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REVIEW

Regional anesthesia for cardiothoracic surgery

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Abstract

Cardiac and thoracic surgery have been connected to high perioperative opioid use for a long time. With increasing knowledge of regional anesthesia in the thoracic region, thoracic nerve blocks have become supplemental methods of analgesia. As part of multimodal analgesia, they are important factors of enhanced recovery after surgery and contribute to a diminished opioid use. Myofascial nerve blocks are more superficial than the classic thoracic epidural anesthesia or paravertebral block and are therefore safer for use in anticoagulated patients. In this article, we present a number of thoracic blocks; the paraneuraxial paravertebral block; the myofascial plane blocks which are the retrolaminar block, the erector spinae plane block, the serratus anterior plane block, the pectoral nerves I and II block, the transversus thoracis plane block and the parasternal intercostal nerve block; the perineural intercostal nerve block and also local anesthetic infusion by a wound catheter. We conclude with local experience from a cardiac and thoracic surgical center.

Keywords

Regional anesthesia; Cardiac anesthesia; Thoracic anesthesia; Nerve block; Pain management

1. Introduction

Regional anesthesia has found its place in cardiac and thoracic surgery only in recent times. Cardiac and thoracic surgeries have until recently been connected to high opioid consumption with only thoracic epidural anesthesia as an alternative [1, 2]. Providing adequate analgesia after cardiothoracic surgery is essential since postoperative complications often postpone hospital discharge and are linked to higher morbidity and mortality. Constant respiratory movement of the chest potentiates the pain from thoracic drainage and the postoperative wound [3]. Postoperative pain can contribute to complications, such as pneumonia, pulmonary atelectasis, prolonged hospital stays and chronic pain [4, 5]. The most common opioid side effects such as respiratory depression, lethargy, nausea, constipation and pruritus also contribute to postoperative complications. Nowadays, multimodal analgesic techniques are gaining popularity in a desire to reduce the use of opioids.

Regional anesthetic techniques emerged with the development of ultrasound, awareness of the opioid side effects and their potential long-term abuse. Ultrasound-guided interventions enable more exact injection of the local anesthetics to desired locations with fewer complications, which results in more efficient pain relief. The golden standard, which used to be thoracic epidural anesthesia, is now accompanied by thoracic wall blocks (Fig. 1). They can reduce the total postoperative opioid consumption and contribute to faster recovery after surgery. Fast track recovery after cardiac and thoracic surgery includes shortening time to tracheal extubation and hospital discharge [6, 7]. While the efficiency of truncal blocks has already been proven in clinical studies, the optimal dosage, concentration and choice of the drugs used in specific truncal blocks are still investigated [8–10]. Another alternative analgesic technique is the local wound infiltration with a catheter after mini-sternotomies and mini-thoracotomies [11, 12]. This article gives information about a variety of truncal blocks in cardiothoracic surgeries.

2. Neuraxial block

Thoracic epidural anesthesia (TEA) has long been the golden standard for thoracic surgeries due to its high efficiency [13]. On the other hand, it is very invasive and it causes unwanted arterial hypotension by sympathetic block. As for cardiac anesthesia, the use of TEA is still controversial because of concomitant anticoagulant use and the risk of epidural hematoma [14]. TEA reduces the risk of perioperative myocardial infarction, respiratory depression and atrial arrhythmias when used for cardiac surgery [15, 16]. In a large meta-analysis, researchers compared the risks and benefits of cardiothoracic TEA from 66 randomized studies. They concluded it provides excellent analgesia for cardio-thoracic surgery with a reduction in mortality (number needed to treat (NNT) = 70). No cases of epidural hematoma have been reported [17].

To reduce the risk of epidural hematoma, TEA must be administered at least 18 hours prior cardiac surgery. When

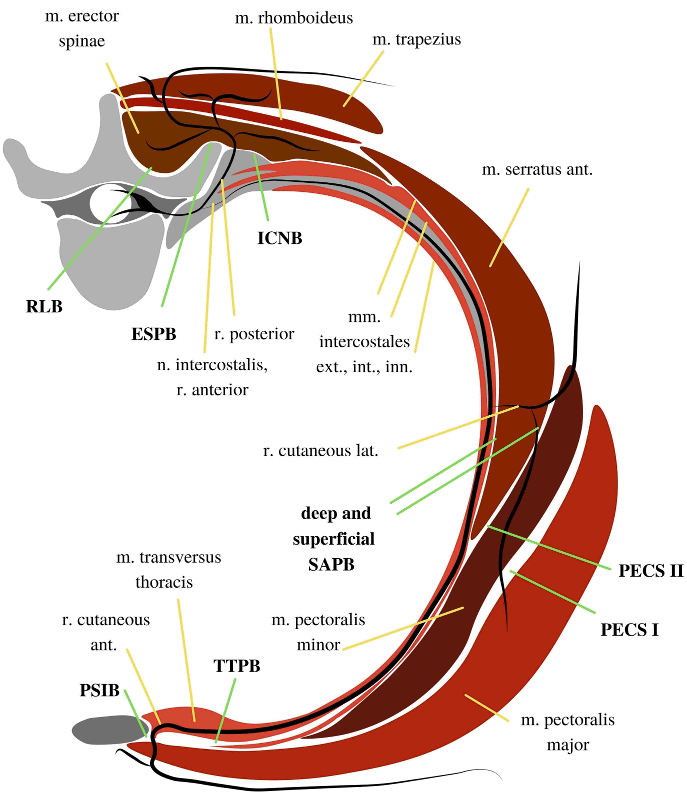

FIGURE 1. Thoracic myofascial plane blocks marked on a cross section of the thoracic wall. RLB—retrolaminar block, ESPB—erector spinae plane block, ICNB—intercostal nerve block, SAPB—serratus anterior plane block, PECS—pectoral nerves block, TTPB—transversus thoracis plane block, PSIB—parasternal intercostal nerve block.

anticoagulants are continued in the postoperative period, the epidural catheter can only be removed after a certain period of time. The catheter can be removed 4 hours after discontinuing therapeutical doses of non-fractioned heparin and the activated partial thromboplastin time is at normal value. Non-fractioned heparin infusion can be continued one hour after the catheter removal. For low-molecular-weight (LMW) heparin, 18 hours must pass from the last application before the epidural catheter removal. LMW heparin can be continued in a preventive dose 6 hours after the catheter removal, whereas therapeutical doses may only be administered 48 hours after the catheter removal [18]. Authors believe the fear of neurologic complications following TEA in cardiothoracic surgery is too high. TEA is safe when administered in a correct timeline with anticoagulant drugs. Anesthesiologist should educate all the medical team members for a better compliance with the chosen anesthetic method.

Spinal anesthesia, on the other hand, has not found its place in cardiothoracic surgery. In a large meta-analysis, researchers concluded that spinal analgesia does not improve perioperative morbidity or mortality in patients undergoing cardiac surgery. Clinicians avoid intrathecal administration of local anesthetics or opioids because of the increased risk of neuraxial hematoma formation, which can lead to paraplegia in patients receiving heparin during surgery. The risk of spinal hematoma because of central neuraxial anesthesia in cardiac surgery has statistically been evaluated at 1:1528 for epidural and 1:3610 for spinal block. However, authors of the study have not found any of these complications recorded [19].

3. Paraneuraxial block

According to the Italian VATS (Video-assisted thoracic surgery) association, paravertebral block (PVB) is the first choice of regional anesthesia in thoracic surgery, because it provides a unilateral block and causes less hemodynamic compromise in comparison to TEA [20]. Local anesthetic is injected into the paravertebral space at one or more levels (Fig. 2). Paravertebral space is wedge-shaped in transverse cross-section and is limited by the bodies of thoracic vertebrae and intervertebral foramina medially, the parietal pleura anteriorly and by the transverse processes, head and neck of the rib and the upper costotransverse ligament posteriorly. Local anesthetic, injected into the paravertebral space, diffuses medially into the epidural space, laterally into the intercostal space and cranio-caudally to adjacent paravertebral spaces [21]. The PVB causes sensory, motoric and sympathetic block, depending on the volume and concentration of the injected local anesthetic. Contraindications for PVB are infection at the injection site, empyema or pleural tumor or a tumor of the paravertebral space. Coagulation disorders are considered a relative contraindication. Specific complications of the block are pleural punction and pneumothorax [22]. Features of thoracic regional anesthetic techniques are listed in Table 1.

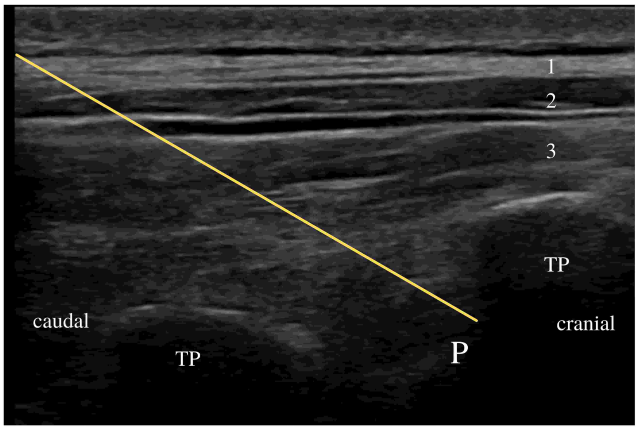

FIGURE 2. The paravertebral block. Legend: 1—m. trapezius, 2—m. rhomboideus, 3—m. erector spinae, TP—transverse process, P—pleura. The needle pathway is marked yellow.

Several meta-analyses have shown that thoracic PVB may be as effective as TEA for post-thoracotomy pain relief and is also associated with fewer complications. Yeung and colleagues executed a meta study of 14 studies with almost 700 participants and proved that PVB reduced the risks of developing minor complications compared to TEA. PVB was as effective as TEA in controlling acute pain. However, there was no difference in 30-day mortality, major complications, or length of hospital stay [23]. In another meta-analysis of 12 clinical trials, they concluded that thoracic PVB may be as

TABLE 1. Thoracic regional anesthetic techniques.

Regional anesthetic technique	Puncture site	Local anesthetic spread	Clinical use
Thoracic epidural anesthesia (TEA)	Sagittal or parasagittal in the level Th6–7	The epidural space approx. 6 levels around the puncture site, spreading 1:2 cranio-caudal	The golden standard of analgesia for thoracotomy, (un)wanted bilateral sympathetic and sensory block, hypotension, greater fluid requirements, specific anticoagulation precautions
Paravertebral block (PVB)	One or more puncture sites parasagittal in the level of operative wound	Paravertebral space	First choice for VATS surgeries; pleural puncture is a possible complication
Erector spinae plane block (ESPB)	Above the transverse process of vertebrae Th4–5	Myofascial plane between the erector spinae muscle and lateral process of the thoracic vertebrae	One of the safest and most efficient thoracic plane blocks in alternative to TEA with the puncture site far from pleura, lungs or spinal cord. Safe for use in anticoagulated patients.
Retrolaminar block (RLB)	Multiple puncture sites above the thoracic lamina, 1 cm parasagittal	Myofascial plane between thoracic lamina and paraspinous muscles	Less efficient than ESPB, lack of RCTs
Serratus anterior plane block (SAPB)	Midaxillary in the level of the 5th rib	Above for the superficial and below for the deep block	Most suitable for anterior thoracotomy, rib fracture or breast surgery
Pectoral nerves block	PECS I between the pectoralis major and minor muscles, US landmark is the pectoral branch of the thoracoacromial artery; an additional lateral injection at the anterior axillary line at the level of the fourth rib between the pectoralis minor and the serratus anterior muscle for PECS II	PECS I: medial and lateral pectoral nerves between the pectoralis major and minor muscles, PECS II also under the pectoralis minor muscle (between the clavipectoral fascia and the superficial border of the serratus muscle)	Most suitable for breast surgery, pacemaker or implantable cardioverter-defibrillator insertion
Transversus thoracis plane block (TTPB)	Parasagittal medial to the mid-clavicular line over the 3rd and 4th rib, needle tip located parasternal	Myofascial plane between the transversus thoracis muscle and the internal intercostal muscles to block the anterior branches of Th2–Th6 intercostal nerves	Sternotomy, sternal fractures, medial coverage for breast surgery or for tunneled pacemaker or implantable cardioverter-defibrillator insertion
Parasternal intercostal nerve block (PSIB)	2 cm lateral to the midline in the 3rd and 5th parasternal intercostal spaces	Between the pectoral major and external intercostal muscles	Median sternotomy
Intercostal nerve block (ICNB)	Multiple injections transcutaneous parasagittal around the level of surgical incision or intrathoracic by the surgeon	Between the medial and innermost intercostal muscles	For rib fractures, chest and upper abdominal surgery such as thoracotomy, mastectomy or gastrostomy

Th—thoracic, RCT—randomized controlled trial, US—ultrasound, VATS—video-assisted thoracic surgery, PECS —pectoral nerves block.

effective as TEA for post-thoracotomy pain relief with a visual analogue pain score (VAS) on activity at 48 h significantly better in the PVB group. They also reported less hypotension and urinary retention in the PVB group [24]. On the other hand, a meta-analysis of 5 studies involving thoracoscopic surgeries showed that the numerical rating scale (NRS) score for resting pain was higher in the thoracic paravertebral block (TPVB) group than in the TEA group at 1–2 hours and 4–6 hours after surgery. Giving a closer look, the difference is statistically significant, but clinically irrelevant (mean difference (MD) =

0.44, 95% coincidence interval (CI) = 0.24 to 0.64, $p < 0.0001$, I2 = 0%; MD = 0.47, 95% CI = 0.23 to 0.70, $p < 0.0001$, I2 = 0%) [25].

Bilateral PVB for cardiac surgery was researched by El Shora and colleagues, who proved its analgesic efficiency for median sternotomy. 140 patients were divided into groups receiving either PVB or TEA. No statistically significant difference in VAS was measured at 12, 24, and 48 hours post operation, rendering the PVB comparable but not superior to TEA [26].

4. Thoracic myofascial plane blocks

4.1 Retrolaminar block

For the retrolaminar block (RLB), local anesthetic is injected between the lamina of thoracic vertebrae and paraspinal muscles, approximately 1 cm lateral to the sagittal plane (Fig. 3). For a better block efficiency, a large volume must be injected, that is at least 30 mL [27]. Cranio-caudal spread is limited to 2–4 segments and the transverse spread to approx. 2.5 cm. The main action site is the interfascial plane, where it blocks the lateral cutaneous branches of the intercostal nerves. Its spread often excludes the paravertebral space, so it does not block the spinal nerves [28, 29]. The utility of the RLB was described only in case reports, while large randomized prospective clinical studies are still missing. In a retrospective analysis, they compared the analgesic efficacy of continuous RLB compared to TEA for VATS marginal lung resection. They proved comparable analgetic efficacy, post-operative pain scores and similar use of rescue analgesia in comparison to TEA [30]. However, not all studies are in favor of the RLB. In a prospective study of patients undergoing minor VATS procedures, they described the RLB as inferior compared to PVB [31].

Bilateral thoracic RLB was used for pediatric open cardiac surgery via median sternotomy in a study by Abdelbaser, where they confirmed a significantly smaller postoperative opioid consumption compared to the placebo group [32].

4.2 Erector spinae plane block

The erector spinae plane block (ESPB) was initially described as rescue analgesia for serial rib fracture [33]. Its use later spread to surgeries that involve the chest wall [34]. ESPB can be used as a single shot or continually with a catheter. Local anesthetic is injected into the myofascial layer between the erector spinae muscle and the lamina of thoracic vertebrae on the level Th4 or Th5 (Fig. 4). Local anesthetic diffuses into the paravertebral space, where it blocks the dorsal and ventral branches of thoracic spinal nerves, lateral branches of spinal nerves that innervate the skin and communicant branches that innervate the sympathetic chain [35]. ESPB blocks multiple levels with a single injection as the local anesthetic spreads cranio-caudally, usually from Th2 to Th9 or even C7 to Th10, depending on the volume of injectate and the level of injection site [36]. The main advantage of the ESPB is its safety profile, because the injection site is far from the spinal cord, pleura and lungs. If an inadvertent vascular puncture occurs, the site can be locally compressed, so it is safe to use in anticoagulated patients [37]. In a meta-analysis from 2020 which included 14 studies, they proved a significant reduction in opioid consumption, smaller pain scores and less post operative nausea and vomiting (PONV) in patients with ESPB compared to those without regional anesthesia for thoracic surgery [38]. Bilateral ESPB with a catheter is a comparable method to TEA for patients undergoing cardiac surgery, with similar results not only regarding pain scores, but also postoperative incentive spirometry, ventilator-dependency duration and intensive care unit length of stay [39].

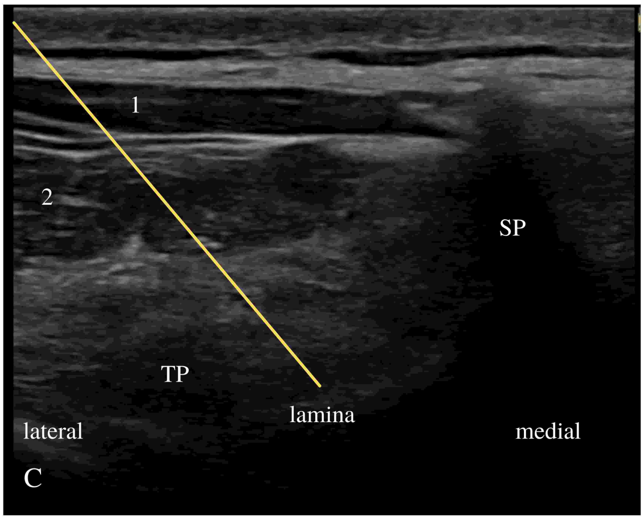

FIGURE 3. The retrolaminar block. 1—m. trapezius, 2—m. rhomboideus, SP—spinous process, TP—transverse process. The needle pathway is marked yellow.

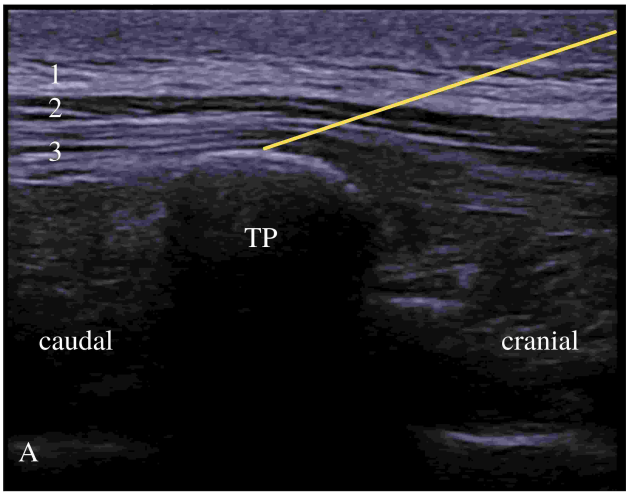

FIGURE 4. The erector spinae plane block. Legend: 1—m. trapezius, 2—m. rhomboideus, 3—m. erector spinae, TP—transverse process, P—pleura. The needle pathway is marked yellow.

4.3 Serratus anterior plane block

Serratus anterior plane block (SAPB) has emerged as a regional anesthetic technique for surgery on the anterolateral wall of the chest, including breast surgery [40, 41]. Local anesthetic is injected under serratus anterior muscle for the deep or above the same muscle for the superficial block. Studies comparing the deep and the superficial block showed superiority of the latter, that lasts longer and has a higher success rate [42]. The needle insertion site is at the level of 5th intercostal space, residing in the mid-axillary line (Fig. 5). The SAPB blocks the lateral cutaneous branches of the intercostal nerves from Th2 to Th7–9. According to cadaveric studies, the local anesthetic also spreads to n. pectoralis lateralis and medialis, n. thoracicus longus and n. thoracodorsalis (Fig. 6). A greater block area is connected to larger injected volumes, up to 40 mL of local anesthetic [43].

The use of SAPB after thoracic surgery was researched in a meta-analysis of 8 studies. They discovered a statistically significant reduction in pain levels and reduced opioid use than in the control group without regional anesthesia, which also experienced more PONV [44]. The use of continuous deep SAPB was investigated by Toscano *et al.* [45], who confirmed its analgesic and opioid sparing effect in patients undergoing mini-thoracotomy mitral valve replacement.

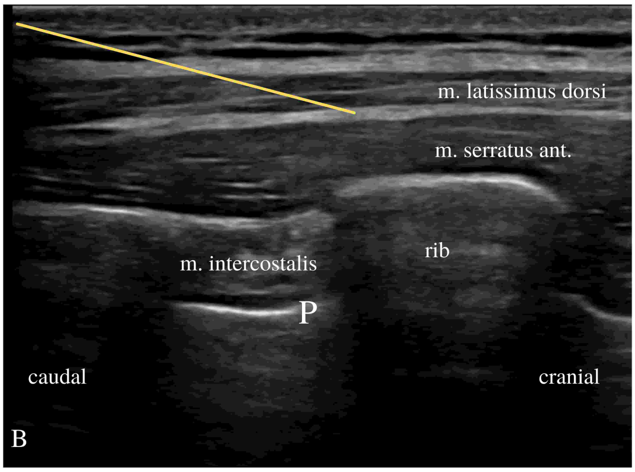

FIGURE 5. The serratus anterior plane block. P—pleura. The needle pathway is marked yellow.

4.4 Pectoral nerves block

The pectoral nerves (PECS) block was initially described for postoperative anesthesia in breast surgery [46]. The PECS block is divided into two different nerve blocks. The PECS I targets the medial and lateral pectoral nerves. Local anesthetic is injected between the pectoralis major and minor muscles. The main landmarks to identify the point of injection under ultrasound guidance are the pectoralis major and pectoralis minor muscles with the pectoral branch of the thoracoacromial artery. With an additional lateral injection at the anterior axillary line on the level of the fourth rib between the pectoralis minor and the serratus anterior muscle, the PECS II also blocks upper intercostal nerves, as well as the long thoracic nerve and the intercostobrachial nerve [47].

A meta-analysis of PECS II as analgesia for breast cancer surgery showed that it reduces pain intensity and morphine consumption during the first 24 hours postoperatively when compared to systemic analgesia alone; it also offers analgesic benefits non-inferior to those of PVB after breast cancer surgery. Evidence supports incorporating PECS II as an alternative to PVB for breast cancer surgery [48].

It is also a useful anesthetic method for the implantation of cardiovascular electronic devices, such as pacemakers or implantable cardioverter-defibrillators [49]. Large meta-analyses of the method for major cardiac surgeries are still missing. A study comparing bilateral PECS II block with intravenous analgesia only for coronary artery bypass grafting surgeries or coronary valve surgeries via median sternotomy showed that pain scores evaluated at rest and cough were substantially lower in the PECS group at times 0, 3, 6, 12, and 18 hours from extubation [50].

4.5 Transversus thoracis plane block

The transversus thoracis plane block (TTPB) is a regional anesthetic method for relieving post-sternotomy pain. The local anesthetic is administered as a single shot into the myofascial plane between the transversus thoracis muscle and the internal intercostal muscles in order to block the anterior branches of Th2–Th6 intercostal nerves [51–53].

A study by Shokri *et al.* [54] compared cardiac surgery patients receiving bilateral TTPB with those receiving general anesthesia only. In the first 24 hours after surgery, they found that the proportion of patients needing extra opioid analgetic doses, total postoperative opioid demand and pain scores were substantially lower in the group which received TTPB than in the comparative group with general anesthesia only. Ventilation time and intensive care unit stay in the TTPB group were substantially shorter. Between the study groups, they found no distinctive differences in postoperative complications. Abdelbaser and colleagues studied the analgesic potency of TTPB when used in pediatric cardiac surgery. They discovered its use decreased perioperative opioid consumption and reduced postoperative pain intensity in comparison to general anesthesia only [55].

4.6 Parasternal intercostal nerve block

Parasternal intercostal nerve block (PSIB) targets the anterior and posterior intercostal nerves that reside on the inferior side of each rib lateral to the sternum (Fig. 7). The technique is typically performed by the surgeon at the time of sternal closure by multiple injections of local anesthetic into the parasternal intercostal spaces between the pectoral major and external intercostal muscles, but can also be performed pre-operatively under ultrasound guidance [15].

Preoperative PSIB was studied for use in coronary artery bypass grafting via median sternotomy. The PSIB reduced the maximum concentrations of remifentanil and propofol required to maintain hemodynamic stability and depth of anesthesia during sternotomy [56]. PSIB was also studied for postoperative analgesia in pediatric patients undergoing cardiac surgery. Time to extubation was significantly lower in patients who were administered the PSIB with ropivacaine than in the control group. The pain scores were lower in the PSIB group with a significantly lower cumulative fentanyl dose requirement over a 24-hour period [57].

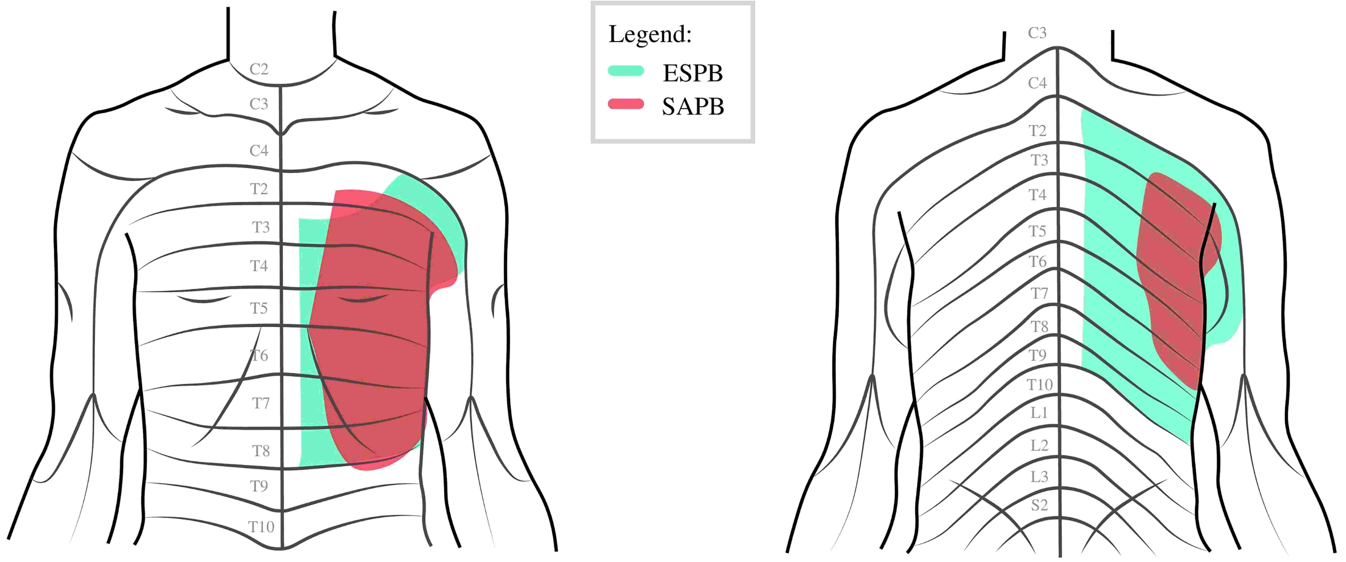

FIGURE 6. Comparison of block dermatomal coverage between the erector spinae plane block and the serratus anterior plane block. ESPB—erector spinae plane block, SAPB—serratus anterior plane block.

A study evaluated the effectiveness of ultrasound-guided parasternal intercostal nerve block for postoperative analgesia in patients undergoing median sternotomy for mediastinal mass resection. They applied local anesthetic in the 3rd and 5th parasternal intercostal spaces bilaterally. The PSIB group required 20% less sufentanil added by the patient-controlled analgesia (PCA) pump compared to the control group and reported lower pain scores in rest and cough 24 hours after surgery [58].

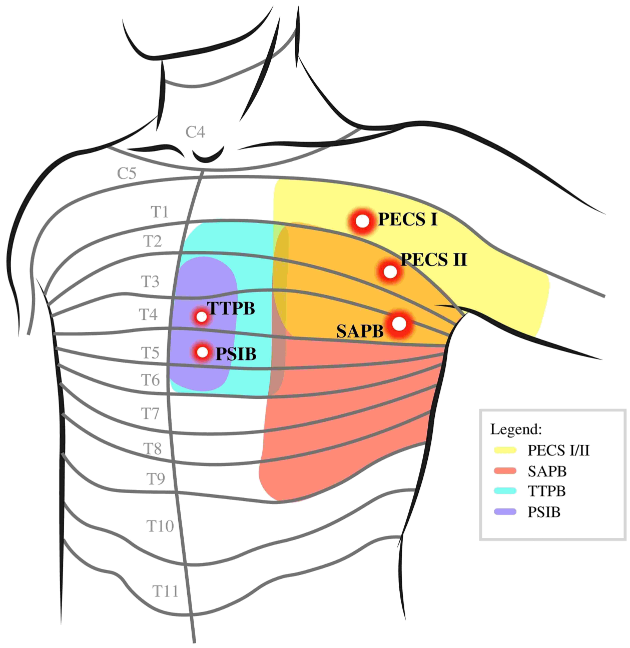

FIGURE 7. Anterior and lateral chest wall plane blocks. PECS I/II—pectoralis nerves block, PSIB—parasternal intercostal nerve block, SAPB—serratus anterior plane block, TTPB—transversus thoracis plane block.

5. Perineural block

The intercostal nerve block (ICNB) is performed under ultrasound guidance preoperatively by the anesthesiologist or at the end of the surgery by the surgeon, when the operative field yields access to the intrathoracic injection site. Local anesthetic is injected in multiple levels paravertebral between the internal and innermost intercostal muscles. 3–5 mL of anesthetic is sufficient for each level unilaterally. Contraindication for the ICNB is infection at the injection site, which also includes empyema [59–61].

In a meta-analysis of 59 studies, the single shot ICNB was associated with a reduction of pain during the first 24 hours after thoracic surgery and was clinically non-inferior to TEA or PVB. However, TEA and PVB were associated to larger decreases in postoperative opioid use, suggesting that ICNB may be most beneficial for cases where TEA and PVB are contraindicated [62]. In a study comparing regional anesthetic methods for cardiac surgery via thoracotomy, ICNB was declared inferior to PECS II and SAPB blocks [63].

6. Local anesthesia through a wound catheter

Local anesthetic, delivered through a wound catheter is a successful method of postoperative analgesia in most surgical fields. Nevertheless, it has produced mixed results in cardiac surgery when used after full sternotomy. In a study by Mijovski *et al.* [64], the effectiveness of 0.2% ropivacaine wound infusion through a catheter delivered by PCA pump was investigated in 70 patients for mini-thoracotomy aortic valve replacement. The cumulative dose of the opioid needed in the first 48 hour after surgery was significantly lower in the group receiving local anesthetic compared to placebo. They reported high patient satisfaction regarding pain relief and there were no infections of the wound or local anesthetic toxic side effects. A similar study by Dowling *et al.* [65] confirmed that continuous infusion of local anesthetics improved postoperative pain control while lowering the total opioid analgesia required in patients who underwent full median sternotomy. In another study by Agarwal *et al.* [66], the data safety monitoring board stopped the study after enrolling 85 patients because of excessive sternal wound infections (9%, n = 44) in the ropivacaine group. It is unclear why they provided contradictory results.

As for thoracic surgery patients, Fiorelli *et al.* [12] investigated the effects of local anesthetic through a wound catheter in patients undergoing muscle-sparing thoracotomy and lung cancer resection. The local anesthetic group compared with the control (placebo) group had a significant reduction of postoperative interleukin-6, interleukin-10 and tumor necrosis factor alpha blood concentration levels, lower pain scores, and a decrease of additional morphine intake during the entire postoperative course. Spirometry results, such as the recovery of the flow expiratory volume in one second % and the forced vital capacity % were also reported better in the research than in the placebo group.

7. Institutional experience

Anesthesiologists, intensivists and cardiac surgeons at the University medical center Ljubljana Cardiovascular surgery department collaborate in the local anesthetic wound infusion protocol. Patients, undergoing mini sternotomy, receive the local anesthetic via a pre-programmed PCA pump without a continuous opioid infusion. In the occasion of breakthrough pain, the patients receive a bolus of piritramide. They report high patient satisfaction and low opioid consumption [64].

The team of anesthesiologists in cooperation with thoracic surgeons at the Surgery Bitenc center in Slovenia implement regional anesthetic techniques for thoracic surgery patients to provide optimal, safe and patient-centered analgesia. The most commonly performed block is the continuous ESPB with a catheter for VATS lung resections. The use of ESPB diminished total opioid consumption in VATS patients and is used especially in older, fragile patients. They report good efficacy and high patient satisfaction with the analgesic method [35].

8. Conclusion

Numerous studies and meta-analyses show that analgetic treatment after cardiothoracic surgery can be improved by adding regional anesthetic techniques in context of multimodal anesthesia. There is no single method which exerts superior analgetic proprieties and is completely safe. Therefore, we must combine different types of post-operative analgesia and adjust them inter-individually according to the patient and surgery. New regional techniques emerged as a step towards minimal opioid use to diminish their side effects and potential addiction. Implementation of regional blocks is safer under ultrasound guidance and with some precaution, they can also be performed on anticoagulated patients. Deepened knowledge of anatomy and regional anesthetic techniques enables the anesthesiologist to provide the optimal, safe and patient-centered analgesia.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

PG—designed the article and wrote the original draft. JK—contributed to the initial concept and article design. MŠ—contributed to the initial concept, supported the process and provided expert supervision. All authors reviewed, edited and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Ochroch J, Usman A, Kiefer J, Pulton D, Shah R, Grosh T, *et al*. Reducing opioid use in patients undergoing cardiac surgery—preoperative, intraoperative, and critical care strategies. Journal of Cardiothoracic and Vascular Anesthesia. 2021; 35: 2155–2165.

[2] Ip HY, Abrishami A, Peng PW, Wong J, Chung F. Predictors of postoperative pain and analgesic consumption: a qualitative systematic review. Anesthesiology. 2009; 111: 657–677.

[3] Sengupta S. Post-operative pulmonary complications after thoracotomy. Indian Journal of Anaesthesia. 2015; 59: 618.

[4] Marshall K, McLaughlin K. Pain management in thoracic surgery. Thoracic Surgery Clinics. 2020; 30: 339–346.

[5] Kolettas A, Lazaridis G, Baka S, Mpoukovinas I, Karavasilis V, Kioumis I, *et al*. Postoperative pain management. Journal of Thoracic Disease. 2015; 7: S62–S72.

[6] Batchelor TJP, Rasburn NJ, Abdelnour-Berchtold E, Brunelli A, Cerfolio RJ, Gonzalez M, *et al*. Guidelines for enhanced recovery after lung surgery: recommendations of the Enhanced Recovery after Surgery (ERAS®) Society and the European Society of Thoracic Surgeons (ESTS). European Journal of Cardio-Thoracic Surgery. 2019; 55: 91–115.

[7] Charlesworth M, Klein A. Enhanced recovery after cardiac surgery. Anesthesiology Clinics. 2022; 40: 143–155.

[8] Sostaric M, Gersak B, Novak-Jankovic V. The analgesic efficacy of local anesthetics for the incisional administration following port access heart surgery: bupivacaine versus ropivacaine. The Heart Surgery Forum. 2010; 13: E96–E100.

[9] Chin KJ. Thoracic wall blocks: from paravertebral to retrolaminar to serratus to erector spinae and back again—a review of evidence. Best Practice & Research Clinical Anaesthesiology. 2019; 33: 67–77.

[10] Boezaart A, Warltier D. Perineural infusion of local anesthetics. Anesthesiology. 2006; 104: 872–880.

[11] Chiu K, Wu C, Wang M, Lu C, Shieh J, Lin T, *et al*. Local infusion of bupivacaine combined with intravenous patient-controlled analgesia provides better pain relief than intravenous patient-controlled analgesia alone in patients undergoing minimally invasive cardiac surgery. The Journal of Thoracic and Cardiovascular Surgery. 2008; 135: 1348–1352.

[12] Fiorelli A, Izzo AC, Frongillo EM, Del Prete A, Liguori G, Di Costanzo E, *et al*. Efficacy of wound analgesia for controlling post-thoracotomy pain: a randomized double-blind study. European Journal of Cardio-Thoracic Surgery. 2016; 49: 339–347.

[13] Rawal N. Epidural technique for postoperative pain. Regional Anesthesia and Pain Medicine. 2012; 37: 310–317.

[14] Šoštarič M, Mavri A, Vene N, Poredoš P, Kodrič N. Management of antithrombotic therapy in patients undergoing regional anesthesia. Slovenian Medical Journal. 2009; 78: 619–625.

[15] Caruso TJ, Lawrence K, Tsui BCH. Regional anesthesia for cardiac surgery. Current Opinion in Anaesthesiology. 2019; 32: 674–682.

[16] Svircevic V, van Dijk D, Nierich AP, Passier MP, Kalkman CJ, van der Heijden GJ, *et al*. Meta-analysis of thoracic epidural anesthesia versus general anesthesia for cardiac surgery. Anesthesiology. 2011; 114: 271-282.

[17] Landoni G, Isella F, Greco M, Zangrillo A, Royse CF. Benefits and risks of epidural analgesia in cardiac surgery. British Journal of Anaesthesia. 2015; 115: 25–32.

[18] Horlocker TT, Wedel DJ, Benzon H, Brown DL, Enneking KF, Heit JA, *et al*. Regional anesthesia in the anticoagulated patient. Regional Anesthesia and Pain Medicine. 2003; 28: 172–197.

[19] Zangrillo A, Bignami E, Biondi-Zoccai GGL, Covello RD, Monti G, D'Arpa MC, *et al*. Spinal analgesia in cardiac surgery: a meta-analysis of randomized controlled trials. Journal of Cardiothoracic and Vascular Anesthesia. 2009; 23: 813–821.

[20] Piccioni F, Segat M, Falini S, Umari M, Putina O, Cavaliere L, *et al*. Enhanced recovery pathways in thoracic surgery from Italian VATS Group: perioperative analgesia protocols. Journal of Thoracic Disease. 2018; 10: S555–S563.

[21] Bouman EAC, Sieben JM, Balthasar AJR, Joosten EA, Gramke H, van Kleef M, *et al*. Boundaries of the thoracic paravertebral space: potential risks and benefits of the thoracic paravertebral block from an anatomical perspective. Surgical and Radiologic Anatomy. 2017; 39: 1117–1125.

[22] Novak-Jankovič V. Regional anaesthesia in thoracic and abdominal surgery. Acta Clinica Croatica. 2019; 58: 96–100.

[23] Yeung JH, Gates S, Naidu BV, Wilson MJ, Gao Smith F. Paravertebral block versus thoracic epidural for patients undergoing thoracotomy. The Cochrane database of systematic reviews. 2016; 2: Cd009121.

[24] Baidya DK, Khanna P, Maitra S. Analgesic efficacy and safety of thoracic paravertebral and epidural analgesia for thoracic surgery: a systematic review and meta-analysis. Interactive CardioVascular and Thoracic Surgery. 2014; 18: 626–635.

[25] Liang XL, An R, Chen Q, Liu HL. The analgesic effects of thoracic paravertebral block versus thoracic epidural anesthesia after thoracoscopic surgery: a meta-analysis. Journal of Pain Research. 2021; 14: 815–825.

[26] El Shora HA, El Beleehy AA, Abdelwahab AA, Ali GA, Omran TE, Hassan EA, *et al*. Bilateral paravertebral block versus thoracic epidural analgesia for pain control post-cardiac surgery: a randomized controlled trial. The Thoracic and Cardiovascular Surgeon. 2020; 68: 410–416.

[27] Voscopoulos C, Palaniappan D, Zeballos J, Ko H, Janfaza D, Vlassakov K. The ultrasound-guided retrolaminar block. Canadian Journal of Anesthesia/Journal Canadien D'AnesthéSie. 2013; 60: 888–895.

[28] Damjanovska M, Stopar Pintaric T, Cvetko E, Vlassakov K. The ultrasound-guided retrolaminar block: volume-dependent injectate distribution. Journal of Pain Research. 2018; 11: 293–299.

[29] Onishi E, Toda N, Kameyama Y, Yamauchi M. Comparison of clinical efficacy and anatomical investigation between retrolaminar block and erector spinae plane block. BioMed Research International. 2019; 2019: 1–8.

[30] Nobukuni K, Hatta M, Nakagaki T, Yoshino J, Obuchi T, Fujimura N. Retrolaminar versus epidural block for postoperative analgesia after minor video-assisted thoracic surgery: a retrospective, matched, non-inferiority study. Journal of Thoracic Disease. 2021; 13: 2758–2767.

[31] Sugiyama T, Kataoka Y, Shindo K, Hino M, Itoi K, Sato Y, *et al*. Retrolaminar block versus paravertebral block for pain relief after less-invasive lung surgery: a randomized, non-inferiority controlled trial. Cureus. 2021; 13: e13597.

[32] Abdelbaser I, Mageed NA, Elfayoumy SI, Magdy M, Elmorsy MM, ALseoudy MM. The effect of ultrasound-guided bilateral thoracic retrolaminar block on analgesia after pediatric open cardiac surgery: a randomized controlled double-blind study. Korean Journal of Anesthesiology. 2022; 75: 276–282.

[33] Forero M, Adhikary SD, Lopez H, Tsui C, Chin KJ. The erector spinae plane block. Regional Anesthesia and Pain Medicine. 2016; 41: 621–627.

[34] Thiruvenkatarajan V, Adhikary S, Pruett A, Forero M. Erector spinae plane block as an alternative to epidural analgesia for post-operative analgesia following video-assisted thoracoscopic surgery: a case study and a literature review on the spread of local anaesthetic in the erector spinae plane. Indian Journal of Anaesthesia. 2018; 62: 75.

[35] Gams P, Danojević N, Bitenc M, Šoštarič M. Continuous erector spinae plane block as part of opioid-sparing postoperative analgesia after video-assisted thoracic surgeries: Series of 4 cases. Indian Journal of Anaesthesia. 2020; 64: 516.

[36] De Cassai A, Tonetti T. Local anesthetic spread during erector spinae plane block. Journal of Clinical Anesthesia. 2018; 48: 60–61.

[37] Toscano A, Capuano P, Galatà M, Tazzi I, Rinaldi M, Brazzi L. Safety of ultrasound-guided serratus anterior and erector spinae fascial plane blocks: a retrospective analysis in patients undergoing cardiac surgery while receiving anticoagulant and antiplatelet drugs. Journal of Cardiothoracic and Vascular Anesthesia. 2022; 36: 483–488.

[38] Huang W, Wang W, Xie W, Chen Z, Liu Y. Erector spinae plane block for postoperative analgesia in breast and thoracic surgery: a systematic review and meta-analysis. Journal of Clinical Anesthesia. 2020; 66: 109900.

[39] Singh N, Nagaraja P, Ragavendran S, Asai O, Bhavya G, Manjunath N, *et al*. Comparison of continuous thoracic epidural analgesia with bilateral erector spinae plane block for perioperative pain management in cardiac surgery. Annals of Cardiac Anaesthesia. 2018; 21: 323.

[40] Ahiskalioglu A, Yayik AM, Demir U, Ahiskalioglu EO, Celik EC, Ekinci M, *et al*. Preemptive analgesic efficacy of the ultrasound-guided bilateral superficial serratus plane block on postoperative pain in breast reduction surgery: a prospective randomized controlled study. Aesthetic Plastic Surgery. 2020; 44: 37–44.

[41] Blanco R, Parras T, McDonnell JG, Prats-Galino A. Serratus plane block: a novel ultrasound-guided thoracic wall nerve block. Anaesthesia. 2013; 68: 1107–1113.

[42] Qiu L, Bu X, Shen J, Li M, Yang L, Xu Q, *et al*. Observation of the analgesic effect of superficial or deep anterior serratus plane block on patients undergoing thoracoscopic lobectomy. Medicine. 2021; 100: e24352.

[43] Kunigo T, Murouchi T, Yamamoto S, Yamakage M. Spread of injectate in ultrasound-guided serratus plane block: a cadaveric study. JA Clinical Reports. 2018; 4: 10.

[44] Liu X, Song T, Xu H, Chen X, Yin P, Zhang J. The serratus anterior plane block for analgesia after thoracic surgery. Medicine. 2020; 99: e20286.

[45] Toscano A, Capuano P, Costamagna A, Burzio C, Ellena M, Scala V, *et al*. The serratus anterior plane study: continuous deep serratus anterior plane block for mitral valve surgery performed in right minithoracotomy. Journal of Cardiothoracic and Vascular Anesthesia. 2020; 34: 2975–2982.

[46] Blanco R, Fajardo M, Parras Maldonado T. Ultrasound description of Pecs II (modified Pecs I): a novel approach to breast surgery. Spanish Journal of Anesthesiology and Reanimation. 2012; 59: 470–475.

[47] Versyck B, van Geffen GJ, Chin KJ. Analgesic efficacy of the Pecs II block: a systematic review and meta-analysis. Anaesthesia. 2019; 74: 663–673.

[48] Hussain N, Brull R, McCartney CJL, Wong P, Kumar N, Essandoh M, *et al*. Pectoralis-II myofascial block and analgesia in breast cancer surgery. Anesthesiology. 2019; 131: 630–648.

[49] Helander EM, Webb MP, Kendrick J, Montet T, Kaye AJ, Cornett EM, *et al*. PECS, serratus plane, erector spinae, and paravertebral blocks: a comprehensive review. Best Practice & Research Clinical Anaesthesiology. 2019; 33: 573–581.

[50] Nagaraja P, Kumar K, Kalyane R, Singh N, Krishna M, Babu B, *et al*. Efficacy of bilateral pectoralis nerve block for ultrafast tracking and postoperative pain management in cardiac surgery. Annals of Cardiac Anaesthesia. 2018; 21: 333.

[51] Fujii S, Bairagi R, Roche M, Zhou JR. Transversus thoracis muscle plane block. BioMed Research International. 2019; 2019: 1–6.

[52] Zhang Y, Li X, Chen S. Bilateral transversus thoracis muscle plane block provides effective analgesia and enhances recovery after open cardiac surgery. Journal of Cardiac Surgery. 2021; 36: 2818–2823.

[53] Murata H, Hida K, Hara T. Transverse thoracic muscle plane block. Regional Anesthesia and Pain Medicine. 2016; 41: 411–412.

[54] Shokri H, Ali I, Kasem AA. Evaluation of the analgesic efficacy of bilateral ultrasound-guided transversus thoracic muscle plane block on post-sternotomy pain: a randomized controlled trial. Local and Regional Anesthesia. 2021; 14: 145–152.

[55] Abdelbaser II, Mageed NA. Analgesic efficacy of ultrasound guided bilateral transversus thoracis muscle plane block in pediatric cardiac surgery: a randomized, double-blind, controlled study. Journal of Clinical Anesthesia. 2020; 67: 110002.

[56] Bloc S, Perot BP, Gibert H, Law Koune JD, Burg Y, Leclerc D, *et al*. Efficacy of parasternal block to decrease intraoperative opioid use in coronary artery bypass surgery via sternotomy: a randomized controlled trial. Regional Anesthesia and Pain Medicine. 2021; 46: 671–678.

[57] Chaudhary V, Chauhan S, Choudhury M, Kiran U, Vasdev S, Talwar S. Parasternal intercostal block with ropivacaine for postoperative analgesia in pediatric patients undergoing cardiac surgery: a double-blind, randomized, controlled study. Journal of Cardiothoracic and Vascular Anesthesia. 2012; 26: 439–442.

[58] Chen H, Song W, Wang W, Peng Y, Zhai C, Yao L, *et al*. Ultrasound-guided parasternal intercostal nerve block for postoperative analgesia in mediastinal mass resection by median sternotomy: a randomized, double-blind, placebo-controlled trial. BMC Anesthesiology. 2021; 21: 98.

[59] Lopez-Rincon RM, Kumar V. (ed.) Ultrasound-Guided Intercostal Nerve Block. StatPearls Publishing: Treasure Island (FL). 2021.

[60] Chen N, Qiao Q, Chen R, Xu Q, Zhang Y, Tian Y. The effect of ultrasound-guided intercostal nerve block, single-injection erector spinae plane block and multiple-injection paravertebral block on postoperative analgesia in thoracoscopic surgery: a randomized, double-blinded, clinical trial. Journal of Clinical Anesthesia. 2020; 59: 106–111.

[61] Lee J, Lee DH, Kim S. Serratus anterior plane block versus intercostal nerve block for postoperative analgesic effect after video-assisted thoracoscopic lobectomy. Medicine. 2020; 99: e22102.

[62] Guerra-Londono CE, Privorotskiy A, Cozowicz C, Hicklen RS, Memtsoudis SG, Mariano ER, *et al*. Assessment of intercostal nerve block analgesia for thoracic surgery. JAMA Network Open. 2021; 4: e2133394.

[63] Kaushal B, Magoon R, Chauhan S, Bhoi D, Bisoi A, Khan M. A randomised controlled comparison of serratus anterior plane, pectoral nerves and intercostal nerve block for post-thoracotomy analgesia in adult cardiac surgery. Indian Journal of Anaesthesia. 2020; 64: 1018.

[64] Mijovski G, Podbregar M, Kšela J, Jenko M, Šoštarič M. Effectiveness of wound infusion of 0.2

[65] Dowling R, Thielmeier K, Ghaly A, Barber D, Boice T, Dine A. Improved pain control after cardiac surgery: results of a randomized, double-blind, clinical trial. The Journal of Thoracic and Cardiovascular Surgery. 2003; 126: 1271–1278.

[66] Agarwal S, Nuttall GA, Johnson ME, Hanson AC, Oliver WC Jr. A prospective, randomized, blinded study of continuous ropivacaine infusion in the median sternotomy incision following cardiac surgery. Regional Anesthesia and Pain Medicine. 2013; 38: 145–150.

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