Journal of Cardiothoracic and Vascular Anesthesia 38 (2024) 964–973

Contents lists available at ScienceDirect

Journal of Cardiothoracic and Vascular Anesthesia

journal homepage: www.jcvaonline.com

Original Article

Clinical Outcomes of Erector Spinae Plane Block for Midline Sternotomy in Cardiac Surgery: A Systematic Review and Meta–Analysis

Jacob J. Greene, BSc[*,†], Sharon Chao, BSc[*], Ban C.H. Tsui, MD[*,1]

[*]*Department of Anesthesiology, Perioperative and Pain Medicine, Stanford University School of Medicine, Stanford, CA*

[†]*University of California - San Francisco School of Medicine, University of California - San Francisco, San Francisco, CA*

Objectives: To evaluate the benefit of single-shot erector spinae plane block (ESPB) on pain at postoperative hours 4 and 12, duration of mechanical ventilation, hospital length of stay, intensive care unit (ICU) length of stay, cumulative postoperative opioid usage, and incidence of postoperative nausea and vomiting (PONV) after cardiac surgery via sternotomy

Design: A systematic review and meta-analysis of randomized controlled trials and prospective clinical trials.

Setting: Studies were identified through the search of PubMed and EMBASE on July 19, 2023.

Participants: Adults and children undergoing cardiac surgery via sternotomy.

Interventions: Single-shot ESPB versus standard-of-care analgesia.

Measurements and Main Results: A systematic review and meta-analysis of 10 studies (N = 695 patients). The single-shot ESPB arm exhibited statistically significant reductions in pain score at postoperative hour 4 (standardized mean difference [SMD] −2.95, 95% CI −5.86 to -0.04, p = 0.0466), duration of mechanical ventilation (SMD −1.23, 95% CI −2.21 to −0.24, p = 0.0145), cumulative postoperative opioid usage (SMD −1.48, 95% CI −2.46 to −0.49, p = 0.0033), and PONV incidence (risk ratio 0.4358, 95% CI 0.2105-0.9021, p = 0.0252). The single-shot ESPB arm did not exhibit a statistically significant reduction in pain score at postoperative hour 12, length of hospital stay, and length of ICU stay.

Conclusions: Single-shot ESPB improves near-term clinical outcomes in patients undergoing cardiac surgery via sternotomy. More randomized controlled trials are needed to validate these findings.

Key Words: erector spinae plane block; cardiac surgery; sternotomy; analgesia

PAIN CONTROL is extremely important for cardiac surgery via sternotomy. Standard postoperative care after these surgeries relies on opioids for pain relief. However, opioid-based analgesia has been associated with a risk of longer intubation time and a greater risk of respiratory depression.[1] Prolonged mechanical ventilation dependence has been correlated with postoperative complications and increased mortality, thereby motivating the discovery of opioid-sparing analgesic alternatives to improve patient outcomes.[2,3] Recently, regional anesthetic techniques like the high thoracic epidural, paravertebral block, and erector spinae block have gained traction for their ability to effectively alleviate pain through the use of local anesthesia while reducing the risk of opioid side effects.[4-6]

Initially introduced in 2016, the erector spinae plane block (ESPB) has been used progressively in a multitude of surgeries. Later case reports in 2018 demonstrated ESPB's utility as a possible cardiac regional anesthetic technique that could aid in postoperative analgesia after cardiac surgery.[6] Most of the

Jacob Greene, in part supported by the Foundation for Anesthesia Education and Research Medical Student Anesthesia Research Fellowship; ID 1061300.

[1]*Address correspondence to* Ban C.H. Tsui, MD, Department of Anesthesiology, Perioperative and Pain Medicine, Stanford University School of Medicine, Stanford, CA 94305.

E-mail address: bantsui@stanford.edu (B.C.H. Tsui).

https://doi.org/10.1053/j.jvca.2023.12.014
1053-0770/

literature thus far has reported ESPB as effective, yet a clear consensus regarding its efficacy within cardiac surgery is still to be reached. Although individual studies are important indicators of regional block efficacy, each study has its own possible limitations that alter the impact of the intervention. To the authors' knowledge, 1 meta-analysis sought to evaluate the effect of the ESPB during cardiac surgery via sternotomy on 4-hour pain score, 12-hour pain score, time to extubation, and length of stay (LOS) in the intensive care unit (ICU).[7] However, the study included both single-shot and continuous ESPB infusion during cardiac surgery via sternotomy without subgroup analysis, only evaluated adult patients, and only included 5 studies for review. Hence, the authors aimed to perform this meta-analysis to garner a complete view of the impact of a bilateral single-shot ESPB on postextubation pain score, duration of mechanical ventilation, hospital LOS, ICU LOS, postoperative opioid usage, and frequency of postoperative nausea and vomiting (PONV) in adult and pediatric patients undergoing cardiac surgery via sternotomy.

Methods

Study Registration

To examine the ability of the bilateral single-shot ESPB to reduce postoperative pain, duration of mechanical ventilation, hospital and ICU LOS, postoperative opioid administration, and risk of developing PONV after cardiac surgery via sternotomy, a systematic review and meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[8] Accordingly, this study was registered with the International Prospective Register of Systematic Reviews (identification number: CRD42023441311).

Study Search and Selection

After registration, a search of electronic databases was performed. The 2 databases searched were PubMed and EMBASE (Fig 1, A). After searching, 2 independent reviewers screened, downloaded, and read publications. Only publications published in English were screened. Only studies that met inclusion criteria and did not violate exclusion criteria were included (Fig 1, B). An unbiased third reviewer resolved disagreements between reviewers 1 and 2.

Outcome Measures

The outcome measures of interest were decided a priori. These outcomes of interest were as follows: numerical rating score at postextubation hours 4 and 12 in terms of an 11-point visual analog scale, duration of mechanical intubation in terms of minutes, total amount of time spent in the hospital in terms of hours, total amount of time spent in the ICU in terms of hours, total cumulative postoperative opioid usage in terms of morphine milligram equivalents (MMEs) per kilogram of body weight administered, and incidence of PONV. Postextubation hours 4 and 12 were selected as time points because they fall within and beyond the previously published 12-[9] to 24-hour[10-12] analgesic window for single-shot ESPB, respectively, and they are commonly reported data points in studies. These outcomes were extracted for both the intervention and control arms of the included studies.

Data Extraction

Data from the included studies were extracted into spreadsheets by the independent reviewers. The original study authors did not need to be contacted for additional information beyond what was published in the manuscript and supplementary figures. The extracted data included the following: study title, digital object identifier, first author name, publication date, protocol for intervention arm, protocol for control arm, number of participants, number of participants by sex, number of participants by surgery type, age of participants in years (mean ± SD), body mass index of participants (mean ± SD), duration of surgery (mean ± SD), weight of participants in kilograms (mean ± SD), numerical rating score at postextubation hours 4 and 12 (mean ± SD), duration of mechanical intubation (mean ± SD), amount of time spent in the hospital (mean ± SD), amount of time spent in an ICU (mean ± SD), total cumulative MMEs per kilogram of body weight administered (mean ± SD), and incidence of PONV. For studies in which median and IQR were reported instead of mean and SD, the median was used to estimate the mean, and IQR/1.35 was used to estimate SD, as per sections 6.5.2.9 and 6.5.2.5 of the Cochrane Handbook for Systematic Reviews of Interventions version 6.3.[13] For studies in which the standard error was reported instead of SD, the standard error was multiplied by the square root of the sample size to calculate SD.

Risk of Bias Assessment

Two independent reviewers used the Cochrane risk-of-bias tool for randomized trials version 2 to assess the risk of bias.[14] Disagreements between reviewers were resolved by an unbiased third reviewer. The 5 domains analyzed were (1) "randomization process," (2) "deviations from intended interventions," (3) "missing outcomes data," (4) "measurement of the outcome," and (5) "selection of the reported result." Each domain was assigned a score of "low risk," "some concerns," or "high risk." The Cochrane risk-of-bias tool for randomized trials version 2 score of "some concerns" represented a medium risk. An overall bias score was assigned using this scoring system. Risk-of-bias VISualization tool was used to generate Supplementary Fig S1.[15]

Statistical Analysis of Outcomes

All statistical analyses were performed with the Metafor package in R version 4.3.0 (R Foundation for Statistical Computing). For statistical analysis of continuous outcome measures (numerical rating score at postextubation hours 4 and 12, duration of mechanical intubation, amount of time spent in the hospital, amount of time spent in an ICU, and total

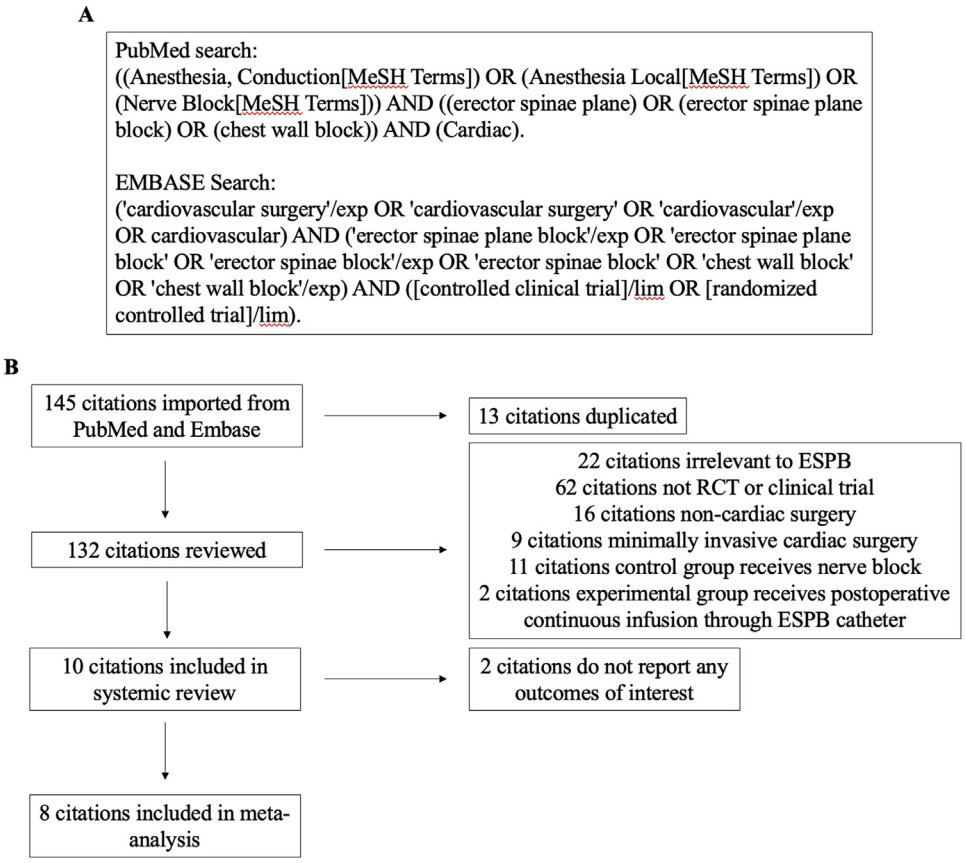

Fig 1. (A) PubMed and EMBASE search strategy. The search covered dates ranging from database creation through July 19, 2023. (B) The Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram for selection of studies. A total of 145 studies were returned in the initial search, and 13 of these studies were duplicates. The 132 unique studies were reviewed for inclusion or exclusion. Of the included 10 studies, 8 reported at least 1 outcome of interest for use in quantitative meta-analysis.

cumulative MME per kilogram of body weight administered), standardized mean differences (SMDs) were computed. A random-effects model was used to produce the pooled statistic and 95% CI. I^2 and Tau^2 statistics were used to assess between-study heterogeneity. The risk ratio (RR) was computed for statistical analysis of the binary outcome measure (incidence of PONV). A random-effects model was used to produce the pooled statistic and 95% CI. For all outcome measures, funnel plots were used to assess publication bias via visual symmetry as determined by 2 independent reviewers. The statistical approaches and analyses underwent a comprehensive review, evaluation, and approval by a qualified statistician.

Results

Study Selection

The search of electronic databases returned 145 citations, 13 of which were duplicates. Of the 132 unique citations, 10 citations were determined to meet the inclusion criteria, and of these 10 included studies, 8 reported data relevant to the authors' outcomes of interest (Fig 1, B). None of these studies were known to have missing outcomes data for individual participants. Study characteristics are presented in Table 1. In all 10 studies, patients undergoing cardiac surgery via sternotomy either received a bilateral single-shot ESPB with general anesthesia or received general anesthesia without a bilateral single-shot ESPB.[16-25] In all included studies, bilateral single-shot ESPB was performed immediately before or immediately after induction. In 7 of the studies, patients were older than or equal to 18 years.[16-19,23-25] In 3 of the studies, patients were younger than 18 .[20-22] Demographic information of included studies are presented in Table 2. None of the between-group comparisons for any demographic variable measured in the original citations had a p value ≤ 0.05.[16-25]

Self-Reported Pain Score at Postextubation Hour Four

A total of 4 studies reported pain scores at postextubation hour 4.[16,21-23] One hundred twenty-eight patients received a bilateral single-shot ESPB, and 126 patients received standard-of-care analgesia. Patients who received a bilateral single-shot ESPB had lower self-reported pain at postextubation hour 4 compared to the control arm (SMD = −2.95, 95% CI = −5.86 to −0.04, p = 0.0466) (Fig 2). Significant statistical heterogeneity was observed (I^2 = 98.4%, Tau^2 = 8.645, and p < 0.001) (Fig 2). The funnel plot of publication bias showed relative asymmetry (Supplementary Fig S2). The overall risk of bias arising from the design and execution of each study

Table 1
Characteristics of included studies

Author	Year	Study Type	Population	Intervention	Control	GA	PCA
Athar[16]	2021	Double-blind RCT	Adults	ESPB	Sham ESPB	Both arms	Both arms
Balan (2022)[18]	2022	NR RCT	Adults	ESPB	No block	Both arms	Both arms
Balan (2023)[17]	2023	NR RCT	Adults	ESPB	No block	Both arms	Both arms
Demir[19]	2022	NR RCT	Adults	ESPB	No block	Both arms	Both arms
Gado[20]	2022	Double-blind RCT	Children	ESPB	No block	Both arms	Both arms
Karacaer[21]	2022	Triple-blind RCT	Children	ESPB	No block	Both arms	Both arms
Kaushal[22]	2020	Single-blind RCT	Children	ESPB	No block	Both arms	Both arms
Krishna[23]	2019	Single-blind RCT	Adults	ESPB	No block	Both arms	Both arms
Silva[24]	2022	NR RCT	Adults	ESPB	No block	Both arms	Both arms
Wiech[25]	2022	Prospective cohort study	Adults	ESPB	No block	Both arms	Both arms

Abbreviations: ESPB, bilateral single-shot erector spinae plane block; GA, general anesthesia; NR, blinding not reported in original study; PCA, patient-controlled analgesia; RCT, randomized controlled trial.

was judged as "low" in all 4 studies[16,21-23] (Supplementary Fig S1).

Self-Reported Pain Score at Postextubation Hour 12

A total of 6 studies reported pain scores at postextubation hour 12.[16,18,21-23,25] One hundred ninety-five patients received a bilateral single-shot ESPB, and 193 patients received standard-of-care analgesia. Patients who received a bilateral single-shot ESPB did not have a statistically significant difference in self-reported pain at postextubation hour 12 compared to the control arm (SMD = −0.66, 95% CI = −1.44 to 0.12, p = 0.0983) (Fig 3). Significant statistical heterogeneity was observed (I^2 = 92.1%, Tau^2 = 0.871, and p < 0.001) (Fig 3). The funnel plot of publication bias showed relative symmetry (Supplementary Fig S3). The overall risk of bias arising from the design and execution of each study was judged as "low risk" in 5 studies[16,18,21-23] and "some concerns" (medium risk) in one study[25] (Supplementary Fig S4).

Duration of Mechanical Ventilation

A total of 7 studies reported the duration of mechanical ventilation.[16,18,19,21-23,25] Two hundred thirty-two patients received a bilateral single-shot ESPB, and 224 patients received standard-of-care analgesia. Patients who received a bilateral single-shot ESPB had a lower duration of mechanical ventilation than the control arm (SMD = −1.23, 95% CI = −2.21 to −0.24, p = 0.0145) (Fig 4). Significant statistical heterogeneity was observed (I^2 = 95.3%, Tau^2 = 1.674, and p < 0.001) (Fig 4). The funnel plot of publication bias showed relative symmetry (Supplementary Fig S5). The overall risk of bias arising from the design and execution of each study was judged as "low risk" in 6 studies[16,18,19,21-23] and "some concerns" (medium risk) in 1 study[25] (Supplementary Fig S6).

Length of Hospital Stay

A total of 4 studies reported length of hospital stay.[18,19,21,25] One hundred twenty-four patients received a bilateral single-shot ESPB, and 118 patients received standard-of-care analgesia. Patients who received a bilateral single-shot ESPB did not have a statistically significant difference in length of hospital stay compared to the control arm (SMD = −0.08, 95% CI = −0.79 to 0.63, p = 0.828) (Fig 5). Significant statistical heterogeneity was observed (I^2 = 86.3%, Tau^2 = 0.447, and p < 0.001) (Fig 5). The funnel plot of publication bias showed relative asymmetry (Supplementary Fig S7). The overall risk of bias arising from the design and execution of each study was judged as "low risk" in 3 studies[18,19,21] and "some concerns" (medium risk) in 1 study[25] (Supplementary Fig S8).

Length of ICU Stay

A total of 5 studies reported length of ICU stay.[18,19,21-23] One hundred ninety patients received a bilateral single-shot ESPB, and 187 patients received standard-of-care analgesia. Patients who received a bilateral single-shot ESPB did not have a statistically significant difference in length of ICU stay compared to the control arm (SMD = −2.81, 95% CI = −7.78 to 2.16, p = 0.268) (Fig 6). Significant statistical heterogeneity was observed (I^2 = 99.7%, Tau^2 = 31.944, and p < 0.001) (Fig 6). The funnel plot of publication bias showed relative asymmetry (Supplementary Fig S9). The overall risk of bias arising from the design and execution of each study was judged as "low" in all 5 studies[18,19,21-23] (Supplementary Fig S10).

Postoperative Opioid Use

A total of 6 studies reported cumulative postoperative opioid usage.[18,20-23,25] Two hundred thirty patients received a bilateral single-shot ESPB, and 228 patients received

Table 2
Demographics of Included Studies

Author	Total (N) Sex (N)		Age, mean ± SD, y		BMI, mean ± SD		Surgery Type, N		Surgery Duration mean ± SD, min	
	ESPB	CTL	ESPB	CTL	ESPB	CTL	ESPB	CTL	ESPB	CTL
Athar[16]	Total (15) Male (13) Female (2)	Total (13) Male (NR) Female (NR)	54.5 ± 4.2	55.2 ± 3.9	26.3 ± 2.6	25.8 ± 2.3	CABG (6) MVR (5) AVR (4)	CABG (7) MVR (5) AVR (3)	165 ± 31	171 ± 25
Balan (2022)[18]	Total (40) Male (26) Female (14)	Total (43) Male (26) Female (17)	61.5 ± 10.4	63 ± 10.4	28.9 ± 3.9	29.6 ± 4.9	CABG (16) CABG + VR (4) AVR (9) MVR (6) ASDR (2) VSDR (1) MR (1) AAAR (1)	CABG (19) CABG + VR (3) AVR (15) MVR (1) A+M VR (1) MR (2) AAAR (2)	286 ± 58.4	296.8 ± 64.1
Balan (2023)[17]	Total (42) Male (27) Female (15)	Total (43) Male (26) Female (17)	62 ± 10.6	63 ± 10.4	28.6 ± 4	29.6 ± 4.9	CABG ± VS (20) VS (17) Misc (5)	CABG ± VS (22) VS (17) Misc (4)	283.3 ± 59	296.8 ± 64.1
Demir[19]	Total (37) Male (26) Female (11)	Total (31) Male (24) Female (7)	61.1 ± 10.7	56.2 ± 12.6	27.9 ± 2.9	27.3 ± 3.9	CABG (28) AVR (4) MVR (3) A+M VR (1) CABG + VR (1)	CABG (24) MVR (3) A+M VR (3) MR (1)	NR	NR
Gado[20]	Total (50) Male (22) Female (28)	Total (48) Male (21) Female (27)	2.4 ± 2.1	2.8 ± 2.1	NR	NR	VSDR (27) ASDR (11) AVSDR (8) SAMR (3) PAB (1)	VSDR (19) ASDR (14) AVSDR (10) SAMR (2) MVR (2) SVASR (1)	145.9 ± 23.7	142.8 ± 27.8
Karacaer[21]	Total (20) Male (11) Female (9)	Total (20) Male (10) Female (10)	6 ± 2.3	6 ± 2.6	NR	NR	ASDR (8) VSDR (10) AME (2)	ASDR (8) VSDR (11) AME (1)	181.1 ± 34.3	143 ± 41.2
Kaushal[22]	Total (40) Male (22) Female (18)	Total (40) Male (23) Female (17)	2.4 ± 1.8	2.5 ± 2	NR	NR	ASDR (25) VSDR (15)	ASDR (28) VSDR (12)	NR	NR
Krishna[23]	Total (53) Male (31) Female (22)	Total (53) Male (30) Female (23)	48.3 ± 1.7	49.6 ± 1.5	25.0 ± 0.1	24.0 ± 0.1	CABG (26) ASDR (13) MVR (14)	CABG (27) ASDR (11) MVR (15)	NR	NR
Silva[24]	Total (25) Male (NR) Female (NR)	Total (29) Male (NR) Female (NR)	NR	NR	NR	NR	NR	NR	NR	NR
Wiech[25]	Total (27) Male (24) Female (3)	Total (24) Male (22) Female (2)	64.7 ± NR	67.1 ± NR	29.1 ± NR	28.6 ± NR	CABG (27)	CABG (24)	159 ± NR	163 ± NR

Abbreviations: AAAR, abdominal aortic aneurysm repair; A+M VR, aortic valve replacement or repair with mitral valve replacement or repair; AME, aortic membrane excision; ASDR, atrial septal defect repair; AVR, aortic valve replacement or repair; AVSDR, atrioventricular septal defect repair; BMI, body mass index; CABG, coronary artery bypass graft; CABG + VR, coronary artery bypass graft with valve replacement; CABG ± VS, coronary artery bypass graft with or without valve surgery; CTL, control; ESPB, bilateral single-shot erector spinae plane block; Misc, miscellaneous cardiac surgery; MR, myxoma resection; MVR, mitral valve replacement or repair; NR, not reported in original study; PAB, pulmonary artery banding; SAMR, subaortic membrane resection; SVASR, supravalvular aortic stenosis repair; VR, valve replacement; VS, valve surgery; VSDR, ventricular septal defect repair.

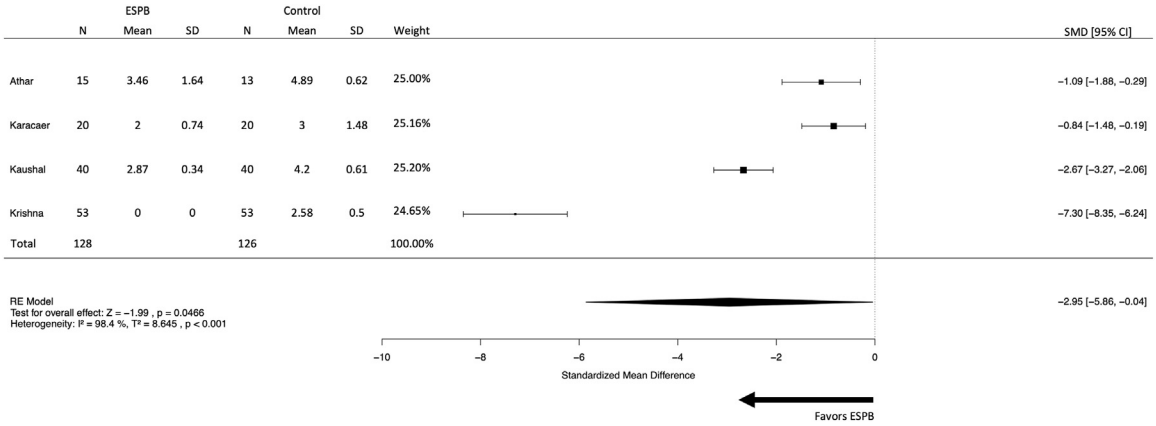

Fig 2. Forest plot of self-reported pain score at postextubation hour 4. The following 4 studies were included in the comparison between the bilateral single-shot bilateral single-shot erector spinae plane block arm versus the control arm: Athar,[16] Karacaer,[21] Kaushal,[22] and Krishna.[23] Standardized mean difference equals −2.95 (−5.86 to −0.04). Data in the table are presented in terms of the 11-point numeric rating scale. ESPB, bilateral single-shot erector spinae plane block; RE, random effects; SMD, standardized mean difference; T, tau.

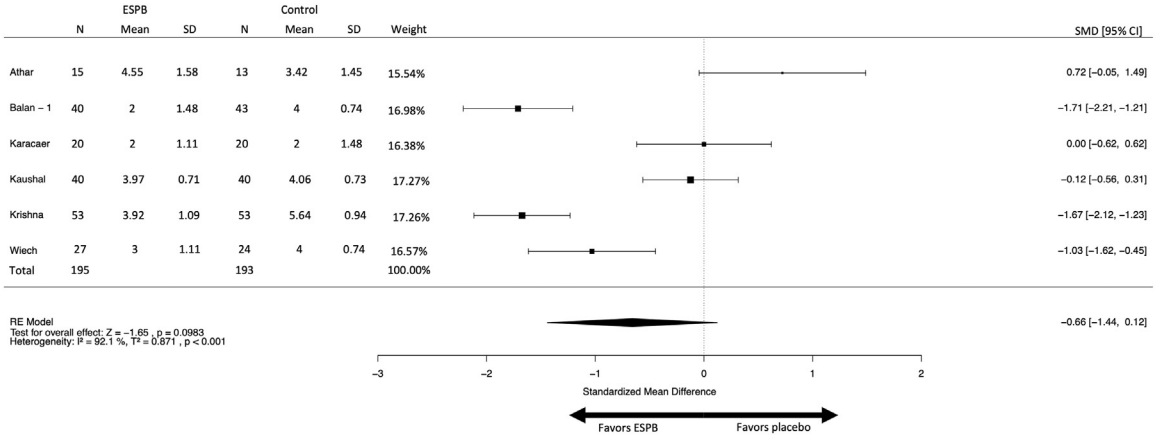

Fig 3. Forest plot of self-reported pain score at postextubation hour 12. The following 6 studies were included in the comparison between the bilateral single-shot bilateral single-shot erector spinae plane block arm versus the control arm: Athar,[16] Balan (2022),[18] Karacaer,[21] Kaushal,[22] Krishna,[23] and Wiech.[25] Standardized mean difference equals −0.66 (−1.44 to 0.12). Data in the table are presented in terms of the 11-point numeric rating scale. ESPB, bilateral single-shot erector spinae plane block; RE, random effects; SMD, standardized mean difference; T, tau.

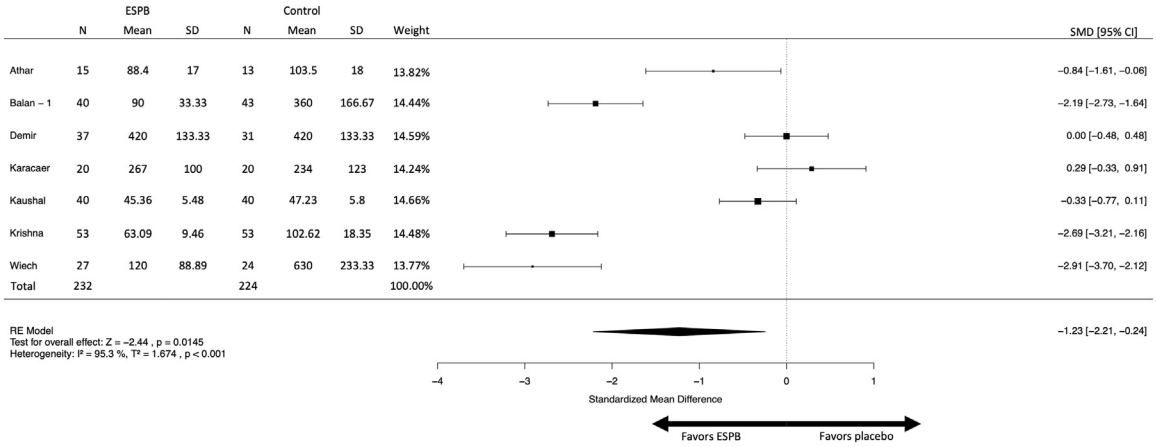

Fig 4. Forest plot of duration of mechanical ventilation. The following 7 studies were included in the comparison between the bilateral single-shot bilateral single-shot erector spinae plane block arm versus the control arm: Athar,[16] Balan (2022),[18] Demir,[19] Karacaer,[21] Kaushal,[22] Krishna,[23] and Wiech.[25] Standardized mean difference equals −1.23 (−2.21 to −0.24). Data in the table is presented in terms of minutes. ESPB, bilateral single-shot erector spinae plane block; RE, random effects; SMD, standardized mean difference; T, tau.

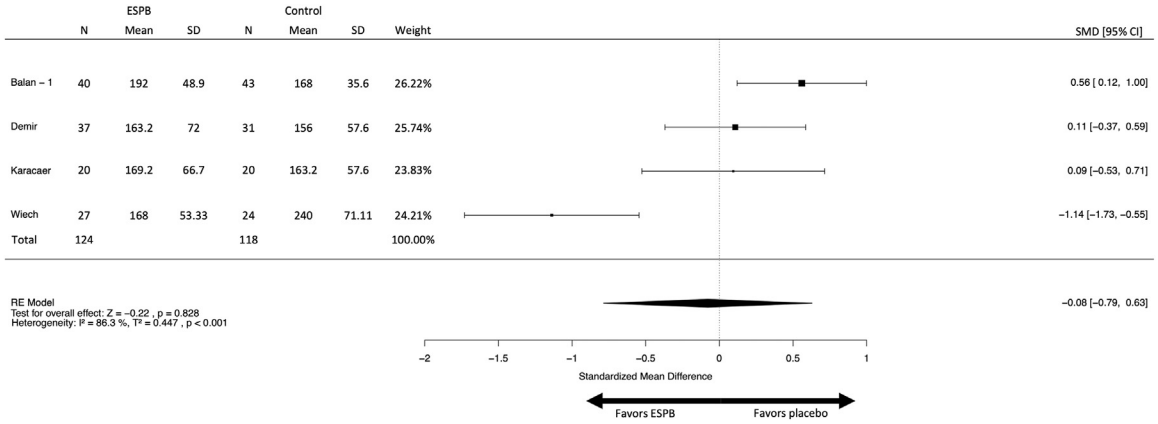

Fig 5. Forest plot of length of hospital stay. The following 4 studies were included in the comparison between the bilateral single-shot bilateral single-shot erector spinae plane block arm versus the control arm: Balan (2022),[18] Demir,[19] Karacaer,[21] and Wiech.[25] Standardized mean difference equals −0.08 (−0.79 to 0.63). Data in the table are presented in terms of hours. ESPB, bilateral single-shot erector spinae plane block; RE, random effects; SMD, standardized mean difference; T, tau.

standard-of-care analgesia. Patients who received a bilateral single-shot ESPB had lower cumulative postoperative opioid usage compared to the control arm (SMD = −1.48, 95% CI = −2.46 to −0.49, p = 0.0033) (Fig 7). Significant statistical heterogeneity was observed (I^2 = 95.3%, Tau^2 = 1.439, and p < 0.001) (Fig 7). The funnel plot of publication bias showed relative asymmetry (Supplementary Fig S11). The overall risk of bias arising from the design and execution of each study was judged as "low risk" in 4 studies[18,21-23] and "some concerns" (medium risk) in 2 studies[20,25] (Supplementary Fig S12).

PONV

A total of 5 studies reported PONV.[16,18,20-22] One hundred sixty-five patients received a bilateral single-shot ESPB, and 166 patients received standard-of-care analgesia. Patients who received a bilateral single-shot ESPB had a reduction in the incidence of PONV compared to the control arm (RR = 0.4358, 95% CI = 0.2105-0.9021, p = 0.0252) (Table 3). No significant statistical heterogeneity was observed (I^2 = 0.0%, Tau^2 = 0, and p = 0.824) (Table 3). The funnel plot of publication bias showed relative symmetry (Supplementary Fig S13). The overall risk of bias arising from the design and execution of each study was judged as "low risk" in 4 studies[16,18,21,22] and "some concerns" (medium risk) in 1 study[20] (Supplementary Fig S14).

Discussion

The ESPB has been used increasingly in various surgeries since its initial description in 2016.[26] However, the impact of the ESPB on clinical outcomes after cardiac surgery via midline sternotomy has yet to be well-established. The results of this meta-analysis showed that the bilateral single-shot ESPB had a statistically significant effect in decreasing patient self-reported pain at postextubation hour 4 (Fig 2), duration of mechanical ventilation (Fig 4), cumulative postoperative opioid usage (Fig 7), and incidence of PONV (Table 3) compared to standard-of-care, multimodal analgesia with or without a

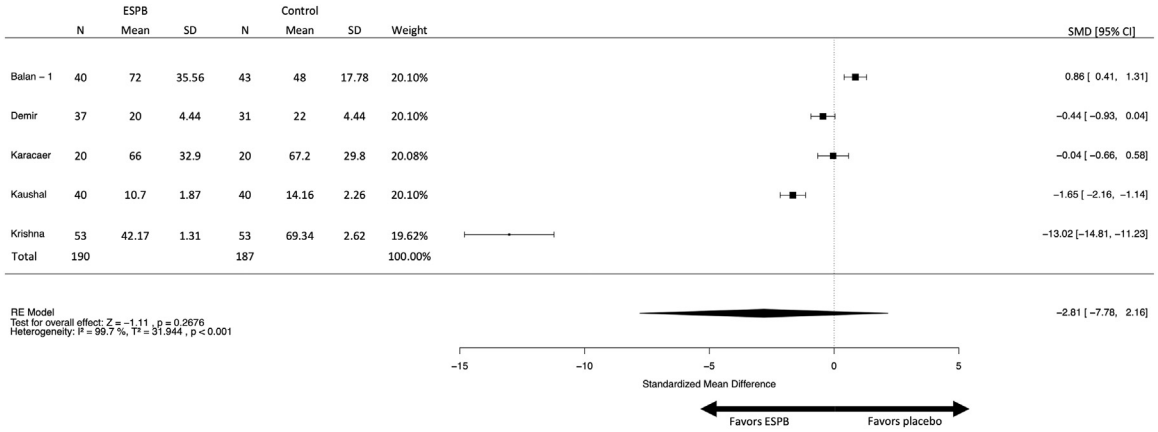

Fig 6. Forest plot of length of intensive care unit stay. The following 5 studies were included in the comparison between the bilateral single-shot erector spinae plane block arm versus the control arm: Balan (2022),[18] Demir,[19] Karacaer,[21] Kaushal,[22] and Krishna.[23] Standardized mean difference equals −2.81 (−7.78 to 2.16). Data in the table are presented in terms of hours. ESPB, bilateral single-shot erector spinae plane block; ICU, intensive care unit; RE, random effects; SMD, standardized mean difference; T, tau.

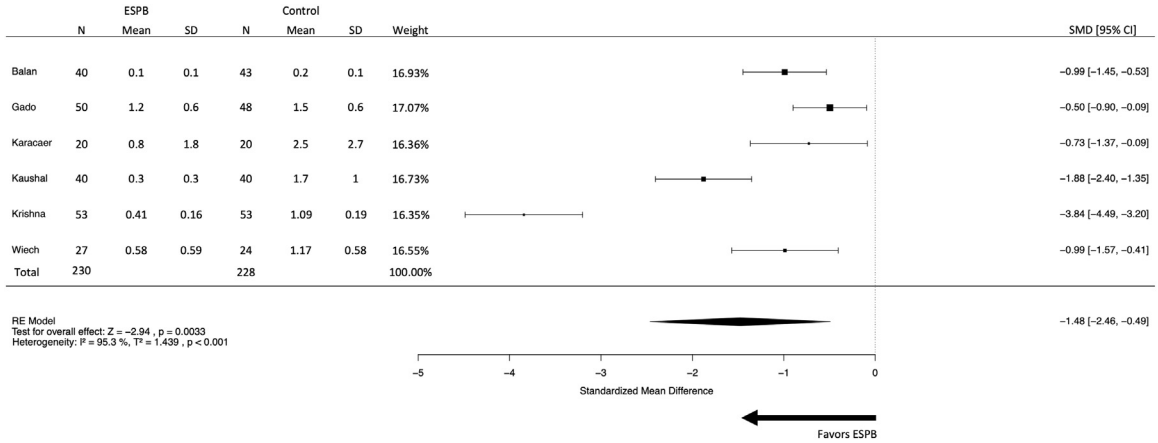

Fig 7. Forest plot of postoperative opioid use. The following 6 studies were included in the comparison between the bilateral single-shot erector spinae plane block arm versus the control arm: Balan (2022),[18] Gado,[20] Karacaer,[21] Kaushal,[22] Krishna,[23] and Wiech.[25] Standardized mean difference equals −1.48 (−2.46 to −0.49). Data in the table are presented in terms of morphine milligram equivalent per kg. ESPB, bilateral single-shot erector spinae plane block; kg, kilogram of body weight; MME, morphine milligram equivalent; RE, random effects; SMD, standardized mean difference; T, tau.

sham bilateral single-shot ESPB with only sterile saline. On the other hand, this meta-analysis suggested that the bilateral single-shot ESPB did not have a statistically significant effect on patient self-reported pain at post-extubation hour 12 (Fig 3), length of hospital stay (Fig 5), and length of ICU stay (Fig 6).

Although bilateral single-shot ESPB reduced the duration of mechanical ventilation, it did not reduce the length of ICU stay. Although mechanical ventilation is one key reason for admission to the ICU, there are many other criteria for ICU admission, including frequent and/or invasive hemodynamic monitoring and frequent medication titration.[27] Such factors are unlikely to be affected by ESPB's analgesic effects.

Multiple meta-analyses have reported that the analgesic effects of the bilateral single-shot ESPB diminish after 12 hours[9] to 24 hours.[10-12] Four- and 12-hour pain scores were chosen as time points to evaluate self-reported pain scores because the 4-hour pain score is within the analgesic window for single-shot ESPB, whereas the 12-hour pain score lies outside of it. Given the single-shot ESPB's analgesic window of fewer than 12-to-24 hours, an intermittent or continuous analgesic delivery through the catheter is likely needed to impact the outcomes of interest with time horizons exceeding 12-to-24 hours, such as 12-hour pain score, length of hospital stay, and length of ICU stay. To the best of the authors' knowledge, only 2 randomized controlled trials have reported 12-hour pain scores while receiving ESPB via continuous infusion.[28,29] The 12-hour pain scores of the experimental groups were significantly lower than those of the control groups in both studies. These 2 studies did not qualify for inclusion in the meta-analysis because they used a continuous infusion of ESPB.

Although the findings of this study demonstrated statistical significance, the clinical importance remains debatable. This is because the measure of effect reported in this study for

Table 3
Risk Ratio of Postoperative Nausea and Vomiting

	ESPB		Control			
Study	Events	Total	Events	Total	Weight	Risk Ratio [95% CI]
Athar[16]	1	15	4	15	12.34%	0.2500 (0.0315,-1.9835)
Balan (2022)[18]	0	40	3	43	6.16%	0.1534 (0.0082-2.8796)
Gado[20]	2	50	4	48	19.43%	0.4800 (0.0921-2.5007)
Karacaer[21]	1	20	4	20	11.98%	0.2500 (0.0306-2.0453)
Kaushal[22]	5	40	8	40	50.10%	0.6250 (0.2236-1.7468)
Total	9	165	23	166	100.00%	0.4358 (0.2105-0.9021)
Test for overall effect	Z = −2.24					
	p = 0.0252					
Heterogeneity	I^2 = 0.0%					
	T^2 = 0.0					
	p = 0.824					

The following 5 studies were included in comparison between the bilateral single-shot ESPB arm versus the control arm: Athar,[16] Balan (2022),[18] Gado,[20] Karacaer,[21] and Kaushal.[22] Risk ratio equals 0.4358 (0.2105-0.9021).
Abbreviation: ESPB, bilateral singe-shot erector spinae plane block.

outcomes clinically reported on a continuous scale was reported as SMD—a unitless measure of effect.[13] Reporting these outcomes as SMD minimized interstudy variance and, thus, minimized the skew of the overall measure of effect. However, SMD can be challenging to interpret clinically. When reported in terms of the units from the data table presented in each outcome's forest plot, bilateral single-shot ESPB reduced 4-hour postextubation pain score by 1.64 points on a numerical rating score from 0 to 10 compared to the standard-of-care analgesia patients undergoing cardiac surgery via midline sternotomy (Fig 2). It also reduced the duration of mechanical ventilation by 111.89 minutes (Fig 4), and reduced cumulative postoperative opioid usage by 0.67 MMEs per kilogram of body weight (Fig 7). In meta-analyses, however, comparability among studies is more limited using mean difference than SMD.[13] This is why SMD is the standard way of reporting outcome effect sizes. The incidence of PONV in the bilateral single-shot ESPB versus the standard-of-care analgesia patients after cardiac surgery via midline sternotomy is reported as an RR of 0.4358 (Table 3). Thus, the risk of developing PONV in the bilateral single-shot ESPB patients was 0.4358 times that of the standard-of-care analgesia patients. Because opioids are known to increase the risk of developing PONV, this observation may have been due to the reduction in cumulative postoperative opioid usage.[30] The aforementioned parameters exhibited statistically significant results per their respective figures; however, the sustained clinical significance of these limited improvements remains questionable.[31]

A previous meta-analysis by King et al. evaluated the effect of mixed-type (ie, both single-shot and continuous infusion) ESPB in cardiac surgery via midline sternotomy, and suggested no improvement in 4-hour pain score, 12-hour pain score, intraoperative opioid use, time to extubation, and ICU LOS.[7] King et al. did not perform subgroup analysis of the single-shot and continuous ESPB groups, analyzed only 5 citations with a total sample size of 319 participants, only analyzed studies with adults, and did not evaluate key outcomes such as cumulative postoperative opioid usage, the incidence of PONV, and total length of hospital stay.[7]

Explanations for the difference in findings between King et al. and this updated systematic review and meta-analysis include the following: this study only evaluated the effect of the bilateral single-shot ESPB; analyzed 10 citations with a total sample size of 695 participants; analyzed studies with both adults and children; and evaluated key outcomes, such as cumulative postoperative opioid usage, the incidence of PONV, and total length of hospital stay. Thus, the findings of this updated meta-analysis provide a more up-to-date and comprehensive review of the clinical impact of a bilateral single-shot ESPB in patients undergoing cardiac surgery via midline sternotomy.

Study Limitations

This meta-analysis had several limitations. Since the ESPB was first described in 2016, 10 studies were included in this systematic review, and 8 studies were included in the meta-analysis.[26] Within those studies, there was variability in the type and volume of local anesthetics used, as not all studies reported the average mass of patients for each ESPB's given dose per kilogram of body weight. Additionally, not all studies reported patients being blinded to the block procedure. In Krishna et al.,[23] bilateral single-shot ESPB was administered before general anesthesia. Thus, patients were not blinded to their experimental arm. Despite also placing bilateral single-shot ESPB before general anesthesia, Athar et al.[16] used a sham block in patients assigned to the control arm. Patients were blinded to their trial assignment. Other studies did not use a sham block but rather only standard-of-care analgesia. The lack of patient blindness to trial assignment in Krishna et al.[23] could have influenced their self-reported pain scores. Hence, a sensitivity analysis was conducted in Supplementary Fig S15, wherein the data from Krishna et al.[23] were excluded from the dataset for the postextubation hour 4. The statistical significance remained strong even after excluding the study conducted by Krishna et al. (with Krishna et al., $p = 0.0466$; without Krishna et al., $p = 0.008$). In other words, removing Krishna et al.[23] from the included studies for the postextubation hour 4 forest plot did not change the statistical significance or interpretation of the results (Supplementary Fig S15).

The SMD calculated for Krishna et al.'s ICU LOS seemed unusually low due to the very small standard error originally reported in the paper (Fig 6). However, removing Krishna et al.[23] from the included studies in this analysis did not change the statistical significance or interpretation of the results (Supplementary Fig S16). Lastly, based on the relative symmetry of the funnel plots, there was no evidence of publication bias in pain score at postextubation hour 12, duration of mechanical ventilation, and incidence of PONV (Supplementary Figs S3, S5, and S13), but there was evidence of publication bias in pain score at post-extubation hour 4, length of hospital stay, length of ICU stay, and cumulative postoperative opioid usage (Supplementary Figs S1, S7, S9, and S11).

In conclusion, this study found a statistically significant reduction in self-reported pain at postextubation hour 4, duration of mechanical ventilation, cumulative postoperative opioid usage, and incidence of PONV in patients undergoing cardiac surgery via midline sternotomy who receive a bilateral single-shot ESPB compared to standard-of-care analgesia. These findings were consistent with the analgesic window of the single-shot ESPB. However, the extent to which these reductions are clinically meaningful still needs to be determined. This uncertainty in clinical significance, combined with evidence for publication bias, reveal a need for more randomized controlled trials with continuous- or intermittent-infusion ESPB versus standard-of-care analgesia in patients undergoing cardiac surgery via midline sternotomy. The longer analgesic effect duration can better reveal the clinical benefit of the ESPB.

Declaration of competing interest

None.

Acknowledgments

Karla Lindquist, PhD, at the University of California, San Francisco, for reviewing and attesting to the validity of the statistical methods and presented results.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1053/j.jvca.2023.12.014.

References

[1] Caruso TJ, Lawrence K, Tsui BCH. Regional anesthesia for cardiac surgery. Curr Opin Anesthesiol 2019;32:674.
2 Agarwal HS, Wolfram KB, Saville BR, et al. Postoperative complications and association with outcomes in pediatric cardiac surgery. J Thorac Cardiovasc Surg 2014;148;609-616.e1.
3 Liu J, Zhang S, Chen J, et al. Risk factors for ventilator-associated events: A prospective cohort study. Am J Infect Control 2019;47:744–9.
4 Guay J, Kopp S. Epidural analgesia for adults undergoing cardiac surgery with or without cardiopulmonary bypass. Cochrane Database Syst Rev 2019;3:CD006715.
5 Yeung JHY, Gates S, Naidu BV, et al. Paravertebral block versus thoracic epidural for patients undergoing thoracotomy. Cochrane Database Syst Rev 2016;2:CD009121.
6 Tsui BCH, Navaratnam M, Boltz G, et al. Bilateral automatized intermittent bolus erector spinae plane analgesic blocks for sternotomy in a cardiac patient who underwent cardiopulmonary bypass: A new era of Cardiac Regional Anesthesia. J Clin Anesth 2018;48:9–10.
7 King M, Stambulic T, Servito M, et al. Erector spinae plane block as perioperative analgesia for midline sternotomy in cardiac surgery: A systematic review and meta-analysis. J Card Surg 2022;37:5220–9.
8 Moher D, Liberati A, Tetzlaff J, et al. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. J. Clin. Epidemiol. 2009;62:1006–12.
9 Koo C-H, Hwang J-Y, Shin H-J, et al. The effects of erector spinae plane block in terms of postoperative analgesia in patients undergoing laparoscopic cholecystectomy: A meta-analysis of randomized controlled trials. J. Clin. Med. 2020;9:2928.
[10] Yang X, Zhang Y, Chen Y, et al. Analgesic effect of erector spinae plane block in adults undergoing laparoscopic cholecystectomy: a systematic review and meta-analysis of randomized controlled trials. BMC Anesthesiol 2023;23:7.
[11] Zhang Y, Liu T, Zhou Y, et al. Analgesic efficacy and safety of erector spinae plane block in breast cancer surgery: a systematic review and meta-analysis. BMC Anesthesiol 2021;21:59.
12 Gao Y, Liu L, Cui Y, et al. Postoperative analgesia efficacy of erector spinae plane block in adult abdominal surgery: A systematic review and meta-analysis of randomized trials. Front Med (Lausanne) 2022;9:934866.
[13] Higgins J, Thomas J, Chandler J, et al. Cochrane Handb. Syst. Rev. Interv. Version 6.3. Retrieved from: https://training.cochrane.org/handbook/current
14 Sterne JAC, Savović J, Page MJ, et al. RoB 2: A revised tool for assessing risk of bias in randomised trials. BMJ 2019;366:l4898.
15 McGuinness LA, Higgins JPT. Risk-of-bias VISualization (robvis): An R package and Shiny web app for visualizing risk-of-bias assessments. Res Synth Methods 2021;12:55–61.
16 Athar M, Parveen S, Yadav M, et al. A randomized double-blind controlled trial to assess the efficacy of ultrasound-guided erector spinae plane block in cardiac surgery. J Cardiothorac Vasc Anesth 2021;35:3574–80.
17 Balan C, Tomescu DR, Bubenek-Turconi SI. Nociception control of bilateral single-shot erector spinae plane block compared to no block in open heart surgery—A post hoc analysis of the NESP randomized controlled clinical trial. Medicina (Kaunas) 2023;59:265.
18 Balan C, Tomescu DR, Valeanu L, et al. Nociception level index-directed erector spinae plane block in open heart surgery: A randomized controlled clinical trial. Medicina (Kaunas) 2022;58:1462.
19 Demir AZ, Özgök A, Balcı E, et al. Preoperative ultrasound-guided bilateral thoracic erector spinae plane block within an enhanced recovery program is associated with decreased intraoperative lactate levels in cardiac surgery. Perfusion 2022;02676591221140754. Online ahead of print.
20 Ali Gado A, Alsadek WM, Ali H, et al. Erector spinae plane block for children undergoing cardiac surgeries via sternotomy: A randomized controlled trial. Anesthesiol Pain Med 2022;12:e123723.
21 Karacaer F, Biricik E, Ilgınel M, et al. Bilateral erector spinae plane blocks in children undergoing cardiac surgery: A randomized, controlled study. J Clin Anesth 2022;80:110797.
22 Kaushal B, Chauhan S, Magoon R, et al. Efficacy of bilateral erector spinae plane block in management of acute postoperative surgical pain after pediatric cardiac surgeries through a midline sternotomy. J Cardiothorac Vasc Anesth 2020;34:981–6.
23 Krishna SN, Chauhan S, Bhoi D, et al. Bilateral erector spinae plane block for acute post-surgical pain in adult cardiac surgical patients: A randomized controlled trial. J Cardiothorac Vasc Anesth 2019;33:368–75.
24 Silva LM, Brandão AJFM, Godoy JT, et al. Postoperative analgesia efficacy of erector spinae plane block in patients submitted to cardiac surgery: Randomized clinical trial. Braz J Anesthesiol 2022;72:678–9.
25 Wiech M, Żurek S, Kurowicki A, et al. Erector spinae plane block decreases chronic postoperative pain severity in patients undergoing coronary artery bypass grafting. J Clin Med 2022;11:5949.
26 Forero M, Adhikary SD, Lopez H, et al. The erector spinae plane block: A novel analgesic technique in thoracic neuropathic pain. Reg Anesth Pain Med 2016;41:621–7.
27 Nates JL, Nunnally M, Kleinpell R, et al. ICU admission, discharge, and triage guidelines: A framework to enhance clinical operations, development of institutional policies, and further research. Crit Care Med 2016;44:1553.
28 Kodali VRK, Shree S, Prasad M, et al. A comparative study of bilateral erector spinae block versus intravenous dexmedetomidine for perioperative pain management in patients undergoing off-pump coronary artery bypass grafting - A single-blind randomized controlled trial. J Cardiothorac Vasc Anesth 2022;36:4085–92.
29 Wasfy SF, Kamhawy GA, Omar AH, et al. Bilateral continuous erector spinae block versus multimodal intravenous analgesia in coronary bypass surgery. A randomized trial. Egypt J. Anaesth 2021;37:152–8.
30 Frauenknecht J, Kirkham KR, Jacot-Guillarmod A, et al. Analgesic impact of intra-operative opioids vs. opioid-free anaesthesia: a systematic review and meta-analysis. Anaesthesia 2019;74:651–62.
31 Sharma H. Statistical significance or clinical significance? A researcher's dilemma for appropriate interpretation of research results. Saudi J Anaesth 2021;15:431–4.