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Truncal regional nerve blocks in clinical anesthesia practice

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Regional anesthetic techniques are important components of successful multimodal analgesic strategies. When used successfully, truncal nerve blocks of the chest wall, abdomen, and paraneuraxial nerves, in combination with other analgesic modalities, may offer similar analgesic efficacy as neuraxial techniques, which are associated with a greater risk profile. Moreover, in comparison to neuraxial techniques, truncal nerve blocks are relatively simple to perform and technically straightforward to learn. The transversus abdominus plane (TAP) block is often incorporated into the multimodal analgesia regimen for surgical patients undergoing

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various abdominal and gynecological procedures. Rectus sheath blocks (RSB) were originally introduced to help relax the anterior abdominal wall during surgery and as an adjunct pain therapy. With the advancement of technology and the development of ultrasound guided techniques, RSB now have a more ubiquitous role and have been shown to decrease postoperative pain and opioid consumption. Different variations of the quadratus lumborum block may provide visceral and sensory analgesic coverage. Moreover, truncal blocks, including ilioinguinal, iliohypogastric, pectoralis nerve (PECS) blocks, serratus anterior, intercostal, and erector spinae plane blocks, have gained routine clinical use for various surgeries. In this review, we discuss the techniques, anatomy, indications, complications, and benefits of truncal nerve blocks commonly used in clinical practice.

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Introduction

Regional anesthetic techniques are important components of successful multimodal analgesic strategies. Truncal nerve blocks of the chest wall, abdomen, and, paraneuraxial nerves have gained increased attention in recent years. Since its first use for guidance during a transversus abdominis plane (TAP) block, ultrasound has led to the development and clinical implementation of novel truncal nerve blocks, which include rectus sheath, ilioinguinal, iliohypogastric, and erector spinae plane blocks [1]. When using ultrasound to perform each of the truncal nerve block techniques, in contrast to peripheral nerve blocks, individual nerves or neural plexus do not need to be identified. Instead, ultrasound is employed to identify a target muscular plane into which local anesthetic is injected in such a way that the anesthetic spreads along the desired fascial plane to anesthetize traversing nerves [2]. When used successfully in combination with other analgesic modalities, truncal nerve blocks may offer similar analgesic efficacy as neuraxial techniques, which are associated with a greater risk profile [3]. Moreover, truncal nerve blocks are technically simple to perform and relatively straightforward to learn. Despite this, resultant sensory blockade may be variable related to differences in technique used, anatomical differences in traversing nerves, and differences in individual spread of injectate.

Since the initial description of the ultrasound-guided TAP block by Hebbard et al., a multitude of different truncal blocks has emerged [4]. The quadratus lumborum block (QLB), first described by Blanco et al., in 2007 and later modified by Sauter et al., in 2013, is the posterior variant of the TAP block performed exclusively under ultrasound guidance. Truncal blocks allow for broad coverage owing to interfascial spread [5]. TAP blocks, for instance, have utility in a multitude of abdominal procedures, including laparoscopic surgeries, caesarean sections, unilateral abdominal surgeries, and hernia repairs. The QLB expands upon the TAP block, providing more posterior and more caudal dermatomal coverage. This technique demonstrates utility in posterior abdominal surgeries, such as nephrectomies, in addition to the surgical procedures that indicate a TAP block. Several studies have shown efficacy in hip surgery, knee surgery, and lumbar spinal surgery, as well as some chronic pain cases. In this review, we discuss the techniques, anatomy, indications, complications, and benefits of truncal nerve blocks commonly used in clinical practice.

Types of truncal blocks

Blocks of the anterior abdominal wall

Transversus abdominis plane block

The TAP block is often incorporated into a multimodal analgesia regimen for surgical patients undergoing various abdominal and gynecological procedures. Examples include hernia repairs, total abdominal hysterectomy, colorectal surgery, appendectomy, and laparoscopic cholecystectomy. TAP blocks should also be considered in the obese patient population, as these blocks obviate the need for spinal or epidural anesthesia, as these procedures can be more technically challenging in this patient population and pose a higher risk [6]. Decreasing postoperative pain and opioid requirements is beneficial and often contributes to earlier ambulation and a shorter time to discharge from the hospital. TAP blocks can be performed in the preoperative period, intraoperatively or postoperatively. Jain et al. demonstrated that patients who received bilateral US-guided TAP block preoperatively before laparoscopic hernia repair had improved VAS pain scores, decreased use of rescue analgesics, improved time-to-ambulation, and a faster return of bowel sounds within 24 h postoperatively [7]. The efficacy of TAP blocks is further supported in a randomized, prospective double-blind study showing a statistically significant difference in time-to-ambulate and discharge readiness in the group that received TAP block bilaterally postoperatively after endoscopic abdominal wall hernia repair [8]. TAP blocks work particularly well in the first 24–48 h postoperatively. Patients receiving a bilateral TAP block status post total abdominal hysterectomy had reduced mean IV morphine requirements during the first 24 h postoperatively. Fewer opioid requirements resulted in less opioid-related complications, including respiratory depression and postoperative nausea and vomiting [9]. Despite the TAP block being very reliable, ubiquitous, and efficacious with pain control, there are cases where its use is limited or not indicated. TAP blocks should not be administered to patients with active or possible infection over the injection site. Other limitations include the need for a bilateral block for midline incisions and the absence of effectiveness for visceral pain [10].

The advent of ultrasound has improved reliability and minimized complications with TAP blocks. The anatomical landmark technique was first described by Rafi before ultrasound. Surface landmarks were used to determine needle insertion sites within the lumbar triangle of Petit. The “pop” sensation felt would serve as the endpoint for the correct needle depth [11]. Using the ultrasound-guided technique, a transversely oriented probe is applied to the anterolateral abdominal wall, and the TAP is identified between the internal oblique and transversus abdominis muscles. The probe is then moved posterolateral to lie across the midaxillary line just superior to the iliac crest over the triangle of Petit. The needle is introduced anteriorly and advanced in the plane. The layer should be visible upon injection of local anesthetic [12]. A surgeon-assisted approach is another feasible technique for TAP blocks. A laparoscopic-assisted technique was performed with the visualization of the injection area with an intra-abdominal laparoscopic camera [13]. This allows for direct visualization of the needle and helps prevent intraperitoneal injection. The TAP has a good safety profile; however, complications must still be acknowledged. Damage to the liver and bowel hematoma have been described, but with few reports in the literature [14,15]. Visceral damage can occur as well if the needle is advanced too far. Other potential complications include a transient femoral nerve palsy that may involve the sacral plexus due to the proximity of the TAP to the femoral nerve [16].

Rectus sheath block

Bilateral rectus sheath blocks (BRSB) were originally introduced to help relax the anterior abdominal wall during surgery and as an adjunct in the pain regimen. With the advancement of technology and the development of ultrasound-guided techniques, BRSB now have a more ubiquitous use and have been shown to decrease postoperative pain and opioid use. Classically, BRSB are indicated in surgeries requiring midline skin incisions, particularly those utilizing a vertical incision. Umbilical hernia repair, open gastrectomy, laparoscopic gynecological procedures, surgical oncology cases, and transplantation of the pancreas are all procedures where BRSB could be beneficial and should be considered. Certain procedures can require large abdominal incisions. Patients undergoing open gastrectomy for gastric cancer who received BRSB immediately after induction of general anesthesia had reduced remifentanil requirements during surgery and a statistically significant reduction in PCA boluses for pain control at 1 and 2 h postoperatively [17]. The intensity of pain contributes to a negative effect on the patient's immunity; therefore, it is imperative to utilize BRSB in this surgical patient population. BRSB utilizing catheters in combination with PCA were shown to be just as efficacious as thoracic epidural analgesia (TEA) in patients undergoing pancreatic transplantation. This included postoperative pain scores and length of hospital stay [18]. Another study comparing TEA and BRSB demonstrated increased time-to-mobilization for the group receiving TEA in patients who underwent a laparotomy for colorectal surgery [19]. BRSB serves as a safer alternative to TEA, given some of the complications associated with TEA including epidural hematoma, sympathectomy, and hypotension. Decreasing opioid consumption is critical in medicine given the opioid epidemic. The use of BRSB in patients undergoing ventral hernia repair decreased morphine consumption within 24 h post-operatively and reduced VAS pain scores [20]. This further supports the use of BRSB in the multimodal analgesia regimen.

One of the limitations of the BRSB is its inability to provide visceral analgesia. Another important consideration is for those patients with increased body habitus. The anesthetic being injected should be adjusted to the patient's BMI, as incorrect concentrations can lead to inadequate analgesia. The variable course and distribution of the thoracolumbar nerves is an additional challenge to performing the rectus sheath block. RSB can be used for surgical anesthesia; however, the spread of the anesthetic has its limitations. RSB was 53% effective for surgical anesthesia in patients undergoing umbilical hernia repair [21]. It has been demonstrated that poor correlation between the depth of the posterior sheath and the age, weight, and height in pediatric patients makes it difficult to gauge the depth of the rectus sheath when performing the block [22].

The aim of the technique when performing an RSB is to block the terminal branches of the 9th, 10th, and 11th intercostal nerves running between the internal oblique and transversus abdominis muscles and penetrate the posterior wall of the rectus abdominis. The blind technique using landmarks has been outdated by the newer ultrasound-guided technique. The probe should be placed in the transverse plane and positioned to visualize the posterior rectus sheath. There are both “in-plane” and “out-of-plane” approaches. The local anesthetic is then injected between the rectus abdominis muscle and the posterior rectus sheath. Lower local anesthetic doses achieving a RSB have been demonstrated using the ultrasound-guided compared to the blind technique [22]. There are various ways to perform the block. A laparoscopic rectus sheath block for colostomy using the transperitoneal approach was one of the first of its kind shown in a case report [23]. This further demonstrates the utility of the RSB. The RSB has a good safety profile, and with the advent of ultrasound, complications are minimal. Advancing the needle too far and piercing abdominal organs are a cause for concern. Systematic toxicity from the local anesthetic is another concern. A systematic review of concentrations of local anesthetic after TAP and RSB blocks supported the conclusion that these blocks are safe, despite detectable systemic concentrations in the blood [24]. Overall, rectus sheath blocks should continue to be utilized and studied for future literature.

Quadratus lumborum block

The quadratus lumborum block involves local anesthetic injection between the quadratus lumborum (QL) and the psoas major muscle (PMM) [5]. For extended duration of analgesia, a catheter can be used for a continuous infusion [5]. There are four different techniques described (QLB1, QLB2, QLB3, and QLB4), which involve injections on different aspects of QL [5]. QLB1 involves injection on the posterolateral side of QL in the area of contact with the transversalis fascia where TAM tapers off into the aponeurosis [5]. QLB2 is a posteromedial approach with injection between the posterior QL and the medial lamina of thoracolumbar fascia (TLF), which separates QL from latissimus dorsi and paraspinal muscles [5]. QLB3 is the anterior approach and involves application of local anesthetic in front of QL at the level of its attachment to the transverse process of L4 vertebra—this block involves witnessing of the “Shamrock sign,” with local anesthetic separating erector spinae muscle (ESM) posterior, PMM anterior, and QL lateral [5]. Lastly, QLB4 is an injection into the muscle itself [5]. The approaches are best visualized using ultrasound, and among the four, no superior approach has been determined [25].

Overall, QL blocks result in more expansive sensory blockage as opposed to a TAPs blockade (T10-L3 vs. T10-T12) [26]. Elsharkawy et al. demonstrated this finding in a cadaveric study on six fresh cadavers that were injected with India ink dye using the anterior approach [26]. The affected nerves include the femoral nerve, lateral femoral cutaneous nerve, ilioinguinal nerve, and iliohypogastric nerve while sparing the sacral nerve roots and all nerves below L5 [26]. The same group carried out a similar study examining the posterolateral and posteromedial approach and found that the posteromedial produces more cranial spread, similar to a low thoracic ESPB [27].

Indications for QL blocks are varied and include general surgical procedures such as exploratory laparotomy, bowel resection, cholecystectomy, cesarean section/hysterectomy, prostatectomy/renal surgery including transplant, and abdominoplasty. Numerous utilizations of the QL block have been demonstrated in recent years. Blanco et al. randomized 76 patients to receive a either a QL or a transversus abdominis block prior to undergoing cesarean delivery. Although pain control between the groups was similar, a significant number of patients in the QL group requested and used less morphine than the transversus abdominis block group at 12, 24, and 48 h post surgery (but not at 4 and 6 h) [28]. In a 50-patient study that looked at children undergoing unilateral hernia repair, Oksuz et al. found that QL blocks were statistically more effective at achieving a reduction of pain at seven time points in the first 24 postoperative hours (30 min, 1, 2, 4, 6, 12, and 24 h) [29]. In a 60-patient RCT, Dam et al. demonstrated that a QL block during percutaneous nephrolithotomy significantly decreases time-to-first-opioid-use, time-to-ambulation, and length of stay against a control group [30]. In a planned 120-patient RCT, Yuan et al. compared transmuscular QL blocks with thoracic paravertebral blocks in patients undergoing laproscopic nephrectomies; this study is still recruiting patients (NCT03414281) [31]. In a 50-patient triple-blinded study, Bjelland et al. found no statistical significance when using QL blocks for abdominoplasty and analyzing primary outcomes of morphine usage in the first 24 post-operative hours, postoperative pain, and postoperative nausea [32]. There is also a two-patient case series of total hip replacement as an indication that involved effective lumbar and sacral nerve plexus blocking [33]. A similar case report was published by Bak et al. (Bak et al., 2019). Another potential for expansion is noted by Oh and Kwon who use a QL block during radiofrequency ablation of varicose veins due to its advantages over deeper lumbar plexus block [35].

Despite benefits, several limitations of the QL block have been reported. Even for a well-trained provider, QL blocks take longer to administer than subcostal TAP blocks. In a study comparing QL and TAP blocks, Baytar et al. found that pain reduction prior to laparoscopic cholecystectomy was similar in a group of 54 patients that received a QL block versus a group of 53 patients who received a TAP block [36]. This result suggests that in certain circumstances, procedure may govern the necessity for expanded blockade. These findings were similar to those of a study by Fujimoto et al. in which 60 patients, who had received major gynecological laparoscopic surgery, were randomized to QL block and control groups [37]. No statistical significance was observed in postoperative fentanyl doses or pain ratings [37].

Related to the anatomical location of the block, the complications are fewer than those of a deeper block; however, the possibility remains for over-insertion that could puncture the kidney and cause acute kidney injury. Furthermore, given the proximity to the peritoneal space, puncturing the colon is also a possibility. There are four lumbar arteries that run posteriorly to psoas major that could also be potentially knicked causing an internal hemorrhage. Although possible, the risks presented by this procedure are minimal, assuming proper training [25]. Dirzu et al. reported a case study of a Romanian patient who received a continuous QL block for postoperative pain control following proximal femur surgery and experienced urinary retention that continued for the entire 72 h of infusion. This episode of urinary retention resolved with cessation of analgesic infusion [38].

Ilioinguinal nerve and iliohypogastric nerve (Hernia) blocks

The ilioinguinal nerve (IIN) and iliohypogastric nerve (IHN) arise from the L_1 nerve and emerge from the upper part of the lateral border of PMM [39]. IIN is the smaller nerve and travels caudally to IHN [39]. The lateral cutaneous branch of IHN can pierce the internal and external OM just superior to the iliac crest. Hence, these blocks should be performed as proximally as possible to avoid sparing of these cutaneous branches [39]. The anesthetic is placed in the same plane as the TAP block [40,41]. Although, an ultrasound assists accuracy and precision greatly, the lack of an ultrasound machine should not be a singular deterring factor as the optimal injection point is consistently around 2.5 mm from the ASIS on the line between the ASIS and umbilicus [40,41].

Ilioinguinal and iliohypogastric nerve blocks have been reported to be effective for analgesia following inguinal hernia repair and elective caesarean section. Gu et al. performed an RCT on 62 patients with aged cervical cancer that administered a perioperative block or a placebo and found a significant decline in propofol and sufentanil requirement during the procedure, postoperative VAS score, and time until first dose/total amount of doses of postoperative painkillers. Staker et al. randomized 100 pregnant women to receive a combination ilioinguinal-transversus abdominis block or a sham block at the conclusion of surgery [42]. They demonstrated statistically significant decreases in fentanyl administration and pain scale scores [42]. Kamal et al. randomized 60 patients undergoing inguinal hernia surgery between US-guided TAP or US-guided IIN/IHN blocks and demonstrated a statistically significant decrease in the analgesic requirement of the IIN/IHN groups as measured by first analgesic request and total tramadol requirement [43]. A study with the same organization was set up by Frassanito et al. that enrolled 80 patients and also found decreased need for extra local anesthetic and lower postoperative VAS scores [44].

Unfortunately, the failure rate of this nerve block has been reported anywhere from 10% to 25% mostly due to a suboptimal injection site; this has been greatly improved with ultrasound-guided injections [41]. In 2015, Khedekar et al. performed a trial with 60 patients scheduled for inguinal hernia repair and randomized them to receive an ultrasound-guided or conventional anatomically based block; there was a statistical significance in time-to-onset of motor block and time-to-rescue analgesia, while also requiring a decreased total drug load [45].

While effective, IIN/IHN blocks were found to be inferior to ESPB blocks for children undergoing inguinal surgeries in a 60-patient randomized trial performed by El-Emam and El-Motlb looking at first analgesic request and rescue analgesics [46].

Multiple case studies have been presented showing both transient and prolonged femoral nerve palsies most likely secondary to improper injection site [48,49]. Other side effects include nausea, dizziness, and a bitter taste in the mouth [50]. There is a rare potential complication of arterial thrombosis that was reported in the original approach and was seen again by Klos et al. during an acetabular repair [51]. Due to the approach, some vasculature is required to be subject to compression and traction [51]. Given this information, the patient should be monitored carefully postoperatively [51].

Blocks of the chest wall

Pectoralis nerve (PECS) block

The surgical indications for which the pectoralis (PECS) block may be effective can be attributed to the sensory distribution of the pectoral nerves. Innervation of the pectoral muscles is primarily from brachial plexus that branches to the lateral pectoral nerve (LPN) and medial pectoral nerve (MPN). LPN comes from the lateral cord of the brachial plexus and the roots of T_{5-7} cervical nerves and is distributed along the deep surface of pectoralis major muscle (PMm) and innervates the clavicular head. It provides sensory information to the acromioclavicular joint, subacromial bursa, periosteum of the clavicle, anterior articular capsule of shoulder, and costoclavicular ligaments [4]. MPN comes from the medial cord of the brachial plexus and from roots C_8 and T_1 and runs along the deep surface of the pectoralis minor muscle (Pmm). Two to three MPN branches pierce the PMm and end in the muscle, innervating the costal head. It provides sensory innervation to the inferolateral part of PMm, as well as partial innervation of the ventral arm and chest wall near the axilla [4]. The PECS-1 block is an interfascial block between PMm and Pmm, which aims to block both LPN and MPN [52]. PECS-2 block aims between the lateral edge of Pmm and the serratus muscle at the level of the third rib [3,4,53]. PECS-zero, a modified clavipectoral fascial plane block, has been proposed for patients who have pectoral muscle damage in the interfacial area most likely secondary to a lymph node dissection; it will act as a PECS-2 block in patients that have limited response to the PECS-2 approach [54].

Various roles of the PECS blocks have been demonstrated in recent years. Karaca et al. performed a randomized trial of 51 patients and concluded that the PECS 1 and 2 blocks were superior and shortened the patient's hospital stay after breast augmentation [55]. Ekinci et al. showed that PECS-1 provided effective analgesia after breast augmentation surgery [56]. O'Scanill et al. showed that an even more effective regimen was the combination of a pre-incisional PECS block and postoperative local anesthetic infusion than either alone [57].

Zhao et al. performed a meta-analysis on PECS for radical mastectomies that involved 8 RCTs and 2 cohorts for a total of 993 patients and recommended that PECS-2 is an effective anesthetic for modified radical mastectomies to reduce intra- and postoperative opioids while also alleviating early post-surgical pain [58]. Versyck et al. performed a similar meta-analysis and arrived at the same conclusion [59]. Combination PECS-1/2 block has been used as a complete replacement for general anesthesia in the case of some radical mastectomies and is useful due to its lessened adverse respiratory effects [60,61].

Other indications include anterior shoulder surgery due to the anterosuperior part of the shoulder being innervated by the articular branch of the lateral pectoral nerve [64], vascular surgery in the case of an axillofemoral-femoral bypass to prevent general anesthesia and tracheal intubation in patients at greater risk [65], chest wall surgery [66], intractable postherpetic neuralgia that is refractory to neuro axial blocks [67], and open subpectoral biceps tenodesis [68].

The PECS-2 block has replaced the paravertebral blockade because it has been deemed easier to perform and has a lower risk of pneumothorax; however, in axillary dissections, one of the most common complications is trauma to the long thoracic nerve that can lead to a winged scapula; in most cases, the nerve is electrically or mechanically stimulated to ensure correct identification, but on multiple cases after injection of anesthetic the nerves response has been blocked, thereby preventing identification and leading to easier injury [69].

Serratus anterior plane block

Ultrasound-guided serratus anterior plane block (SAPB) induces analgesia in the anterolateral and posterior chest wall by targeting the thoracic intercostal, thoracodorsal, and long thoracic nerves [70]. In a study of the anatomical basis of the block in six soft-fix embalmed cadavers, Mayes et al. found that the analgesic effects of SAPB are mediated specifically via the blockade of the lateral cutaneous branches of the intercostal nerves rather than direct blockade of the intercostal nerves [71]. The injection site for SAPB is more lateral and posterior than that for PECS blocks [70]. The block is performed either superficially or deep to the serratus anterior muscles, with the two main anatomical landmarks being the serratus anterior muscles and the latissimus dorsi. Identification of the plane of injection for SAPB is performed in one of two ways [72]. In the in-plane approach, the transducer is oriented in the coronal plane and moved laterally and distally while counting down to the fourth and fifth ribs from the clavicle [72]. The transducer is then tilted posteriorly to identify the latissimus dorsi [72]. In the out-of-plane approach, the transducer is placed across the axilla for identification of the latissimus dorsi and easier localization of the thoracodorsal artery in the fascial plane between the two muscles [72]. While a longer duration of analgesic effect has been observed with superficial injection, both in-plane and out-of-plane approaches are considered appropriate [72].

Compared to intercostal nerve block, which covers only one intercostal space, SAPB induces analgesia across T2-T9 with a single injection [70,72]. The effects of SAPB in dermatomes T2-T9 make it efficacious in pain management following lateral thoracic wall surgeries such as thoracotomy and breast surgery [72]. The wide dermatomal distribution of SAPB has also enabled it to be implemented for postoperative analgesia following laparotomy in the upper abdomen [73]. In a case report of a patient with severe pain at the thoracotomy incision site that impaired tidal breathing, Madabushi et al. described how induction of analgesia with a single bolus via SAPB followed by continuous infusion facilitated significant pain relief and uncomplicated recovery [74]. A prospective, randomized, double-blinded study of 104 patients who underwent elective thoracoscopy demonstrated that SAPB is an effective adjuvant treatment option for postthoracic surgery analgesia compared to the current standard of intravenous opioids, NSAIDs, and acetaminophen [75]. Patients in the SAPB group had significantly lower levels of pain following surgery as assessed by visual analog scale (VAS) scores, required a decreased total dosage of morphine and tramadol during the first few hours after surgery, and had a lower incidence of vomiting compared to the control group [75].

Although SAPB is a modified PECS block that was developed to serve as an alternative to epidural and paravertebral blocks, the findings of Mayes et al. indicate that the block could be effective for superficial surgery of the lateral thorax such as thoracotomy and radical mastectomy. However, it may not be equivalent to paravertebral block for other applications such as rib fracture [71,76–78] [3]. Case reports have also demonstrated that SAPB used in conjunction with other modalities of analgesia such as multilevel continuous thoracic paravertebral blocks results in a summative analgesic effect and decreases use of intravenous analgesics [79,80]. For those patients whose needs cannot be addressed with a superficial block, such as patients with postmastectomy pain syndrome, the more recently developed deep SAPB has been shown to be of value [81]. The unique superficial targeted injection point of SAPB block may be advantageous in certain circumstances [70]. The block has been shown to successfully treat intercostal neuralgia in a case report of a patient suffering from posttraumatic intercostal neuralgia following a rib fracture [70]. Bilateral single-injection SAPB has also been shown to decrease pain and opioid consumption during the postoperative period compared to intravenous PCA alone in patients undergoing minimally invasive repair of pectus excavatum [82]. Additionally, although the injection site of SAPB is proximal to the course of the thoracodorsal artery, the superficial nature of the block avoids damage to the intercostal vascular and neural structures as well as the pleura [70]. Thus, the superficial induction of SAPB is associated with decreased risk of pneumothorax, hemothorax, and severe refractory pain [70]. A comparison of SAPB and ESPB demonstrated that the two blocks not only had equivalent performances in analgesia but also comparable adverse effect profiles, with no significant difference in hospital course or incidence of skin itching, nausea, and vomiting [83].

Intercostal nerve blocks

Intercostal nerves arise from ventral rami of thoracic spinal nerves, which run from T1-T12. These are mixed nerves of both sensory and motor fibers [2]. Collateral branches of the intercostal nerves travel along the upper border of the rib below [2]. They supply motor innervation to intercostal muscles, latissimus dorsi, serratus anterior, and abdominal wall muscle [2]. Sensory innervation is supplied to the pleura, peritoneum, abdominal wall, and anterior and lateral chest [2]. Intercostal nerve block (ICNB) induces analgesia by blocking the ipsilateral sensory and motor fibers of the intercostal nerves [84]. The injection site for ICNB can be anywhere proximal to the midaxillary line—the landmark for the origin of the lateral cutaneous branch—two dermatomes above and two below the analgesic target [84]. The block is usually performed at the angle of the rib, which is superficial and easily located via palpation while the patient is in the prone, sitting, or lateral position [84]. In the subcostal groove, the widest part of the angle of the rib, the intercostal nerve, is located inferior to the posterior intercostal artery, which is inferior to the intercostal vein [84]. The intercostal nerve is best approached with needle entry at 20° cephalad at the inferior border of the rib [84]. Of note, given that the pleura is located on average 8 mm from the posterior aspect of the rib, deeper advancement of the needle significantly increases risk of pneumothorax [84].

ICNB is indicated for rib fractures and for postoperative pain following chest and upper abdominal surgery [85,86]. ICNB has also been combined with general anesthesia and demonstrated efficacy in attenuating pain, inhibiting the stress response, and improving postoperative hospital course in patients undergoing minimally invasive mitral valve surgery (MIMVS) [87]. Specifically, ICNB using liposomal bupivacaine (LipoB) has been shown to be superior to standard bupivacaine in decreasing the use of postoperative opioids in the first 24 h following video-assisted thoracoscopic surgery (VATS) [88]. Of note, the exact efficacy of ICNB in patients undergoing VATS may require further exploration given the findings of Dominguez et al. in a retrospective review of 80 VATS patients [89]. This study determined that although LipoB decreases length of hospital stay in VATS patients and facilitates earlier ambulation, it does not decrease 24-h postoperative pain score or opioid usage [89]. Unlike the short duration of action of most local anesthetics used in single-shot ICNB, LipoB facilitates prolonged blockade lasting 72–96 h [90]. ICNB using LipoB was shown to be not only safe and effective at maintaining low postoperative pain scores in patients undergoing lung resection but also comparable to thoracic epidural analgesia in terms of perioperative complications and hospital course [90].

A retrospective cohort study of 339 patients with isolated multiple rib fractures compared the efficacy of continuous ICNB and epidural analgesia in reducing average pain scores [91]. ICNB and epidural anesthesia were found to have equivalent effects on pain scores, but ICNB was associated with statistically significant clinical outcomes such as improvement in incentive spirometry volume, shorter ICU LOS, and shorter overall hospital length of stay [91]. Likewise, ICNB has been found to improve postoperative analgesia, leading to decreased need for rescue analgesics such as postoperative tramadol in patients following nonreconstructive breast surgery [92]. ICNB has also been shown to improve clinical outcomes in patients following thoracotomy for esophageal cancer, in whom treatment with ICNB compared to control resulted in not only significantly decreased VAS scores but also decreased postoperative cognitive dysfunction measured by the Mini-Mental State Examination (MMSE) scale [93]. In a case report of a nontraditional application of ICNB, four rounds of multilevel ICNB with LipoB were found to successfully treat chronic chest pain, resulting in sensory blockade of up to seven days, analgesia lasting two months, and significant improvement of overall pain control and quality of life [94].

Complications of ICNB include delayed pneumothorax, peritoneal penetration, abdominal visceral penetration, local anesthetic toxicity, hematoma, and occurrence of spinal anesthesia [84]. While asymptomatic pneumothorax can be managed with observation and supplemental oxygen as needed, tension pneumothorax, while rare, requires emergent tube thoracostomy [84]. Risk of local anesthetic toxicity and spinal anesthesia can be reduced by adherence to maximal dosing guidelines [84]. Notably, risk of pneumothorax is increased in patients on positive pressure ventilation while incidence of spinal anesthesia is increased when ICNB is performed under general anesthesia [84].

Paraneuraxial nerve blocks

Erector spinae plane block

The erector spinae plane block (ESPB) was first described in 2016 as another alternative to conventional thoracic regional anesthetic techniques such as thoracic epidural and paravertebral injections [95,96]. Clinical studies have demonstrated that the block targets both the ventral and dorsal spinal rami [97]. Specifically, cadaveric injection studies suggest that ESPB acts on the ventral rami of spinal nerves in the paravertebral space via penetration of the intertransverse connection tissues and further facilitates visceral analgesia via the rami communicantes and sympathetic chain [98]. Exploration of the anatomical basis of the block has shown that cranio-caudal local anesthetic spread allows for anesthesia of the majority of the thoracic cavity [95]. Notably, spread of local anesthetic solution in clinical practice may be affected by intrathoracic pressure changes, tissue changes, and gravitational effects [99].

One of the advantages of ESPB compared to more conventional techniques is that this block targets a plane that is far removed from the pleura and neuraxial structures, improving its safety profile [99]. The mechanism of action of ESPB has also been shown to involve both transforaminal and epidural spread, giving the technique an advantage over direct intercostal nerve blockade [97]. In delivery of ESPB, local anesthetic is injected into the fascial plane deep to the erector spinae muscle group to achieve analgesia of the thoracic and abdominal walls [98]. Anatomically, ESPB targets the tips of the transverse processes, giving it a distinct advantage over retrolaminar block, which targets the laminae and involves injection over the thick spinalis and transversospinalis muscle groups that increase the variability of local anesthetic spread [98].

ESPB has been used as a regional anesthetic modality for thoracic, breast, thoracolumbar spine, and abdominal surgeries. ESPB is performed at the level of T4-5 for breast and thoracic surgeries, but at present there is a need for further assessment of ESPB application in breast surgery as there are differing reports about the efficacy of the block in delivering adequate analgesia for patients undergoing breast resection [99–101]. ESPB has seen more consistent success in treating pain associated with traumatic rib fractures, facilitating significant decreases in NRS pain scores both at rest and with activity [102]. ESPB is performed at T7–8 to target the thoracoabdominal nerves for abdominal surgery and has been demonstrated to have a role in simplifying complex analgesia protocols in surgeries that require multiple procedures and incisions [101]. Specifically, ESPB applied at T7 has been shown to significantly decrease postoperative pain following laparoscopic bariatric surgery [101]. Recent literature has shown that ESPB is efficacious not only in the acute but also in the chronic setting [96]. The block has been successfully used to treat patients with unrelenting refractory thoracic neuropathic pain and chronic shoulder pain, allowing patients to not only decrease their opioid load but also improve their overall quality of life [96,103].

The technical simplicity of ESPB compared to epidural and paravertebral blocks contributes to its favorable side-effect profile and inherently low risk of associated neurovascular injury [104]. It has been implemented in numerous clinical fields, including upper limb amputation, retropubic prostatectomy, and a range of other thoracic and abdominal procedures with few reports of complications [104,105]. There has been one report of iatrogenic pneumothorax following ESPB, but the study in question fails to report direct causation and rule out other mechanisms to explain this adverse effect [104]. At this time, continued evaluation of the risk of complications and unexpected consequences associated with ESPB is warranted [104,105].

In summary, truncal nerve blocks have evolved in recent years with the onset of ultrasound technology. Truncal blocks, in combination with other analgesic modalities, have efficacy for the chest wall, abdomen, and paraneuraxial nerves. Future studies will help assist in best practice techniques and refined strategies for placement providing anesthesiologists with powerful tools for analgesia in both acute and chronic pain settings.

Practice points

- Truncal nerve blocks have evolved in recent years with the onset of ultrasound technology.
- Truncal blocks, in combination with other analgesic modalities, have efficacy for the chest wall, abdomen, and paraneuraxial nerves.
- Truncal blocks allow for broad coverage owing to interfascial spread.
- Several studies have shown efficacy in hip surgery, knee surgery, and lumbar spinal surgery, as well as some chronic pain cases.

Research agenda

- A systematic review of concentrations of local anesthetic after transverse abdominal plane (TAP) and Rectus sheath block (RSB) blocks supported the conclusion that these blocks are safe despite detectable systemic concentrations in the blood. Overall rectus sheath blocks should continue to be utilized and studied for future literature.
- Future studies will help assist in best practice techniques and refined strategies for placement providing anesthesiologists with powerful tools for analgesia in both acute and chronic pain settings.

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