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PECS, serratus plane, erector spinae, and paravertebral blocks: A comprehensive review

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Thoracic planar blocks represent a novel and rapidly expanding facet of regional anesthesia. These recently described techniques represent the potential for excellent analgesia, enhanced technical safety profiles, and reduced physiological side effects versus traditional techniques in thoracic anesthesia. Regional techniques, particularly those described in this review, have potential implications for mitigation of surgical pathophysiological neurohumoral changes. In the present investigation, we describe the history, common indications, technique, and limitations of pectoral nerves (PECS), serratus plane, erector spinae plane, and thoracic paravertebral plane blocks. In summary, these techniques provide excellent analgesia and merit consideration in thoracic surgery.

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History

Procedures involving the chest wall and thoracic region are associated with poorly tolerated acute pain and may predispose patients to pathophysiological changes associated with the development of chronic postsurgical pain [1]. In addition, in oncological surgery, local anesthesia and opioid-sparing/free techniques have been posited to reduce the incidence of metastatic disease burden [2]. As such, anesthesia methods have been developed in attempts to mitigate the associated postoperative pain and discomfort. Currently used techniques include PECS blocks, serratus plane blocks (SPB), erector spinae blocks (ESPBs), and thoracic paravertebral blocks (TPVBs).

The PECS blocks have quickly gained popularity related to their relative efficacy, simplicity, and safety [3]. Several different approaches have been described for the PECS block. Blanco first described the PECS I block and later described the PECS II as a modification of the PECS I for more extensive surgeries and those involving axillary dissections [4,5]. A different approach to the PECS I block was described two years later by Pérez et al. [6]. Their approach has a needle entry point that is lateral to that initially described by Blanco [3–5]. In a cadaveric study, the medial PECS I approach reached the medial and lateral pectoral nerves. In addition to these nerves, the lateral PECS I approach also spreads to the axilla anesthetizing the intercostobrachial nerve, and the additional injection of the PECS II reaches the lateral cutaneous branches of the intercostal nerves III–VI, as well as to the long thoracic nerve [3].

First described in 1905 by Hugo Sellheim, the TPVB was established as a less hazardous replacement for thoracic epidural anesthesia. Revisited and made popular in 1979, the TPVB currently provides a unilateral somatic and sympathetic anesthesia classically used intraoperatively for pain for a variety of procedures [7,8]. Developed in the last decade, the PECS blocks, SPBs, and ESPBs were created as a safer alternative to the traditional neuraxial block and TPVB.

The SPB was developed by targeting the potential spaces above and below the serratus anterior muscle (SAM). The SPB anesthetizes the thoracic intercostal nerves in the anterolateral and the posterior chest wall [9,10].

The ESPB aims to deposit local anesthetic in a plane deeper into the erector spinae muscles and superficial to the costotransverse ligament complex – a fenestrated connective tissue aggregation below which lies the paravertebral space containing somatic and sympathetic neural tissue [11].

PECS

A PECS block is a fascial plane block that provides analgesia to the upper anterior chest wall. With the PECS I block, the medial and lateral pectoral nerves are targeted to anesthetize the pectoralis muscle. The PECS II block is an extension of the PECS I block and involves a second injection to block the upper intercostal nerves. These blocks have been used for analgesia during and after breast cancer and reconstructive surgery [12]. They have also shown promise to provide supplemental analgesia during placement of cardiovascular implantable electronic devices and upper arm fistula creation [13,14].

PECS blocks were first described by Blanco in 2011, and to date, there are few published trials on this technique [4]. A study in 2014 compared PECS blocks to paravertebral blocks at T4 in patients undergoing modified radical mastectomy. In this study, the patients who received PECS blocks required less opioid intraoperatively and reported better pain control postoperatively [15]. Another study randomized 120 patients to PECS blocks plus general anesthesia compared to general anesthesia alone during unilateral modified radical mastectomy. Patients in the PECS group had statistically significant lower pain scores, lower intraoperative and postoperative opioid requirement, less postoperative nausea and vomiting, shorter Post Anesthesia Care Unit (PACU) stay, lower PACU sedation scores, as well as shorter hospital stays following surgery [16]. Another RCT published in 2017 compared PECS II block to thoracic paravertebral blocks at T3 in 40 patients undergoing modified radical mastectomy. Both groups received blocks with the same amount and concentration of ropivacaine and had a morphine PCA postoperatively. Patients in the PECS group had decreased morphine requirements in the first 24 h, lower pain scores, and longer duration of analgesia [17]. Overall, the PECS blocks are simple, easy-to-learn techniques that produce analgesia for surgeries involving the upper anterior chest wall.

Technique

The PECS I block is performed using a linear ultrasound probe. The probe is positioned in a sagittal orientation at the distal end of the clavicle, medial to the coracoid process, similar to when performing an infraclavicular block. After locating the axillary artery and vein, the probe is moved in a caudal direction until the 2nd and 3rd ribs are visualized. Pectoralis major is identified as the large superficial muscle underneath the subcutaneous tissue, with the pectoralis minor deep into it. Subsequently, the pectoral branch of the thoracoacromial artery is identified between the pectoralis muscles, and the lateral pectoral nerve typically neighbors the artery. A standard block needle is then used to deposit a large volume of dilute local anesthetic in the fascial plane between the pectoralis muscles [3,4].

PECS II is the second or modified version of the PECS I block and consists of two separate injections (Fig. 1). The first injection consists of depositing a local anesthetic in the fascial plane targeted by the PECS I block. The probe is then moved onto the anterior axillary line over the 3rd and 4th ribs. A slight rotation is made to the probe to allow needle insertion along a superior-medial to inferior-lateral passage. The local anesthetic is then deposited in the plane between pectoralis minor and SAM [3,5].

Serratus plane

The Serratus Anterior Plane Block (SAPB) is a modification of the PECS blocks. Like the PECS blocks, the SAPB was developed as an alternative to thoracic epidural, paravertebral, intercostal, and intrapleural blocks. This block has shown some efficacy in the management of postoperative pain following breast surgery, thoracoscopy, thoracotomy, and multiple rib fractures [18]. There is some evidence that it has potential to reduce postoperative opioid consumption and may be an alternative to general anesthesia in minimally invasive cardiac surgery [18].

In his original 2013 paper, Blanco et al. presented this block as a novel ultrasound-guided (USG) regional anesthetic technique. A serratus block using 0.4 mL/kg of levobupivacaine and 0.125% gadolinium was performed at two different levels in the midaxillary line on four female volunteers. The degree of paresthesia was recorded. Fat-suppression MRI with 3D reconstructions of the spread of local anesthesia in the serratus plane was performed. All volunteers reported long-lasting paresthesia (750–840 min) in the T2–T9 distribution, with a mean duration of 752 min. There were no reported side-effects in this initial descriptive study [9]. In 2016, Hetta et al. published a prospective, randomized controlled trial to assess the analgesic efficacy and safety of the pectoralis–serratus interfascial plane block compared to the thoracic paravertebral block for post-mastectomy pain. In this study, 64 women scheduled for unilateral modified radical mastectomy with axillary dissection were

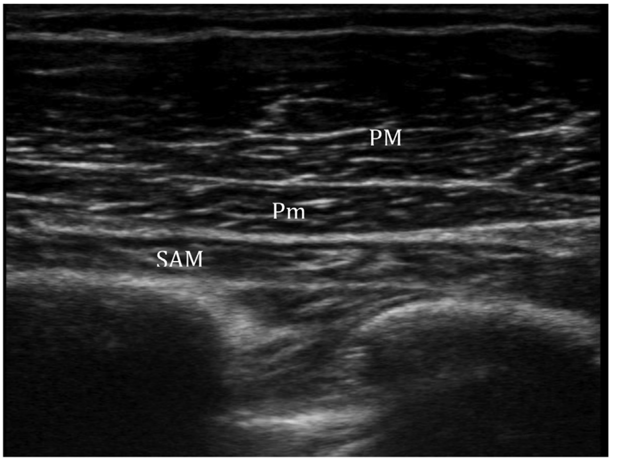

Fig. 1. PECS (PM – pectoralis major, Pm – pectoralis minor, SAM – serratus anterior). Ultrasound image of the second injection of PECS II block between Pm and SAM.

randomized to receive either a pectoralis–serratus interfascial plane block (n = 32, PS group) or a thoracic paravertebral block (n = 32, PV group). Recorded variables included 24-h morphine consumption and time to rescue analgesic, and the pain intensity was evaluated using a visual analog scale (VAS) at 0, 2, 4, 6, 8, 16, and 24 h postoperatively. The median postoperative 24-h morphine consumption was significantly increased in the PS group as compared to that in the PV group. The median time to first analgesic request was significantly shorter in the PS group than in the PV group (PS, 6 h [5–7 h], vs. PV 11 h [9–13 h]). The intensity of pain was low in both groups at 0, 2, and 4 h postoperatively. However, there was significant reduction in intensity of pain in the paravertebral group compared to that in the pectoralis–serratus group at 8, 16, and 24 h postoperatively [12]. More recently, studies have been published evaluating the efficacy of the SAPB in the setting of cardiac and thoracic surgery. Park et al. recently published a randomized trial of serratus anterior plane block for analgesia after thoracoscopic surgery. Eighty-nine participants were randomly allocated to one of the two groups. In the first group, the patients received SAPB with 30 mL ropivacaine 0.375% (n = 44). In the second group, patients received either no block without placebo or sham procedure (n = 45). The serratus anterior plane block reduced the mean (SD) remifentanil dose during surgery, 0.12 (0.06) mg h^{-1} vs. 0.16 (0.06) mg h^{-1} and reduced mean (SD) fentanyl consumption in the first 24 h after surgery, 3.8 (1.9) μg kg^{-1} vs. 5.7 (1.6) μg kg^{-1}. Patients who received a block reported significantly reduced “worst” median and significantly better satisfaction with pain management (IQR [range]) pain scores reported in the first 24 postoperative hours: 6 (5–7 [3–10]) vs. 7 (6–7 [3–10]). No differences were found in the rates of length of hospital stay, nausea, vomiting, or dizziness. This study suggests that SAPB may be used to reduce pain and opioid use after thoracoscopic lung surgery [19]. The serratus anterior plane block appears to be a safe and effective technique for acute pain in many perioperative scenarios, including some cardiac and thoracic surgery.

Technique

Patients can be placed in either the supine or the lateral decubitus position. To identify a targeted level, the probe can first be placed just below the mid-clavicular region and moved inferior and laterally to count ribs. The SAM originates on the 1st–8th ribs and inserts along the medial border of the scapula. Blanco originally described this block at the level of the 5th rib. At this level, the teres major, latissimus dorsi, and serratus muscles can be seen [9]. An in-plane approach is used and can be done from either the superior or the inferior edge of the probe. The SPB can be performed either superficial or deep to the SAM. When the block is performed superficial to the SAM, the local anesthetic will spread in the fascial plane deep into the pectoralis muscles and superficial to the SAM. When performing the deep injection, the local anesthetic will be placed deep into the SAM and superficial to the intercostal muscles and ribs (Fig. 2) [9,20]. Performing the injection deep into the SAM may prevent

Fig. 2. SBP (SAM – serratus anterior muscle). Needle is inserted to contact rib. A local anesthetic is administered to split SAM from rib (deep injection).

spread to the long thoracic nerve and thus winging of the ipsilateral scapula. In cadaveric studies, 20 mL injections spread on average to 4 intercostal levels, while 40 mL injections can spread to a range of 4–7 levels. Injections performed at the 3rd rib reliably spread to the axilla and to the 1st and 2nd rib levels [20].

Erector spinae plane

The ESPB is a paraspinal fascial plane block consisting of an injection of local anesthetic deep into the erector spinae muscle and also superficial to the tips of the transverse processes (TPs). It is indicated as an alternative to thoracic epidural anesthesia and thoracic paravertebral block. The ESP block has potentially fewer complications and contraindications and is technically easier to perform. The efficacy of ESPB has been described in cases of rib fractures, breast surgery, thoracoscopic surgery, lumbar spinal surgery, and laparoscopic abdominal surgery [21]. Its use as a single-shot and continuous infusion has been described. The ESPB is particularly suited to traumatic rib fracture analgesia and features in many pain management algorithms for this purpose [22].

There are few controlled clinical trials relating to ESPB; however, there is an abundance of case reports [23]. Recently, Tsui et al. published a pooled review of 242 cases in order to gain more understanding of this block. The inclusion criteria consisted of reports of ESP single-shot continuous infusion, intermittent bolus, and human and cadaveric studies. Eighty-five publications from 21 journals were included in the pooled review. Most publications reported single-shot techniques (80.2%), intermittent boluses (12.0%), and continuous infusions (7.9%). In this review, 90.9% reported use of multimodal analgesia in addition to the ESPB. A reduction in opioid use was reported in 34.7% of cases. Sensory changes were noted by 34.7% of patients. There was one adverse event reported that involved a pneumothorax. Based on the pooled review of the data, the authors concluded that the ESPB seems a safe and effective option for many types of thoracic, abdominal, and extremity surgeries [23]. A recent article described the benefit of performing preoperative ESPB in 4 patients undergoing laparoscopic ventral hernia repair [24]. The authors of this study performed preoperative bilateral ESPBs with 20–30 mL of ropivacaine 0.5% at the level of the T7 TP. The median (range) 24-h opioid consumption was 18.7 mg (0.0–43.0 mg) oral morphine. The highest and the lowest median range of pain scores in the first 24 h was 3.5 (3.0–5.0) and 2.5 (0.0–3.0) on an 11-point numerical rating scale. A cadaver was also used to assess the extent of injectate spread using computerized tomography. There was radiographic evidence of the spread extending cranially to the upper thoracic levels and caudally to the L2–L3 TPs. The authors concluded that the ESPB is promising as an anesthetic technique for abdominal surgeries, such as laparoscopic ventral hernia repair, when performed at the level of the T7 TP. Additionally, the ability to block both supra-umbilical and infra-umbilical dermatomes with a single-level injection and simple technique for successful placement of this block make it an appealing choice. There is growing evidence but still question whether ESPB provides visceral pain relief [25–27]. Clinical trials examining USG ESPB for many types of surgeries, such as thoracic surgery, arthroscopic shoulder surgery, and laparoscopic abdominal surgery are currently ongoing.

Technique

Ideally, placing patients in the sitting position provides optimal ergonomics for the operator, but this block can also be accomplished with the patient in the lateral or prone positions. This block is predominately performed at the level of the thoracic spine but has been described at the cervical, lumbar, and even sacral levels [23,28]. At the desired level, the US probe is placed midline in a transverse orientation to identify the spinous process. Next, the US probe is rotated 90° into a sagittal orientation and then slid laterally to identify the lamina and then the TP, as this is the beacon for desired needle placement. A needle is then inserted in either an in-plane or an out-of-plane technique advancing to land the needle tip upon the TP (Fig. 3). Once the TP is encountered with the tip of the needle, a small volume (1–3 mL) of normal saline or local anesthetic can be used to determine whether the needle tip is within the correct fascial plane. Injection of the solution should result in the erector spinae muscles being hydro-dissected off the TP [11,23]. A volume of 20–30 mL is often used, with the median volume to cover one dermatome being 3.4 mL [29].

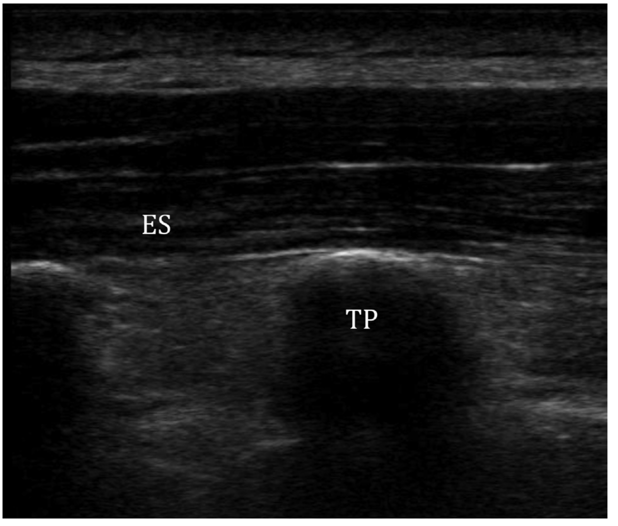

Fig. 3. ESPB (TP – transverse process, ES – erector spinae muscle.) Needle is inserted to contact TP and a local anesthetic is administered to separate the ES muscle off TP.

Thoracic paravertebral

A paravertebral nerve block (PVB) is a unilateral block of the dorsal rami, ventral rami, and sympathetic chain, as they emerge from the spinal canal. PVBs are indicated for a wide range of surgical procedures that require unilateral anesthesia and analgesia. Breast surgery, herniorrhaphy, thoracotomy, breast surgery, and chest wound exploration are common indications. The nature of these operations typically renders the block an analgesic adjunct to general anesthesia. Less well-described indications include cholecystectomy, renal surgery, liver resection, and minimally invasive cardiac surgery [30]. Paravertebral blocks are also indicated for the relief of acute and chronic pain, as in the case of pain related to fractured ribs, or refractory angina pectoris or cancer pain [31]. Most clinical reports and research are related to unilateral blocks; however, bilateral paravertebral blocks have been successfully used in thoracic, abdominal, and pelvic regions, sometimes used as a primary anesthetic [31]. Paravertebral blocks can provide excellent intraoperative and postoperative analgesia conditions with less adverse effects and fewer contraindications that central neural blocks [31]. A clinician may consider a paravertebral block over thoracic epidural analgesia (TEA) in a patient for whom bilateral sympathectomy and subsequent hypotension would be detrimental, such as a patient with severe aortic stenosis [32,33]. Similarly, a unique feature of PVB compared with TEA is that it is relatively safe to perform on patients with marginal coagulation. According to the ASRA guidelines, in patients on antithrombotic or thrombolytic therapy, the same precautions should be taken as when placing an epidural. If bleeding in the thoracic paravertebral space does occur in these patients, significant blood loss, rather than epidural hematoma and neurologic deficit, is the more likely complication [34].

Paravertebral block is well established as a safe and useful regional anesthesia technique for a wide range of surgeries involving thoracic and lumbar regions. This block has many advantages compared to TEA and opioid-based anesthetics [30]. Analgesia is comparable with that provided by a thoracic epidural [32]. Additionally, pronounced hypotension is unusual because sympathetic blockade is rarely bilateral. This may be beneficial in patient populations who are unable to tolerate the hemodynamic effects of sympathectomy [33]. There is less sedation, nausea, vomiting, urinary retention, and constipation with this technique than with opioid-based analgesic techniques. Enteral nutrition and mobilization may therefore be achieved earlier [35,36].

Compared with interpleural blocks, PVB analgesia is more intense and longer lasting. Serum levels of the local anesthetic are also lower [31,37]. Paravertebral blocks have been shown to reduce chronic

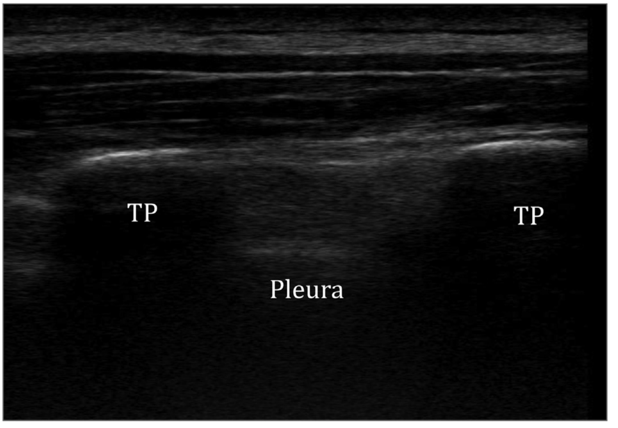

Fig. 4. TPVB. (TP – transverse process) Needle is inserted between TPs into the paravertebral space, and the local anesthetic can be seen to "push down" pleura.

pain after thoracic and breast surgery [38]. This is possibly because of intense block of both the sympathetic and somatic nerves, preventing sensitization of the central nervous system and *N*-methyl-D-aspartate receptor "wind up." Tumor recurrence after breast surgery may also be inhibited [39]. Overall, the paravertebral block is well established as a safe and effective technique for perioperative analgesia and anesthesia in a wide range of surgeries and provides many advantages.

Technique

Thoracic paravertebral blocks can be executed in a variety of approaches. Landmark-based, USG, and ultrasound-assisted techniques have all been described and successfully employed. Ultrasound approaches can be transverse or sagittal and needle insertion can be from an in-plane or an out-of-plane technique [40]. This review focuses on a USG in-plane sagittal approach. USG approaches to the TPVB may have a higher success rate than landmark-based techniques [40]. Approximately 2.5 cm lateral to midline, the probe is placed in a sagittal orientation. Scanning medially and laterally can identify the transition between the TP and the rib. The center of the probe can be aligned between two TPs or the transducer can be moved cranially to place the TP of interest at the caudal border of the ultrasound image (Fig. 4). The health care provider should note the depth and position of the pleura – it appears as a moving hyperechoic structure. A needle is inserted from the inferior edge of the probe from an in-plane technique. The needle can be visualized entering the TPV space, and/or a loss of resistance technique may be used. Injection of the local anesthetic should then result in ventral displacement or "pushing down" of the pleura [41]. The local anesthesia deposited here will track up and down the paravertebral space, providing a broad band of anesthesia on the thorax.

Conclusion

Thoracic anesthesia presents unique challenges to the anesthesiologist. Thoracic incisions are painful and associated with chronic postsurgical pain, and inadequate analgesia is associated with poorer postoperative outcomes [42].

Recent progress has been made in the field of thoracic anesthesia by improving upon analgesic modalities. The most recent progress is the advent of the thoracic plane blocks that we have discussed herein. As clinicians gain experience with these promising techniques, there are likely to have more complete data on the outcomes, range of clinical indications, and complications of these blocks.

Thoracic plane blocks offer excellent analgesia, and the broad goals remain tacit – early ambulation, preservation of pulmonary function and cough, and avoidance of potentially disastrous pulmonary complications. These blocks are also part of an increasing field of interest that centers on novel techniques that aim to mitigate perioperative stress responses, inflammation, and neurohumoral modulation. These blocks may well have advantages relative to older techniques, namely, thoracic epidural reduces technical complication rates and decreased hemodynamic instability [43].

Practice points

- Thoracic anesthesia presents unique challenges to the anesthesiologist.
- Thoracic incisions are painful and associated with chronic postsurgical pain, and inadequate analgesia is associated with poorer postoperative outcomes.
- Thoracic plane blocks offer excellent analgesia, and the broad goals remain tacit – early ambulation, preservation of pulmonary function and cough, avoidance of potentially disastrous pulmonary complications

Research agenda

- Recently, progress has been made in the field of thoracic anesthesia by improving analgesic modalities.
- The most recent progress is the advent of thoracic plane blocks.
- As clinicians gain experience with these promising techniques, there are likely to have more complete data on the outcomes, range of clinical indications, and complications of these blocks.

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