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Current evidence of ultrasound guided fascial plane blocks for cardiac surgery: a narrative literature review

Running title: fascial plane blocks for cardiac surgery

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Running title: fascial plane blocks for cardiac surgery
Abstract

Fascial plane blocks are a useful element for multimodal analgesia after cardiac surgery. These blocks can provide effective analgesia while circumventing serious risks associated with conventional techniques such as neuraxial hematoma and pneumothorax. This narrative review covers blocks performed at parasternal intercostal, interpectoral, pecto-serratus, serratus anterior, erector spinae, and retrolaminar planes which are targets for fascial plane blocks commonly used for cardiac surgery. Brief anatomical considerations, mechanisms, and currently available evidence were reviewed. Additionally, fascial plane blocks for implantation of subcutaneous-Implantable Cardioverter-Defibrillator were also reviewed.

Keywords: Analgesia; Nerve block; Fascia; Thoracic wall; Cardiac surgical procedures; Implantable cardioverter defibrillator; Postoperative pain.
Introduction

Cardiac surgery is performed mainly via sternotomy which has been conventionally countered by high doses of opioid to attenuate undesirable physiologic responses [1]. However, such high doses of opioid are associated with unwanted risks such as prolonged mechanical ventilation and longer intensive care unit or hospital stay. These practices have been changing with the introduction of concepts of enhanced recovery after surgery (ERAS) [2] and fast-tracking [3,4] which aim for quick and high-quality recovery at the same time. As the goal of “quick” and “high-quality” recovery can conflict under a high dose opioid regime, those protocolized perioperative cares should involve an effective analgesic plan other than opioid. Through effective pain control, not only patient comfort and satisfaction but also clinical outcomes can be improved [5-8].

With advancements in surgical instruments and techniques, recent trend of cardiac surgery is getting more and more less invasive and the cases such as minimal invasive direct coronary artery bypass (MIDCAB) graft surgery and anterior thoracotomy for valve surgery are increasing [9]. As the rationale for such less invasive technique is to alleviate physiological deterioration due to extensive surgical wounds and accompanying pain and thereby enhance recovery, immediate or early extubation is often attempted in these patients. In contrast to classical cardiac surgical patients who were heavily sedated with high doses of sedatives and opioids in the early postoperative period, these patients have to cope with stressful period with minimal sedative and opioids without the assistance of mechanical ventilation. To effectively accomplish such challenges, numerous regional techniques have been introduced in this field as an essential element of multimodal analgesic protocol [10-16].

Among the various repertoires of thoracic regional techniques, fascial plane blocks are emerging as an effective alternative for the conventional techniques such as paravertebral, epidural, or spinal blocks [17-19]. Fascial plane blocks are injecting local anesthetic between the muscles through
which peripheral nerve travels [20]. As these techniques are not targeting the nerve itself or
directing the needle toward the neural axis, they can circumvent or at least alleviate the risks of
serious complications such as neural injury and neuraxial hematoma. Especially, as most cardiac
surgical patients are planned to be heparinized, avoiding neuraxial needling is an especially
appealing point. Also, the technical ease of the fascial plane blocks seems one of the factors for its
widespread.

In this article, we reviewed the current evidence of various ultrasound guided fascial plane blocks
for cardiac surgery by summarizing the RCTs so far.
**Materials and Methods**

We performed a literature search for articles related to the chest wall nerve block for cardiac surgery in PubMed, Embase, and Cochrane Library. The search period was from June 22, 2022, to June 26, 2022. In this review, the PICO (Populations of Interest, Exposures, Comparators, and Outcomes) was adults or pediatric patients undergoing cardiac surgery, regional analgesia, a comparative intervention as no blockade or systemic analgesia, and various clinical outcomes including pain score and analgesic consumption. The exclusion criteria included non-English language articles, non-randomized controlled trials, duplicate articles, and irrelevant articles. The search terms used included: (P) “Cardiac Surgical Procedures [Mesh] or “heart surgery” or “Minimal invasive cardiac surgery” or “Anterior thoracotomy”. (I) limited “PECS block,” or “Pectoral nerve block” or “Serratus plane block” or “Parasternal block” or “Transeversus thoracis plane block” or “Erector spinae plane block” or “Retrolaminar block” which are most commonly performed thoracic fascial plane blocks.

We screened 1223 records that were identified through database searches. After removing duplicates, the search strategy resulted in 1026 distinct citations, of which 991 (96.5%) were excluded during the initial screening phase. The primary reasons for the exclusion of papers were the use of non-RCT designs and discordance with the inclusion criteria. After a full-text review, 20 studies were retained. After this systematic search, two additional RCTs of cardiac surgery and three RCTs of S-ICD implantation were included by manual search. Consequently, 25 studies were included in this review (22 for cardiac surgery, Table 1; three for S-ICD implantation).

**Nomenclature**

Recently, American Society of Regional Anesthesia and Pain Medicine (ASRA) and European Society of Regional Anaesthesia and Pain Therapy (ESRA) conducted an international study, aimed
at achieving consensus on the nomenclature of anesthetic techniques of abdominal wall, paraspinal, and chest wall [21]. The names and anatomical definitions of various regional techniques are standardized by a consensus of experts. The suggested nomenclature is designed to make it easy to know where the procedure is being performed on. In this review, the description will be primarily based on the new names. However, with a respect to the authors who had first published the technique, the original nomenclatures were introduced at the beginning of each section. Table 2 summarizes the detailed injection points of the seven techniques described in this article.

**Parasternal intercostal plane (PIP) block**

PIP block is targeting the anterior cutaneous branches of intercostal nerves which innervate the anteromedial chest wall. These nerves penetrate the intercostal muscles and pectoralis major muscle at each thoracic level. It is divided into superficial and deep PIP blocks according to the injection plane, beyond or below the internal intercostal muscle. Since the midline of the chest and abdominal wall slightly overlaps on both sides, bilateral injection is required for complete coverage of the sternal area [22]. All the covered studies in this section had performed PIP block for sternotomy.

**Superficial PIP block**

It was first introduced by Torre et al. on 2014 under the name of “pecto-intercostal fascial plane block” [23]. With an ultrasound probe placed parasaggitally on the lateral border of the sternum and using an in-plane technique, the fascial plane between the pectoralis major and internal intercostal muscles can be hydro-dissected and the injectate can spread multilevel through advancing the needle along the dissection (Fig. 1). Although it can be done in the surgical field under direct vision at sternum closure, it is distinguished from ultrasound guided approach in that the proper spreading of local anesthetic cannot be observed.
Bloc et al. [5] assessed the effect of preoperative superficial PIP block on the intraoperative opioid requirement to maintain hemodynamic stability during sternotomy for CABG. Maximal concentration of remifentanil was reduced in the block group and also some reductions in postoperative proinflammatory cytokines were observed. Hamed et al. [24] evaluated the analgesic efficacy of superficial PIP after various open heart surgery with median sternotomy. The 24-hour cumulative morphine consumption was significantly reduced compared with the control, although the effect size was small (−3.54 mg, 95% CI −6.55 to −0.53). However, quality of oxygenation judged by PaO₂ and ratio of PaO₂/inspired fraction of O₂ in the postoperative period was improved in the block group. Khera et al. [25] also proved improved pain scores with superficial PIP than with placebo, although the reduction in postoperative opioid consumption was not significant.

**Deep PIP block**

The anterior cutaneous nerve runs over the transversus thoracis muscle and traverses intercostal and pectoralis major muscles near the sternal border and enters the superficial plane. Thus, an injection can be performed on a more proximal and deeper plane, which was first described in 2015 as “transversus thoracis plane block” [26]. Ultrasound scanning can be done parasagittally parallel to the lateral sternal border or transversely parallel to the intercostal space (Fig. 1 and 2, respectively). Transversus thoracis muscle is a thin structure located just below the sternum and just above the pleura which is difficult to be clearly distinguished on an ultrasound image. Because the internal mammary artery (IMA) and vein run over it, these vessels should be visualized and used as a landmark in order to avoid inadvertent puncture (Fig. 1B and 2B). [27]. Color-flow doppler is useful in probing IMA and it is usually observed in an ultrasound image aligned with costal cartilage plane. A downward displacement of the pleura by the injectate can be used as an appropriate ultrasound endpoint. Because the needle angle has to be stiffer in a parasagittal approach than a transverse approach due to the narrow needle path (i.e., between the ribs), the
transverse approach can be a little easier and safer method for deep PIP. However, there has been no study comparing the two approaches directly yet.

Fujii et al. [28] reported the safety and analgesic effect at 12 hours postoperatively of deep PIP block in cardiac surgery. The results revealed high patient recruitment, adherence, and satisfaction rate regarding deep PIP block in cardiac surgery. Aydin et al. [29] proved a significant opioid sparing effect of preoperative deep PIP block during postoperative 24 hours, although the improved pain score was only significant until 12 hours postoperatively compared with the placebo group. In the research of Zhang et al. [30], deep PIP block provided not only analgesic effect but also other positive clinical outcomes such as shortened time to extubate, time to first bowel movement, and ICU and hospital stay.

Superficial PIP block is considered a safer technique than deep PIP block as the former is more distant from vascular structure, pleura, and heart. However, since these are emerging techniques, reports about complications are scarce and warrant further research.

Use of PIP blocks in pediatric patients

The PIP blocks can be applied in pediatric patients, and it is possible to achieve multi-level blockade with a single injection, unlike adults who require multilevel injections. Followings are recent RCTs in pediatric patients showing that PIP block could reduce intra- and/or postoperative opioid consumption with improved clinical outcomes.

Abdelbaser et al. [31] revealed that deep PIP almost halved postoperative 24 hours opioid consumption and significantly lowered objective pain scores than the control group in pediatric cardiac surgery via median sternotomy. Zhang et al. investigated deep [6] and superficial PIP [32] through two RCTs. Block groups showed significantly lower pain scores until 24 hours after extubation than the placebo group. But the pain scores were comparable between the groups at
postoperative 48 hours. In those studies, both blockades could also reduce the duration of mechanical ventilation and length of ICU stay which are clinically meaningful outcomes.

**Erector spinae plane (ESP) block**

The ESP block has been used in various surgeries thanks to its technical ease and guaranteed safety [33]. It was first introduced as a novel analgesic technique for thoracic neuropathic pain in a case report by Forero et al. in 2016 [34]. Usually, the probe is placed on the paraspinal area parasagittally and a bony structure is searched. Once the bony shape is identified, the probe is slide to the medial and lateral directions to distinguish the round shape of the rib and the squared-off shape of the transverse process (Fig. 3A). During the rib scanning, the pleura is clearly visible whereas it is not the case for the transverse process scanning. The edge of the transverse process is a preferred target for the needle placement and slight advancement deeper off the edge may be needed to achieve proper spreading of injectate into the plane between the erector spinae muscle and the transverse process [18].

The mechanism that mediates the coverage of the chest wall (other than back) of the ESP block appears to be due to the spreading of local anesthetics close to the paravertebral space where the dorsal and ventral rami of the spinal nerve diverge. Although there is a bunch of evidence showing the analgesic effect of ESP block in various types of surgery including breast, thoracic, and abdominal surgery, its use in cardiac surgery is still limited [35-39]. ESP block has some advantages in terms of safety and technical ease over thoracic paravertebral or epidural blocks which have risks such as hematoma, neural injury, or pneumothorax and are technically challenging.

Athar et al. [8] assessed the efficacy of single-shot ESP block in adult cardiac surgery. It provided superior analgesia with decreased opioid consumption by 64.5% and reduced the duration of mechanical ventilation and sedation score after six hours post-extubation compared with the sham
block. Krishna et al. [40] compared single-shot ESP block with conventional analgesic regimen which includes intravenous paracetamol and tramadol. Interestingly, the analgesic effect of ESP block was almost perfect in the immediate postoperative period that the median NRS score in the ESP block group until the sixth hour post-extubation was zero in that study.

The studies described above evaluated the efficacy of a single-shot ESP block. As the gradual anterior spreading to the thoracic paravertebral space is considered to be a determinant factor for consistent coverage of the anterolateral chest wall [41], a continuous block may provide a more analgesic effect by gradual diffusion of local anesthetic over a prolonged period of time. Wasfy et al. [42] evaluated continuous bilateral ESP block in CABG surgery and found reduced postoperative opioid consumption and pain score in the block group until 48 hours post-extubation. Also, they found improved peak inspiratory flow and reduced duration of mechanical ventilation and ICU stay.

Recently, the mechanism of ESP block was further elaborated that the pathways through which the injectate spreads to the paravertebral space were suggested [43-45]. The superior costotransverse ligament (SCTL) incompletely formed the posterior wall of the thoracic paravertebral space and through the slits including costotransverse foramen, retro-SCTL space is broadly communicated with paravertebral space. Thus, so-called intertransverse process (ITP) blocks that make injection a little closer to the communicating channels (between retro-SCTL and paravertebral space) than ESP block have been introduced under various names [46]. Future research evaluating the usefulness of ITP blocks in cardiac surgery is needed.

**Use of ESP block in pediatric patients**

In 2017, Chin et al. reported ESP block as a part of successful perioperative pain management in a pediatric patient who underwent oncological thoracic surgery [47]. After that, ESP block was applied in a wide range of pediatric clinical scenes [48].

Kaushal et al. [7] evaluated the efficacy of ESP block in pediatric patients with acyanotic
congenital heart disease undergoing cardiac surgery through a midline sternotomy. Pain scores were significantly reduced by the blockade until 10 hours post-extubation. Also, the rescue opioid consumption and the duration of ICU stay were reduced with lower sedation scores in the ESP block group. On the contrary, Karacaer et al. [49] noted no significant differences between ESP block and control groups in terms of pain score, sedation score, extubation time, and length of ICU stay. Gado [50] assessed the efficacy and safety of bilateral ESP blocks in pediatric patients undergoing cardiac surgeries through a median sternotomy. Perioperative opioid consumption was reduced in the ESP block group with comparable postoperative complications such as vomiting, itching, and respiratory depression. Macaire et al. [51] performed bilateral continuous ESP in pediatric cardiac surgery via median sternotomy. Significantly less total morphine consumption during postoperative 48 hours and improved pain scores were noted in the block group compared with the control group. A protocol consisting of programmed intermittent bolus injection in either side (alternatively) catheters was used to avoid local anesthetics systemic toxicity in the study. The plasma ropivacaine concentrations at 1 and 48 hours after the initiation of the blockade were below the known safe level.

**Retrolaminar**

Retrolaminar block was first appeared in 2013, a case report which reported management of the pain due to multiple rib fractures [52]. Similar to the ESP block, it is performed in the parasagittal plane. Sliding the probe from lateral to medial, rib, transverse process, and lamina can be distinguished by their distinctive bony contours which are round, rectangular, and flat structures with small notches, respectively (Fig. 3B). Using an in-plane technique, needle can be introduced until the tip contacts with the flat structure (i.e., laminar). The optimal needle positioning can be
confirmed by observing proper spreading of injectate throughout the plane between the lamina and the erector spinae muscle.

Although this blockade is different from ESP block in that the injection point is the plane between the erector spinae muscles and the lamina [21], the mechanism by which this block is explained is same as ESP block [53]. Currently, the analgesic efficacy of the so-called “paravertebral by proxy” techniques (ESP, retrolaminar, and ITP blocks) is mainly explained by how much the injectate spreads anteriorly to the paravertebral space [54].

Only one recent RCT [55] so far reported their experience using the ultrasound-guided bilateral thoracic retrolaminar block in pediatric open cardiac surgery. The perioperative fentanyl consumption was significantly lower in the block group compared with the control group. Additionally, the block enabled early extubation and shortened ICU stay.

**Interpectoral plane (IPP) / Pectoserratus plane (PSP) / Serratus anterior plane (SAP) blocks**

PECS I (currently IPP), PECS II (currently IPP combined with PSP), and SAP blocks were first introduced by Blanco et al. [56-58]. The IPP block targets the medial and lateral pectoral nerves and is performed by injecting local anesthetic within the fascial plane between the pectoralis major and minor muscles (interpectoral plane) [56]. The PSP block targets the lateral cutaneous nerve within the fascial plane between the pectoralis minor and serratus muscles (pecto-serratus plane) (Fig. 4A). Actually, PECS II block per se consists of the two blocks, IPP and PSP, sometimes erroneously described as PECS I + PECS II [57]. Thus, PECS II block was described as IPP-PSP block in this review to avoid confusion. The SAP block was introduced as a modification of the PECS blocks, with the more lateral and posterior injection to provide analgesia for most of the hemithorax [58]. It is further distinguished as superficial- and deep-SAP block depending on whether the injection is performed at the plane above or below the serratus anterior muscle (Fig. 4B). Therefore, the target
plane for PSP and superficial-SAP is actually the same except that the injection is performed at the territory under the pectoralis minor muscle (PSP) or not (superficial-SAP).

Kaushal et al. [59] compared the efficacy of ultrasound-guided deep-SAP block, IPP-PSP block, and intercostal nerve block for the management of post-thoracotomy pain in pediatric cardiac surgery. These blocks showed comparable efficacy in terms of pain score in the early postoperative period (1 to 4 hours), but more prolonged analgesic effect in SAP and PSP groups.

The mechanism by which IPP or PSP mediates analgesic effect after sternotomy is unclear. Although these blocks are not expected to cover the anterior cutaneous branches of the intercostal nerves, several studies reported effective analgesia of PSP in pediatric cardiac surgery involving median sternotomy [60,61]. In pediatric patients, the injected local anesthetics in the anterolateral chest wall may spread to anteromedial side given the relatively small size of the chest wall, although direct evidence supporting this issue is currently lacking. On the contrary, however, it is hardly expected that the analgesic effect for post-sternotomy could be covered by these blocks in adult patients [62].

Kamal et al. [60] compared the analgesic effect of bilateral IPP-PSP block and conventional intravenous analgesia (control) for post-sternotomy pain after pediatric cardiac surgery. The block group reported lower pain scores and reduced postoperative opioid requirements than the control. Furthermore, the emergence agitation and the duration ICU stay were also lower in the study group. Kumar et al. [61] performed bilateral IPP-PSP block in cardiac surgeries through a midline sternotomy. Pecs group patients required a lesser duration of ventilator support in comparison to parenteral analgesia. In addition, analgesic effects and inspiratory function were also improved.

A study conducted by Gaweda et al. [63] gives us an interesting insight on the distinct mechanism that IPP-PSP block can provide. In that study, patients undergoing mitral/tricuspid valve repair via mini-thoracotomy were randomized into either ESP or ESP with IPP-PSP block groups. The ESP
with IPP-PSP block group showed better analgesic outcomes and patient satisfaction. In theory, the most distinctive nerves that could be blocked by IPP-PSP block other than ESP block were pectoral nerves. As the pectoral nerves per se are motor nerves, the analgesic effect expected from the blockade of these nerves is mainly due to a reduction in pectoral muscle spasm. The additional analgesic effect provided by IPP-PSP in the study could be partially explained by this mechanism.

SAP block is performed at a more posterolateral part of chest wall than where IPP or PSP blocks are performed [58]. A sufficient hydro-dissection of the fascial plan provides blockade of multi-level lateral cutaneous branches of the intercostal nerves. It can be performed on a supine or lateral decubitus position which can be chosen by planned surgical positioning (e.g., supine position for MIDCAB or lateral decubitus position for lung surgery, Fig. 5B). Although it has shown significant analgesic effects in thoracoscopic surgery, its analgesic effect seems smaller than that of paravertebral or ESP blocks [38]. Gautam et al. [64], the only RCT that used SPB in cardiac surgery searched so far, evaluated the role of continuous deep-SAP block for postoperative pain relief in patients undergoing MIDCAB surgery via left anterior thoracotomy. Although they reported reduced pain score and postoperative opioid consumption in the SAP block group, given the fentanyl included in the infusate for continuous blockade (1 µg/mL, infused at 8 mL/h after 20 mL of bolus dose), the efficacy of SAP block itself in the study is questionable.

**Fascial plane blocks for Subcutaneous-Implantable Cardioverter-Defibrillator (S-ICD) implantation**

A proper regional analgesia for S-ICD implantation should cover two areas of the chest wall, one for a pocket creation between the serratus anterior and latissimus dorsi muscles and another for parasternal tunneling of the lead. An authoritative guideline addressing regional techniques for S-ICD implantation is still lacking and only a recommendation led by U.S. physicians published in
2018 exists so far [65]. Since then, a few recent studies were conducted that used SAP and PIP blocks.

Shariat et al. [66] investigated the efficacy of deep-PIP block combined with superficial-SAP block for S-ICD implantation. Compared with the wound infiltration group, intraoperative fentanyl requirements were significantly lower in the block group. However, as the intraoperative fentanyl administration was based on a subjective discretion of a nonblinded anesthesiologist, the validity of the positive result of the study raised some concerns. A larger scale, double-blinded RCT [67] compared analgesic efficacy of the regional techniques consisting of ultrasound-guided deep-PIP block and deep-SAP block versus local infiltration in 80 S-ICD placements. The pain scores assessed by the Critical-Care Pain Observation Tool during the procedure were significantly lower in the block group compared with the local infiltration group. They also conducted a similar study using the same techniques in pediatric patients [68]. The block group showed favorable analgesic outcomes and shorter extubation time and length of PACU stay compared with the control group (sham block).
Conclusions

Evidence suggests that the fascial plane blocks can provide effective analgesia for cardiac surgery. Also, some studies provide evidence of improved postoperative pulmonary mechanics, and reduced length of ICU or hospital stays. However, prudence is needed in interpreting the results of the previous studies and applying them in clinical practice.

1. The coverage of blockade should correspond to the target surgical site. Specifically, sternal coverage of IPP and PSP is not guaranteed in adult patients.

2. The consistency of the blockade can depend on several factors. The efficacy of paravertebral by proxies can be influenced by the degree of paravertebral spreading of the injectate. Also, a lack of delicate control of needle tip placement can impair proper spreading of the injectate into the target plane and thus hinder block consistency.

3. Somatic blockade does not guarantee complete analgesia for cardiac surgery. Therefore, it better be a part of multimodal analgesia rather than a sole analgesic technique.

4. Although the included studies in this review showed positive outcomes in various cardiac surgeries, functional or long term clinical outcomes are limited [69].

It is still considered too early to make up a comprehensive result regarding the efficacy of ultrasound guided fascial plane blocks in cardiac surgery, and more studies comparing various techniques are needed to derive stronger evidence. Nevertheless, most fascial plane blocks for cardiac surgery shows effective analgesia and low procedure related risks. Therefore, the application of these emerging ultrasound guided fascial plane block techniques to cardiac surgery is worthy of consideration.
References


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69. Chung W. Another new kid on the BLOCK for pain control in pediatric cardiac surgery.
Table 1. Evidence summary of ultrasound guided fascial plane blocks in cardiac surgery

<table>
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<tr>
<th>Author/Year</th>
<th>Surgery/approach</th>
<th>Block</th>
<th>Local anesthetics</th>
<th>Sample size</th>
<th>Primary outcome</th>
<th>Other results</th>
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<tr>
<td>PIP</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Fujii/2019 [28]</td>
<td>CABG, valve/ sternotomy</td>
<td>Deep PIP</td>
<td>0.3% or 0.5% ropivacaine 20 mL</td>
<td>C (n=8) B (n=9)</td>
<td>High patient recruitment (95%)</td>
<td>No statistical analysis</td>
</tr>
<tr>
<td>Bloc/2021 [5]</td>
<td>CABG/ sternotomy</td>
<td>Superficial PIP</td>
<td>0.25% ropivacaine, 15×4 mL</td>
<td>C (n=17) B (n=18)</td>
<td>Reduced intraoperative OC</td>
<td>Reduced postoperative proinflammatory cytokines</td>
</tr>
<tr>
<td>Aydin/2020 [29]</td>
<td>CABG, valve/ sternotomy</td>
<td>Deep PIP</td>
<td>0.25% bupivacaine, 20 mL</td>
<td>C (n=24) B (n=24)</td>
<td>Reduced postoperative 24 h OC</td>
<td>Reduced pain score and PONV incidence</td>
</tr>
<tr>
<td>Hamed/2022 [24]</td>
<td>CABG, valve/ sternotomy</td>
<td>Superficial PIP</td>
<td>0.25% bupivacaine, 20 mL</td>
<td>C (n=35) B (n=35)</td>
<td>Reduced 24 h OC</td>
<td>Longer first analgesic request time, reduced wound pain score</td>
</tr>
<tr>
<td>Khera/2021 [25]</td>
<td>CABG, valve/ sternotomy</td>
<td>Superficial PIP</td>
<td>0.25% bupivacaine, 20 mL</td>
<td>C (n=40) B (n=40)</td>
<td>No difference in the 48 h OC</td>
<td>No difference in the incidence of postoperative delirium</td>
</tr>
<tr>
<td>Zhang/2021 [30]</td>
<td>Open cardiac surgery (unspecified)/ sternotomy</td>
<td>Deep PIP</td>
<td>0.4% ropivacaine, 20 mL</td>
<td>C (n=30) B (n=30)</td>
<td>Less perioperative OC</td>
<td>Improved sleep quality, reduced time to extubation, ICU stay</td>
</tr>
<tr>
<td>Abdelbase/2020 [31]</td>
<td>Pediatric/ sternotomy</td>
<td>Deep PIP</td>
<td>0.25% Bupivacaine, 0.2-0.4 mL/kg</td>
<td>C (n=36) B (n=37)</td>
<td>Decreased perioperative OC during 24 h</td>
<td>Lower intraoperative HR and MAP, longer time to first rescue analgesia, shorter time to extubate and ICU stay</td>
</tr>
</tbody>
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<table>
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<th>Group B</th>
<th>Main Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhang/2020 [6]</td>
<td>Pediatric / sternotomy</td>
<td>Deep PIP</td>
<td>0.2% ropivacaine, 0.75 mL/kg</td>
<td>C (n=50) B (n=50)</td>
<td>lower MOPS</td>
<td>Less OC, reduced time to extubate and ICU and hospital stay</td>
</tr>
<tr>
<td>Zhang/2022 [32]</td>
<td>Pediatric / sternotomy</td>
<td>Superficial PIP</td>
<td>0.2% ropivacaine, 1.5 mg/kg</td>
<td>C (n=51) B (n=50)</td>
<td>Lower MOPS at 24 h postoperatively</td>
<td>Lower perioperative OC, reduced time to extubate, shortened initial flatus, and length of ICU and hospital stay</td>
</tr>
<tr>
<td>Athar/2021 [8]</td>
<td>CABG, valve / sternotomy</td>
<td>ESP</td>
<td>0.25% Levobupivacaine, 20 mL</td>
<td>C (n=15) B (n=15)</td>
<td>Reduced OC in postoperative 24 h</td>
<td>Prolonged time to first rescue analgesia, shorter duration of mechanical ventilation</td>
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<tr>
<td>Krishna/2019 [40]</td>
<td>CABG, valve, ASD / unspecified</td>
<td>ESP</td>
<td>0.375% ropivacaine, 3 mg/kg</td>
<td>C (n=53) B (n=53)</td>
<td>Reduced postoperative pain</td>
<td>Higher mean duration of analgesia</td>
</tr>
<tr>
<td>Wasfy/2021 [42]</td>
<td>CABG / sternotomy</td>
<td>Continuous ESP</td>
<td>0.25% bupivacaine, 15 ml 0.125% bupivacaine 8 ml/h for 48 h</td>
<td>C (n=20) B (n=20)</td>
<td>Lower pain score till 48 h after extubation</td>
<td>Reduced total perioperative OC, higher peak inspiratory flow, shorter duration of ventilation and ICU stay</td>
</tr>
<tr>
<td>Gado/2022 [50]</td>
<td>Pediatric / sternotomy</td>
<td>ESP</td>
<td>0.25% bupivacaine, 0.4 mL/kg</td>
<td>C (n=48) B (n=50)</td>
<td>Lower intraoperative OC,</td>
<td>Delayed first rescue analgesia</td>
</tr>
<tr>
<td>Kaushal/2020 [7]</td>
<td>Pediatric / sternotomy</td>
<td>ESP</td>
<td>0.2% Ropivacaine, 1.5 mg/kg</td>
<td>C (n=40) B (n=40)</td>
<td>Reduced pain score until postoperative 10 h</td>
<td>Less postoperative OC, longer duration to first rescue dose requirement,</td>
</tr>
<tr>
<td>Study</td>
<td>Patient group</td>
<td>Technique</td>
<td>Solution</td>
<td>Concentration/Dose</td>
<td>Group</td>
<td>Outcome</td>
</tr>
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<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Karacaer/2022 [49]</td>
<td>Pediatric/ sternotomy</td>
<td>ESP</td>
<td>0.25% bupivacaine</td>
<td>0.5 mL/kg</td>
<td>C (n=20)</td>
<td>Lower OC in postoperative 24 h</td>
</tr>
<tr>
<td>Macaire/2020 [51]</td>
<td>Pediatric/ sternotomy</td>
<td>Continuous ESP</td>
<td>0.1% or 0.2% ropivacaine, 0.5 mL/kg/side</td>
<td>C (n=23) B (n=27)</td>
<td>Decreased OC during postoperative 48 h</td>
<td></td>
</tr>
<tr>
<td>Retrolaminar</td>
<td>Pediatric/ sternotomy</td>
<td>Retrolaminar</td>
<td>0.25% bupivacaine</td>
<td>0.4 mL/kg</td>
<td>C (n=28) B (n=29)</td>
<td>Reduced perioperative OC</td>
</tr>
<tr>
<td>IPP/ PSP/ SAP</td>
<td>Pediatric/ thoracotomy</td>
<td>SAP, IPP-PSP, intercostal nerve</td>
<td>0.2% ropivacaine, 3 mg/kg</td>
<td>SAP (n=36) IPP (n=36) INB (n=36)</td>
<td>mean MOPS at 6, 8, 10, 12 h were lower in SAP and IPP-PSP block</td>
<td></td>
</tr>
<tr>
<td>Kamal/2022 [60]</td>
<td>Pediatric/ sternotomy</td>
<td>IPP-PSP</td>
<td>0.25% bupivacaine</td>
<td>0.5 mL/kg</td>
<td>C (n=20) B (n=20)</td>
<td>Lower pain score at 6 h postoperative</td>
</tr>
<tr>
<td>Kumar/2018 [61]</td>
<td>CABG, valve/ sternotomy</td>
<td>IPP-PSP</td>
<td>0.25% bupivacaine</td>
<td>60 mL</td>
<td>C (n=20) B (n=20)</td>
<td>Less duration of ventilator support</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Gautam/ 2020 [64]</th>
<th>MIDCAB/ left anterior thoracotomy</th>
<th>Continuous Deep SAP</th>
<th>0.2% ropivacaine, 20 mL (1 μg/mL fentanyl), 8 mL/h infusion</th>
<th>C (n=20) B (n=24)</th>
<th>Reduced pain scores</th>
<th>Reduced postoperative 48 h OC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Combined</strong></td>
<td></td>
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<tr>
<td>Gaweda/ 2020 [63]</td>
<td>Valve/ mini-thoracotomy approach</td>
<td>ESP, ESP + IPP-PSP</td>
<td>0.2 mL/kg 0.375% ropivacaine</td>
<td>ESP (n=15) ESP + IPP-PSP (n=15)</td>
<td>ESP + IPP-PSP block reduced OC and pain score</td>
<td>Increased patient satisfaction in ESP + IPP-PSP group</td>
</tr>
</tbody>
</table>

Abbreviations: CABG, coronary artery bypass graft; C, control group; B, block group; OC, opioid consumption; HR, heart rate; MAP, mean arterial pressure; MIDCAB, minimally invasive direct coronary artery bypass; INB, intercostal nerve block; PIP, parasternal intercostal plane; IPP, interpectoral plane; PSP, pectoserratus plane; SAP, serratus anterior plane; ESP, erector spinae plane; PONV, postoperative nausea and vomiting; ICU, intensive care unit; MOPS, modified objective pain score; NRS, numeric rating scale; PAED, pediatric anesthesia emergence delirium.
### Table 2. Injection points of the six techniques performed for cardiac surgery

<table>
<thead>
<tr>
<th>Blocks</th>
<th>Injection points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial parasternal intercostal plane (PIP) block</td>
<td>Superficial to the internal intercostal muscles and ribs and deep to the pectoralis major muscle</td>
</tr>
<tr>
<td>Deep PIP block</td>
<td>Between the internal intercostal and the transversus thoracis muscles</td>
</tr>
<tr>
<td>Interpectoral plane (IPP) block</td>
<td>Between the pectoralis major and pectoralis minor muscles</td>
</tr>
<tr>
<td>Pectoserratus plane (PSP) block</td>
<td>Between the pectoralis minor and serratus anterior muscles</td>
</tr>
<tr>
<td>Superficial serratus anterior plane (SAP) block</td>
<td>Superficial to the serratus anterior muscles</td>
</tr>
<tr>
<td>Deep SAP block</td>
<td>Between the posterior surface of the serratus anterior muscle and the periosteum of the rib</td>
</tr>
<tr>
<td>Erector spinae plane (ESP) block</td>
<td>Between the erector spinae muscles and the transverse process</td>
</tr>
<tr>
<td>Retrolaminar block</td>
<td>Between the erector spinae muscles and the lamina</td>
</tr>
</tbody>
</table>

Abbreviations: PIP, parasternal intercostal plane; IPP, interpectoral plane; PSP, pectoserratus plane; SAP, serratus anterior plane; ESP, erector spinae plane.
**Figure 1.** Sonoanatomy (A) and color doppler image of internal mammary artery (B) captured during parasagittal approach of superficial parasternal interfascial plane (PIP) block.
(A) The fascial plane between the pectoralis major and internal intercostal muscles (PIP) is indicated as a red solid line. Cartilages were captured as echolucent structures. (B) The internal mammary artery is captured as a red colored tubular structure on the long axis view.
Figure 2. Sonoanatomy (A) and color doppler image of internal mammary artery (B) captured during transverse approach of deep parasternal interfascial plane (PIP) block.
(A) The fascial plane between the internal intercostal and transversus thoracis muscles is the target for needle tip placement. Transversus thoracis muscle is often difficult to be clearly distinguished on an ultrasound image. The needle path of the transverse approach is indicated as a red solid line with an arrowhead. (B) The internal mammary artery is captured as a bright colored round structure on the short axis image. It should be visualized and used as a landmark in order to avoid inadvertent puncture.
Figure 3. Sonoanatomy of erector spinae plane (ESP; A) and retrolaminar (B) blocks.

(A) Note the transverse process of the spine captured as bright squared-off bony structures underneath the erector spinae muscle. The edge of the transverse process is a preferred target for the needle placement and slight advancement deeper off the edge may be needed to achieve proper spreading of injectate into the plane between the erector spinae muscle and the transverse process. (B) Note the flat structures (laminar) with small notches and overlying erector spinae muscle. Using an in-plane technique, needle can be introduced until the tip contacts with the laminar. The optimal needle positioning can be confirmed by observing proper spreading of injectate throughout the plane between the lamina and the erector spinae muscle.
Figure 4. Sonoanatomy of interpectoral plane (IPP) and pectoserratus plane (PSP) blocks (A), and deep- and superficial serratus anterior plane (SAP) blocks (B).
(A) The fascial planes between pectoralis major and minor muscles (IPP) and pectoralis minor and serratus anterior muscles (PSP) are indicated as red solid lines. Note that the probe is scanning the right upper quadrant chest wall (over the pectoralis muscles). (B) The planes superficial (superficial-SAP) or deep (deep-SAP) to the serratus anterior muscle are indicated as red solid lines. Note that the probe is scanning the lateral chest wall.