muscles under ultrasound guidance. Pecs blocks include two blocks, Pecs I and Pecs II blocks. Pecs I was originally introduced by Blanco in 2011 in breast surgery [37]. Pecs I block is used to target lateral and medial pectoral nerves located between pectoralis major and minor muscles, in addition to the lateral branches of the intercostal nerves that exit at the level of T2–T4. Pecs II block introduced by Blanco in 2012 [38] covers the long thoracic nerve in addition to the lateral branches of the intercostal nerves that exit at the level of the mid-axillary line to innervate the mammary gland, axilla, and skin from T2 to T6. Blanco subsequently introduced the serratus plane block in 2013 [39], another novel thoracic chest wall analgesia technique. This is used to block the thoracodorsal nerve between the serratus anterior and latissimus dorsi muscles.

Indications Pecs I block is for surgeries limited to pectoralis muscles, and main indications are breast expanders and subpectoral prosthesis where the distension of these muscles is extremely painful. Pecs II block is used for surgeries of the serratus anterior and axilla, such as radical mastectomy with axillary lymph node dissection, auxiliary blocks to brachial plexus block to medial arm for procedures such as arteriovenous fistula creation, and medial elbow surgery. Serratus plane block is indicated in the latissimus dorsi flap procedure. In summary, Pecs blocks and serratus plane are essentially fascial plane blocks intended to provide dermatomal analgesia to the chest wall in the setting of breast surgeries [37, 38, 40, 41], such as breast augmentations, expanders, chest wall tumor resections, mastectomies, sentinel node dissections, and axillary clearances. In addition, Pecs blocks and serratus plane blocks have been reported to provide effective analgesia in thoracotomies [42, 43] and rib fractures [44], and have been used as supplemental techniques to brachial plexus such as proximal medial upper arm [45] and posterior shoulder [46], which are not innervated by the brachial plexus blockade.

Outcomes Pecs blocks and serratus plane block may provide a good alternative to classic postoperative pain control modalities in the chest, such as thoracic epidural and TPVBs, by providing comparable somatic pain control and less severe complications [33, 34, 47]. Pecs blocks may eliminate the risk of midline spread and resultant better hemodynamic stability, which are inherent concerns with thoracic epidurals and TPVBs [40].

A randomized controlled study was performed in 40 radical mastectomy patients, comparing Pecs II blocks with thoracic paravertebral block, which showed Pecs II block group has longer duration of analgesia as compared with the TPVB group, mean (SD), 294.5 (52.76) vs 197.5 (31.35) min in the Pecs II and TPVB groups, respectively, $P < 0.0001$. The 24-h morphine consumption was lower in the Pecs II group as compared with that in TPVB group, mean (SD), 3.90 (0.79) vs 5.30 (0.98) mg in Pecs II vs TPVB groups, respectively, $P < 0.0001$ [48].

In another randomized controlled study of 64 unilateral radical mastectomies with axillary evacuation patients, comparing serratus plane block with thoracic paravertebral block. The median (interquartile range) postoperative 24-h morphine consumption was significantly increased in the serratus plane block group in comparison with that in the thoracic paravertebral group, 20 mg (16–23 mg) vs 12 mg (10–14 mg) ($P < 0.001$). The median postoperative time to first analgesic request was significantly shorter in the serratus plane block group compared with that in the paravertebral group, 6 h [5–7 h] vs 11 h [9–13 h]) ($P < 0.001$). The duration was also longer in the thoracic paravertebral group [49].

In general, these novel chest wall blocks have been associated with decreased opioid consumption and increased patient satisfaction in the postoperative period [40, 41]. They have been used in unilateral or bilateral surgery for upper thoracic procedures. Bilateral blocks and catheter insertions with continuous infusion have been used.

Anatomy and Techniques The chest and axilla are divided into several compartments by fascia where nerve bundle travels within. The novel chest wall blocks are designed to deliver local anesthetics to dedicated fascia plane and to anesthetize the corresponding nerves. To perform the Pecs I block under ultrasound guidance, the patient is placed supine and arm abducted 90°. The ultrasound probe is placed inferior to the clavicle at the deltopectoral groove. After identification of pectoralis major and minor muscles, the needle can be directed in a cephalad to caudad and medial to lateral trajectory. Use hydro-dissection and deposit 10–20 ml local anesthetics in the fascia plane between pectoralis major and minor muscles after the needle tip position is verified. For a Pecs II block, the ultrasound probe continues to scan laterally and downwardly until the serratus muscle starts to be more visible on top of the rib, around the fourth rib level at the anterior axillary line. The local anesthetic can be either deposited between the rib and the serratus anterior muscle or between the pectoralis minor muscle and the serratus anterior muscle, 10–20 ml of local anesthetics is sufficient. There are two potential spaces created by the serratus anterior muscle, superficial and deep, which lie between the muscle and the intercostal nerves, and local anesthetic may be injected into either space; some preliminary studies suggest that injection into the superficial plane may be more effective [32, 39]. For serratus plane block, the probe continues to scan laterally and posteriorly toward the mid-axillary line until the latissimus dorsi muscle starts to appear. A total of 10–20 ml local anesthetics can be deposited in the fascia plane between the anterior serratus muscle and latissimus dorsi muscle. As in any fascia plane blocks, local anesthetic volume is favored over concentration (use a lower concentration such as 0.2–0.25%) when placing these blocks, as the higher volume injectate can better spread throughout the targeted fascial planes.

Summary Pecs blocks and serratus plane blocks are novel chest wall blocks that can be used as effective alternative analgesic techniques for chest wall procedures, which provide effective pain control and without hemodynamic instability seen in neuraxial or paravertebral blocks. On the other hand, unlike neuraxial blocks and paravertebral blocks, these chest wall fascia plane blocks offer no visceral pain control. Potential risks of Pecs blocks such as anesthesia of the long thoracic nerve, injury to the thoracodorsal and long thoracic nerves, vascular injuries, local anesthetic systemic toxicity (LAST), pleural puncture, and pneumothorax are nonetheless rare. In summary, the advantages of these chest wall fascia plane blocks are multifold; it can cover the area that is not covered by thoracic paravertebrals such as lateral pectoralis nerve (C5–C7), medial pectoralis nerve (C8–T1), long thoracic nerve (C5–C7), and thoracodorsal nerve (C6–C8), and it can block the area that is not anesthetized by the brachial plexus such as the medial part of the arm (T1/2) and posterior part of the shoulder (T1/2). In addition, these blocks are relatively superficial in location, easy and safe to perform, and potentially have less stringent requirement on coagulation status.

Rapidly Evolving Novel Blocks

Erector Spinae Block

History The erector spinae plane (ESP) block was first described in 2016 as yet another fascia plane technique for acute and chronic thoracic pain, thanks to the wide adoption of ultrasound technology [50, 51]. It has subsequently emerged as a safe analgesic regional technique with diverse applications from acute to chronic pain, from head/neck to lower extremity procedures [52].

Indications ESP is still at its early stage of development; effect analgesia has been reported in acute rib fractures, pain from metastatic disease of the ribs, malunion of multiple rib fractures, neuropathic conditions such as herpes zoster [50], thoracic lumbar and sacral spine surgery [53–55], scapula fracture, iliac crest bone graft donor site analgesia [56], breast surgery [57], lower extremity pain control [58], thoracotomy [59], abdominal procedure [60], renal transplant [61], tension headache [62], and parathyroidectomy [63].

Outcomes There are few controlled studies in ESP blocks. In a randomized controlled trial of 40 patients, ESP block has been compared with modified Pecs blocks in radical mastectomy. Postoperative tramadol consumption was 132.78± 22.44 mg vs 196± 27.03 mg in Pecs block and ESP groups, respectively, $p = 0.001$, and pain scores were comparable between groups [64]. Tsui et al. performed a pooled review of 242 cases in 2018 and found ESP was mostly used in multimodal analgesia regimen, with 34.7% cases reported sensory changes from ESPB and 34.7% of cases reported a reduction in opioid use. The only complication found was one incidence of pneumothorax. The author subsequently concluded that ESP block appears to be a safe and effective option for multiple type thoracic, abdominal, and extremity surgeries [65]. De Cassai et al. performed a qualitative review of 140 studies in 2019, including four randomized controlled trials. This investigation concluded that ESP provided effective analgesia with opioid reduction effects. A similar conclusion as that of Tsui et al. was reached that ESP block is here to stay in anesthesia; nonetheless, more controlled studies are needed to compare its safety, effectiveness, and efficacy with established analgesia modalities, such as epidural, paravertebral, quadratus lumborum, and Pecs blocks [52]. Reported complications include pneumothorax, phrenic palsy in thoracic ESP block [66], and epidural spread in the bilateral ESP block [67].

Anatomy and Techniques The ESP block is a paraspinal fascial plane block that involves anterior spread of local anesthetic to block the ventral and dorsal rami of the spinal nerves [50]. Local anesthetic is injected anterior to the erector spinae muscle in the plane created by the erector spinae muscle and the tips of the thoracic transverse processes. There is considerable spread in both the cranial and caudal directions from the single injection, which can be an advantage in the setting of several rib fractures [50].

To perform the block, the patient can be positioned in either a sitting, prone, or lateral decubitus position. The transverse process most central to the rib fractures, or targeted pathology, is identified as the target and the ultrasound probe is placed about 2.5 cm lateral to this process allowing for visualization of the adjacent transverse process, but not the ribs (too lateral) or the thoracic laminae (too medial). The needle is advanced in a caudal to cranial or cranial to caudal direction and local anesthetic is injected between the target transverse process and the erector spinae muscle. Correct placement is confirmed by observing linear local anesthetic spread lifting the erector spinae muscle off the transverse process.

A single-shot ESP block may only provide analgesia of limited duration and the placement of a catheter may offer prolonged pain control. This block has relatively few contraindications given that the site of injection is distant from the pleura, major blood vessels, and spinal cord. It may also be easier to perform than the epidural and paravertebral techniques.

It is controversial if transverse approach is better than paramedian sagittal [68].

Summary ESP is a newly emerging fascia plane block performed in the back with documented effectiveness and safety in analgesia when use in multimodal analgesia in a wide range of procedures, with potential in both acute and chronic pain management. Nonetheless, the mechanism is still unclear, and most of the published studies are case reports/case series, with just a few randomized controlled studies. The comparison of ESP with commonly used analgesia modalities in randomized controlled studies is needed.

Suprascapular Nerve Block

History The suprascapular nerve block (SSB) was first described in 1941 by Wertheim and has since been utilized as an analgesic technique for both acute and chronic shoulder pain [69]. While the interscalene brachial plexus block (ISB) has traditionally been the gold standard for postoperative analgesia following shoulder surgery, ISB is associated with hemidiaphragmatic paralysis (HDP) [70, 71] Although not usually harmful in healthy patients [72], HDP can be associated with dyspnea [73], secondary to compromise of respiratory function [72, 74] and is therefore not safe in patients with severe respiratory disease. The SSB is a diaphragm-sparing block resulting in 0% HDP [71, 75] and therefore has been proposed as a safer alternative in this patient population.

Indications SSB is indicated in both acute and chronic shoulder pain.

Outcomes Compared with placebo, SSB consistently provides superior pain relief in both acute and chronic shoulder pain. Specifically, SSB resulted in significantly decreased postoperative pain scores, opioid consumption, and length of hospital stay compared with placebo. Single-shot SSB has also resulted in better pain relief and greater functional improvement for at least 4 weeks as compared with placebo injections and with physical therapy for chronic shoulder pain [69]. When SSB is compared with other upper extremity blocks, results are more mixed. Some studies have shown that postoperative pain scores and opioid consumption do not significantly differ between ISB, SSB, and supraclavicular block (SCB) [74, 76, 77•]. However, SSB has often been shown to provide less adequate analgesia than ISB. Following shoulder surgery, ISB resulted in significantly longer duration of postoperative analgesia [78], lower pain scores with movement, and decreased postoperative opioid consumption compared with SSB [79].

The addition of an axillary block to SSB (SSAX) has been suggested for more complete analgesic coverage of the shoulder. In patients undergoing arthroscopic shoulder surgery, combined SSAX block resulted in significantly lower pain scores for 24 h postoperatively and improved patient satisfaction compared with SSB alone [80, 81] as well as significantly longer analgesia compared with ISB. However, ISB provided more effective analgesia and significantly less opioid consumption in the immediate postoperative period compared with SSAX block [73, 80].

Other combinations of nerve blocks have been investigated as well. Combined SSB and SCB resulted in no significant differences in postoperative pain scores or opioid consumption compared with ISB [75]. However, combined SSB and infraclavicular block (ICB) actually resulted in higher postoperative pain scores and opioid consumption compared with ISB [70].

Similarly, while some studies have also shown enhanced analgesia with SSB following thoracotomy [82], others have failed to find an analgesic benefit of SSB following thoracic surgery [69, 83]. Such mixed results may be due to varying contributions of musculoskeletal pain and referred diaphragmatic pain in thoracotomy patients.

Standard complications associated with peripheral nerve blocks are applicable to SSB, including bleeding, infection, local trauma, residual motor blockade, and intravascular injection. The most serious complication associated with SSB is pneumothorax from the posterior approach; the anesthetizing needle can traverse the suprascapular notch and puncture pleura [84], which can be minimized by vigilance regarding depth of needle insertion, proper patient positioning, and utilizing superior approach rather than posterior. There is also the possibility of IV local anesthetic injection, as the suprascapular artery and vein run in close proximity of the nerve [84]. Careful aspiration is essential prior to injection of LA to avoid systemic toxicity.

Many complications occur significantly less frequently with SSB compared with brachial plexus blocks. Specifically, Horner's syndrome, dyspnea, hoarseness, and motor impairment have been shown to have a significantly lower incidence with SSB compared with ISB [73, 74, 76, 77•] Similarly, combined SSAX block results in lower rates of dyspnea [73] and nausea [80] when compared with ISB.

Anatomy and Techniques The suprascapular nerve is a large peripheral nerve composed of both motor and sensory fibers. It accounts for sensory innervation to 70% of the shoulder joint and supplies the bulk of the posterior, medial, and superior regions, while the axillary nerve, a branch of the posterior cord, supplies the majority of the inferior, lateral, and anterior structures [85, 86]. The suprascapular nerve originates from the C5 and C6 nerve roots (with variable contribution from C4) and branches off the lateral aspect of the superior trunk of the brachial plexus. The nerve runs through the supraclavicular fossa (beneath the inferior belly of the omohyoid), courses posterolaterally toward the suprascapular notch, through which it enters the supraspinous fossa (under the superior transverse scapular ligament). In the vicinity of the suprascapular notch, the nerve emits branches, typically one motor to the supraspinatus and two sensory to various posterior, medial, and superior regions of the shoulder joint. The first sensory branch (superior articular) usually emerges near the superior transverse scapular ligament and the second (inferior articular) branches just proximal to the scapular neck [85, 87]. Finally, the suprascapular nerve winds around the greater scapular notch to terminate within the infraspinatus muscle [76, 86].

The SSB can be performed utilizing landmark guidance, image guidance (ultrasound, computed tomography, fluoroscopy), or a nerve stimulator [88]. Most recently, ultrasound guidance has been introduced into this block. In the landmark approach, two lines are drawn, one along the superior border of the scapular spine and the second parallel with the vertebral spine. The suprascapular notch is located 2 to 3 cm toward the middle of the upper/outer quadrant from where the two lines intersect. When a peripheral nerve stimulator is used, the suprascapular nerve is identified by the motor response of external shoulder rotation.

The classic (posterior) approach to SSB was first described by Wertheim and Rovenstine in 1941 and is typically performed with the patient sitting in an upright position. This approach involves targeting the nerve at the suprascapular notch where it enters the supraspinous fossa. In this location, the nerve is often difficult to visualize utilizing ultrasound due to its depth [86, 88], and difficulty in targeting the nerve can arise secondary to significant anatomic variation in the morphology of the suprascapular notch. Furthermore, sensory branches often separate from the main nerve stem before it enters the suprascapular notch [85, 87] and will not necessarily be anesthetized if the nerve is targeted at such a distal point. Utilizing a more proximal approach is potentially less technically challenging and ensures anesthesia of the nerve prior to off-takes of sensory branches [86].

An anterior, shallow approach within the supraclavicular fossa with direct ultrasound identification of the suprascapular nerve as it passes under the omohyoid muscle has been associated with better nerve visualization secondary to more superficial location and less anatomic variability [88]. However, anteriorly, the suprascapular nerve is in closer proximity to the brachial plexus and the pleura, potentially increasing the risk of inadvertent supraclavicular brachial plexus blockade and/or pneumothorax [88].

To avoid the risk of PTX and potential intravascular injection of LA, a superior approach to SSB has been described by some authors [89]. In this approach, the needle is introduced parallel to the blade of the scapula, directed toward the lateral half of the floor of the suprascapular fossa (away from the lung and suprascapular vessels) and LA is injected into the floor of the supraspinous fossa [89].

Summary SSB is an example of old blocks with new use and has been one of the major nerve blocks studied for shoulder surgery when diaphragm-sparing effect is paramount. SSB alone or in combination with axillary block, ICB, or SCB has repeatedly been demonstrated to result in similar patient satisfaction compared with ISB [70, 73–75, 77•, 80]. Given that SSB results in significantly lower postoperative pain compared with controls and does not compromise respiratory function, it has been suggested as a clinically appropriate substitute in patients for whom ISB is contraindicated, such as those with severe lung disease [79], opening the benefits of regional anesthesia to a wider patient population.

Axillary Nerve Block

History Interscalene brachial plexus block is a common technique used for postoperative pain relief after shoulder surgery. However, it can result in 100% incidence of ipsilateral phrenic nerve block resulting in a reduction of pulmonary function by 25% [73]. Though this can be transient, there have been cases of permanent phrenic nerve dysfunction and its use is contraindicated in patients with severe pulmonary insufficiency secondary to restrictive lung disease, chronic obstructive pulmonary disease, bronchial asthma, obesity, or contralateral phrenic nerve palsy [72]. Additionally, interscalene brachial plexus blocks can cause numbness and motor weakness of the ipsilateral arm due to blockade of the lower brachial plexus (C7–T1) resulting in patient discomfort. To avoid these significant adverse effects, targeted blocks of the axillary nerve and the suprascapular nerve have been tested as an alternative in shoulder surgery.

Indications Most commonly used together with suprascapular nerve block in a multimodal analgesia for shoulder surgery, especially when interscalene block is contraindicated, such as existing pulmonary pathology.

Outcomes In 2016, in a study by Dhir et al., analgesic efficiency of combined suprascapular and axillary nerve block was compared with interscalene brachial plexus block in 60 patients undergoing elective arthroscopic shoulder surgery [80]. Using ultrasound guidance and 15 ml of 0.5% ropivacaine for each block, they found that PACU pain scores and perioperative pain scores were superior with interscalene brachial plexus block, but 24-h pain scores were better with the combined suprascapular and axillary nerve block group. Though the suprascapular nerve (C5–C6) innervates roughly 60–70% of the shoulder joint and the axillary nerve (C5–C6) supplies approximately 30%, their conclusions note the possibility of nonblocked nerves that supply the anterior shoulder contributing to pain. These nonblocked nerves include the lateral pectoral nerve (C5–C6 levels), the subscapular nerve (C5–C6), and the musculocutaneous nerve (C5–C7) [80]. A similar study in 2018 completed by Neuts et al. [73] recruited 100 subjects utilizing the same suprascapular nerve technique by Harmon and Hearty [90] and the Rothe et al. [91] technique for the axillary nerve block with 10 mL of 0.75% ropivacaine. In their study, they concluded combined suprascapular and axillary nerve block resulted in inferior analgesia immediately post operatively when compared with the interscalene block. Additionally, pain scores and opioid consumption were similar between the two groups at 24 h. A study by Auyong et al. in 2017 compared continuous interscalene, continuous supraclavicular, and continuous suprascapular block effect on vital capacity, ultrasound-measured diaphragm excursion, and pain scores among 75 patients. Their conclusions found that continuous suprascapular block had less impact on vital capacity and diaphragm excursion and has less incidence of other adverse outcomes such as Horner's syndrome, dyspnea, and hoarseness, and there was no statistically significant difference of 24-h opioid consumption and mean pain scores between the three groups [74].

Anatomy and Techniques The axillary nerve (C5, C6) branches off the posterior cord of the brachial plexus and supplies motor innervation to the deltoid and teres minor and provides sensory innervation to the glenohumeral joint, and gives a superior lateral brachial cutaneous branch that provides sensation to the lateral aspect of the shoulder. It travels with the posterior circumflex humeral artery through the quadrangular space which is bordered superiorly by the teres minor, anteriorly by the subscapularis, inferiorly by the teres major, laterally by the neck of the humerus, and medially by the long head of the triceps. The most commonly used technique blocks the axillary nerve at the quadrangular space [91]. The ultrasound transducer is positioned posteriorly on the arm in a sagittal plane to the humeral head. The axillary nerve can be identified traversing the quadrangular space with the posterior circumflex artery and vein [92]. Recently, Chang described novel approaches to block the axillary nerve at the inferior axilla level and at the femoral neck [93, 94].

Summary Axillary nerve block is best used in a multimodal analgesia regimen together with suprascapular nerve blocks in chronic shoulder pain and post shoulder surgery, especially in patients where interscalene brachial plexus block is contraindicated.

Measures in Providing Safe Ambulatory Nerve Block

To ensure peripheral nerve blocks are effectively and safely provided to ambulatory patients, there are several key administrative steps that require the surgical center, surgeons, anesthesiologists, nurses, and patients to be on the same page. To avoid slowing down the turnover in a surgery center and to ensure a smooth work flow, the surgeon can speak to the patient during preoperative visit about the nerve block so that it will not be first time a patient hear about this on the day of surgery, which will speed up preoperative consenting process by the anesthesiologist. The surgeon should also communicate with the anesthesiologist ahead of time on the patient who will benefit block. On the day of the surgeon, block patients can be scheduled to come in earlier than nonblock patients to allow the anesthesiologist sufficient time to perform the nerve block before the surgery, which will provide pre-emptive analgesia, achieve opioid reduction, as well as speed up discharge. Incomplete block or failed block should be managed in recovery room and before discharge. The anesthesiologists should choose motor-sparing nerve blocks, as discussed above, whenever possible to minimize weakness and fall, and to maximize postoperative functional recovery. Upper extremity block patients should be offered with a sling to protect the insensate extremity. Lower extremity block patients can be offered knee immobilizers or crunches, whenever indicated if motor weakness is anticipated. Patient home situation needs to be satisfactory for same-day discharge as well, for example multiple stairs may not be ideal for patients with lower extremity weakness. Upon discharge, patients should be offered a discharge instruction including but not limited to a phone or pager number that can be reached 24/7 for any issues related to the surgery or anesthesia, such as rebound pain after block wears off, signs to watch out for local anesthetic systemic toxicity. All block patients should be followed up through phone calls the next day until sensory and motor are back to the baseline. If significant neurological deficits beyond expectation are found out during follow-up phones, patients should be instructed to return to surgeon's office (for non-urgent issues, such as motor weakness beyond expected duration), or emergency room (for urgent issues, such as concerns for compartment syndrome), or call 911 for emergency such as local anesthetic systemic toxicity. If a patient needs to be admitted to a hospital for uncontrolled pain after block wears off or other block-related issues, a patient can be admitted by the surgeon and the surgeon can subsequently consult an anesthesiology block team or acute pain service, whichever applicable for further management.

Conclusion

The use of ultrasound technologies in recent years has enabled the development of several novel nerve blocks and/or offered old nerve block techniques with improved effectiveness and efficacy. Among the diverse range of novel blocks spanning from the upper extremity, chest, abdomen, and to lower extremity, they all share several similar characteristics, such as motor-sparing, less severe adverse events, and easier to perform. These are the types of nerve blocks that can be easily adopted into ambulatory anesthesia practice to facilitate patient recovery and speed up discharge. Plans to offer nerve blocks to same-day discharge patients need to be well thought out and have all parties on board to ensure effective and safe delivery of this valuable mode of opioid-sparing analgesia and to maintain the productive workflow at ambulatory surgical centers.

Compliance with Ethical Standards

Conflict of Interest Jinlei Li, David Lam, Hanna King, Ellesse Credaroli, Emily Harmon, and Nalini Vadivelu declare no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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