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Erector spinae plane block reduces opioid consumption and improves incentive spirometry volume after cardiac surgery: A retrospective cohort study

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Abstract

Background: Effective postoperative pain management is vital in cardiac surgery to prevent opioid dependency and respiratory complications. Previous studies on the erector spinae plane (ESP) block have focused on single-shot applications or immediate postoperative outcomes. This study evaluates the efficacy of continuous ESP block vs conventional care in reducing opioid consumption and enhancing respiratory function recovery postcardiac surgery over 72 hours.

Methods: A retrospective study at a tertiary hospital (January 2021–July 2022) included 262 elective cardiac surgery patients. Fifty-three received a preoperative ESP block, matched 1:1 with a control group (n = 53). The ESP group received 0.5% ropivacaine intraoperatively and 0.16% ropivacaine every 4 hours postoperatively. Outcomes measured were cumulative oral morphine equivalent (OME) dose within 72 hours postextubation, daily maximum numerical rating scale (NRS) ≥3, incentive spirometry volume, and %baseline performance, stratified by surgery type (sternotomy or thoracotomy).

Results: Significant OME reduction was observed in the ESP group (sternotomy: median decrease of 113 mg, 95% CI: 60–157.5 mg, $p < 0.001$; thoracotomy: 172.5 mg, 95% CI: 45–285 mg, $p = 0.010$). The ESP group also had a lower risk of daily maximum NRS ≥3 (adjusted OR sternotomy: 0.22, $p < 0.001$; thoracotomy: 0.07, $p < 0.001$), a higher incentive spirometry volumes (sternotomy: mean increase of 149 mL, $p = 0.019$; thoracotomy: 521 mL, $p = 0.017$), and enhanced spirometry %baseline (sternotomy: mean increase of 11.5%, $p = 0.014$; thoracotomy: 26.5%, $p < 0.001$).

Conclusion: Continuous ESP block was associated with a reduction of postoperative opioid requirements, lower instances of pain scores ≥3, and improve incentive spirometry performance following cardiac surgery. These benefits appear particularly prominent in thoracotomy patients. Further prospective studies with larger sample size are required to validate these findings.

Keywords: Cardiac surgery; Erector spinae plane block; Incentive spirometry; Respiratory function

1. INTRODUCTION

Pain after cardiac surgery is caused by extended incisions, wound retraction, and chest tube drainage, leading to reduced coughing and breathing strength, decreased patient mobility, prolonged hospitalization, and increased morbidity.[1] In addition to these immediate postoperative challenges, patients who undergo cardiac surgery are at an increased risk of developing persistent pain after the surgery and may become more reliant on opioids for pain management in the long term.[2,3]

Regional analgesia techniques are advised for the prevention of persistent postoperative pain, the reduction of opioid consumption, and the minimization of related side effects after cardiac surgery.[4] Although epidural or paravertebral blocks (PVB) provide effective analgesia, their use in cardiac surgery has decreased owing to the associated risk of complications. The erector spinae plane (ESP) block has gained acceptance for its simplicity in execution and capability to afford substantial analgesia following cardiac procedures,[5–7] with a comparatively lower risk of complications than PVBs and fewer issues pertaining to anticoagulant therapy.[8]

Previous investigations into the use of the ESP block for cardiac surgery have predominantly employed single-shot techniques and focused on pain and opioid use shortly after surgery, typically within the first 24 hours, while offering limited data on respiratory function. The aim of this study is examining the outcomes of a continuous ESP block over a 72-hour postoperative period, comparing its impact on opioid consumption and respiratory function improvement against that of conventional care in cardiac surgery.

2. METHODS

This retrospective cohort study was approved by the Institutional Review Board (IRB) of Taichung Veterans General Hospital

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with a waiver of informed consent on January 28, 2022 (IRB CE22029B) and reported items following the Strengthening the reporting of observational studies in epidemiology (STROBE) checklist (Supplement File 1, http://links.lww.com/JCMA/A244).

2.1. Patient selection and data collection

We included patients aged between 20 and 80 years, undergoing elective cardiac procedures such as coronary artery bypass graft surgery, cardiac valve surgery, and robotic-assisted cardiac surgery. These patients were categorized based on whether they received pre-incision unilateral or bilateral ESP catheter insertion, or no ESP catheter at all. Exclusion criteria included emergent surgeries and re-do cardiac surgeries.

Between January 2021 and July 2022, we enrolled 262 patients in the entire cohort. Among these, 53 patients who received preincisional ESP block were designated as the ESP group, while the remaining 209 patients, who did not receive an ESP block, were labeled as the pre-match without ESP group. Using propensity score matching at a 1:1 ratio, we selected 53 patients from the without ESP group to serve as the control group (n = 53) (matched cohort). The surgical approach distribution was equivalent across both groups, with 42 patients undergoing sternotomy and 11 undergoing thoracotomy. All preoperative demographic and intraoperative data were collected from electronic medical records at Taichung Veterans General Hospital.

2.2. Propensity score matching

Propensity score matching was used to balance confounding factors including age, gender, surgical approach (sternotomy or thoracotomy), and EuroSCORE II (European system for cardiac operative risk evaluation), a risk rating system for predicting mortality after cardiac surgery. Covariates were chosen based on published literature indicating their correlation to postoperative pain trajectory, including age, gender, surgical approach.[9,10] Additionally, EuroSCORE II was included as a more comprehensive indicator of patient physical status than the conventional American Society of Anesthesiologists (ASA) physical status classification, which was usually class III in cardiac surgical patients.[11] The propensity score, representing the probability of receiving ESP or not receiving ESP, was calculated using logistic regression with these covariates as the independent variables. The dependent variable was the treatment status (receiving ESP or not). We opted for the nearest neighbor matching method without replacement, and a match tolerance threshold of 0.2 was applied to each matched pair.

2.3. ESP catheter placement and application

Patients in the ESP group received ESP catheter placement by a single anesthesiologist before surgery. Patients were positioned in the lateral-decubitus or prone position. After light sedation and skin sterilization, the anesthesiologist used ultrasound guidance with a linear transducer (6-13 mHz) positioned in a paramedian sagittal plane at the T5 level to identify the posterior lateral edge of the transverse process and the interfascial plane between the intertransverse ligaments and the erector spinae muscle. A 19G 100 mm Tuohy needle (Sonolong Nanoline, Pajunk®, Geisingen, Germany) was inserted in plane from the caudal to cranial direction, and 5 to 10 mL normal saline was injected to confirm adequate interfascial spreading. Then, a catheter (20 G, SonoLong Echo, echogenic catheter; Pajunk®) was inserted 4 to 6 cm further, placing the tip close to the T4 transverse process. 0.5% ropivacaine (Nang Kung®, Tainan, Taiwan) 0.3 mL·kg^{-1} (ideal body weight) was given in each catheter 30 minutes before the surgical incision and another same dose of 0.5% ropivacaine before sternum closure. After surgery, each catheter was connected to a Sapphire Multi-Therapy infusion pump (Eitan Medical®, Netanya, Israel). The pump was set to deliver an intermittent automatic bolus of 0.3 mL·kg^{-1} 0.16% ropivacaine every 4 hours. We programmed a cumulative dose limit for each 4-hour interval, ensuring only one demand bolus of the same dosage (0.3 mL·kg^{-1}) was available for each side in the time span. A 30-minute lockout time was also set to prevent inadvertent extra bolus administration. Patients who underwent the thoracotomy approach received the same treatment as those in the sternotomy group, but the ESP catheter was only placed ipsilaterally according to the surgical side. After the initial 48-hour period postsurgery, the continuation of ESP block analgesia could be determined based on individual patient preference and clinical indications, with a maximum duration not exceeding 5 days to reduce the likelihood of catheter-related infections.

2.4. Intraoperative and postoperative management

We induced anesthesia by intravenous administration of 2 μg·kg^{-1} fentanyl and 1 to 2 mg·kg^{-1} propofol. The choice and dosage of the neuromuscular agent were based on the attending anesthesiologists' preferences. Anesthesia depth was monitored using the bispectral index (BIS™ sensor; Covidien, Boulder, CO), which was maintained between 40 and 50. Propofol was infused during surgery (target control infusion [TCI] mode; Schnider model, Ce 1-4 μg·mL^{-1}) to maintain anesthesia. Analgesics used were remifentanil infusion (TCI mode, Minto model, Ce 1-7 ng·mL^{-1}), alfentanil infusion (TCI mode; Scott model, Ce 20-50 ng·mL^{-1}), or fentanyl infusion 1 μg·kg^{-1}·h^{-1} based on the preference of the anesthesiologists. Muscle relaxation was achieved with a cisatracurium infusion at 1 to 3 μg·kg^{-1}·min^{-1}. Mechanical ventilation was performed with a tidal volume of 8 mL·kg^{-1} (predicted body weight), positive end-expiratory pressure of 5 cmH_2O and a respiratory rate that maintained normocapnia. During the skin closure phase, dexmedetomidine was administered to all patients at a dose of 0.2 to 0.4 μg·kg^{-1}·h^{-1} and continued during their stay at the Intensive care unit (ICU), where they were intubated and mechanically ventilated. Pain assessment for these intubated patients was conducted using the Critical-Care Pain Observation Tool (CPOT). A CPOT score exceeding three necessitated titration of dexmedetomidine and the provision of intravenous rescue analgesia to maintain comfort. Subsequent to achieving clear consciousness, hemodynamic stability, and muscle power recovery, the clinical team proceeded with weaning and extubation protocols. Postextubation, patient-reported pain levels were evaluated using the numerical rating scale (NRS, 0-10). Intravenous rescue analgesia, with either tramadol 75 mg or morphine at 30 to 50 μg·kg^{-1}, was administered in response to CPOT or NRS scores of 3 or above, or when patients reported distressing pain.

2.5. Outcome measurement

Outcomes were stratified by the type of surgical approach—sternotomy or thoracotomy—owing to the presence of both methods at our institution. The primary outcome of this study was the total oral morphine equivalent (OME) dose received from the time of patient extubation until 72 hours thereafter. OME was calculated using a conversion toolkit within our hospital's electronic medical record system, which standardizes opioid analgesic doses to OMEs according to established guidelines.[12] Secondary outcomes included: (1) the frequency of daily NRS scores of 3 or higher; (2) the volume of daily incentive spirometry; and (3) incentive spirometry performance, expressed as a percentage of the preoperative baseline, within the first 72 hours postextubation.

Postoperative complications were identified through medical record analysis, adhering to the definitions set forth by the European Joint Taskforce's guidelines for perioperative clinical outcomes (EPCO).[13] Recorded complications included pneumonia, pleural effusion, pulmonary edema, atelectasis, acute

kidney injury, surgical site infection, surgical bleeding, delirium, ileus, and newly diagnosed arrhythmias during the postoperative period. Additionally, for patients receiving an ESP block, catheter-related complications such as puncture site hematoma or infection were monitored, documented, and reported by the nursing staff.

2.6. Statistical analyses

Data were analyzed using (IBM® SPSS Statistics 26.0, Chicago, IL, USA) 1989 - 2019. Categorical variables were assessed with Pearson's chi-square test or Fisher's exact test for low expected frequencies. Continuous variables were compared using the Mann–Whitney *U* test, with results presented as median (interquartile range [IQR]). Significance was established at a p value <0.05. Balanced baseline covariates between groups were confirmed using both p values and the standardized mean difference (SMD), with an SMD <0.1 indicating satisfactory balance. Effect size and 95% CI of the difference were reported to demonstrate clinically meaningful differences among outcome variables. For the Mann–Whitney *U* test, we used effect size r, where an r value of <0.3 represented a small effect, between 0.3 and 0.5 indicated a medium effect, and more than 0.5 suggested a large effect. For the chi-square test, we used the Φ (phi) coefficient, with values from 0.1 to 0.2 considered weak, greater than 0.2 as moderate, over 0.4 as relatively strong, and exceeding 0.6 as strong. To compare repeated measures like NRS ≥3 incidence and incentive spirometry performance over time between the ESP and control groups, we used a generalized estimating equation (GEE) model with an exchangeable correlation structure to account for temporal factors. Non-normally distributed variables underwent log transformation for appropriate analyses.

3. RESULTS

Table 1 presents the baseline demographic and clinical characteristics for both the ESP and control groups. In the matched cohorts, there were no statistically significant differences in terms of gender, age, body mass index (BMI), comorbidities, or type of surgery. Further stratification of demographic characteristics by surgical approach—sternotomy or thoracotomy—revealed no statistically significant differences between the ESP and control groups for either patient subset. Additional information regarding demographic characteristics in the pre-matched cohort is reported in Supplement File 2, http://links.lww.com/JCMA/A245.

Table 2 delineates intraoperative and postoperative data, also stratified by surgical approach. No significant differences were observed between the ESP and control groups in terms of

Table 1

Demographic characteristics of ESP and control groups in the matched cohort, stratified by sternotomy and thoracotomy approaches

	Matched cohort			Sternotomy			Thoracotomy		
	ESP (n = 53)	Control (n = 53)	*p*	ESP (n = 42)	Control (n = 42)	*p*	ESP (n = 11)	Control (n = 11)	*p*
Gender			0.840			0.825			0.586
Male	33 (62.3)	34 (64.15)		25 (59.5)	24 (57.1)		8 (72.7)	10 (90.9)	
Female	20 (37.7)	19 (35.85)		17 (40.5)	18 (42.9)		3 (27.3)	1 (9.1)	
Age, y	61 (52.0-70.5)	63 (53-71)	0.615	61.0 (51.8-70.3)	62.0 (52.8-71)	0.632	62.0 (52-72)	65.0 (55-69)	0.834
BMI, kg·m^{-2}	23.9 (22.4-26.1)	25.3 (21.7-28.4)	0.205	23.9 (22.2-25.9)	24.8 (21.6-28.3)	0.348	23.6 (22.7-26.3)	25.9 (22.3-29.8)	0.332
EuroSCORE II	2.7 (1.2-4.1)	2.9 (1.6-5.0)	0.355	2.9 (1.5-4.9)	3.8 (1.7-5.3)	0.395	1.6 (0.7-3.1)	1.7 (1.2-2)	0.606
Pulmonary function									
FEV1, L	2.1 (1.6-2.6)	2.4 (1.8-2.8)	0.269	2.1 (1.5-2.6)	2.3 (1.7-2.7)	0.347	2.5 (2.1-3.2)	2.7 (2.3-3.0)	0.604
FVC, L	2.8 (1.9-3.6)	3.0 (2.3-3.6)	0.523	2.7 (1.8-3.3)	2.9 (2.2-3.3)	0.577	3.1 (2.4-3.9)	3.4 (2.6-3.8)	0.764
FEV1/FVC	0.8 (0.7-0.8)	0.8 (0.8-0.9)	0.142	0.8 (0.7-0.8)	0.8 (0.8-0.9)	0.139	0.8 (0.8-0.9)	0.8 (0.8-0.8)	0.842
Comorbidity									
Hypertension	22 (41.5)	21 (39.6)	0.843	19 (45.2)	17 (40.5)	0.659	3 (27.3)	4 (36.4)	>0.999
Diabetic	15 (28.3)	22 (41.5)	0.154	13 (31.0)	18 (42.9)	0.258	2 (18.2)	4 (36.4)	0.635
CRF	9 (17.0)	9 (17.0)	>0.999	8 (19.0)	9 (21.4)	0.786	1 (9.1)	0 (0.0)	>0.999
Heart failure	14 (26.4)	13 (24.5)	0.824	14 (33.3)	12 (28.6)	0.637	0 (0.0)	1 (9.1)	>0.999
COPD	2 (3.8)	3 (5.7)	>0.999	2 (4.8)	3 (7.1)	>0.999	0 (0.0)	0 (0.0)	-
Asthma	2 (3.8)	2 (3.8)	>0.999	14 (33.3)	6 (14.3)	>0.999	0 (0.0)	0 (0.0)	-
Stroke	3 (5.7)	2 (3.8)	>0.999	2 (4.8)	2 (4.8)	>0.999	1 (9.1)	0 (0.0)	>0.999
MDD	1 (1.9)	0 (0.0)	>0.999	1 (2.4)	0 (0.0)	>0.999	0 (0.0)	0 (0.0)	-
Anxiety	1 (1.9)	0 (0.0)	>0.999	0 (0.0)	0 (0.0)	-	1 (9.1)	0 (0.0)	>0.999
Surgery type			0.123			0.128			0.392
CABG	15 (28.3)	25 (47.2)		11 (26.2)	17 (40.5)		4 (36.4)	6 (54.5)	
CABG with valve	6 (11.3)	1 (1.9)		5 (11.9)	3 (7.1)		0 (0.0)	0 (0.0)	
Valve only	25 (47.2)	25 (47.2)		20 (47.6)	17(40.5)		7 (63.6)	5 (45.5)	
Valve with aorta	2 (3.8)	2 (3.8)		2 (4.8)	5 (11.9)		0 (0.0)	0 (0.0)	
Other	5 (9.4)	0 (0.0)		4 (9.5)	0 (0.0)		0 (0.0)	0 (0.0)	
Surgical approach			0.807						
Sternotomy	42 (79.3)	42 (79.3)							
Thoracotomy	11 (20.8)	11 (20.8)							

Continuous data were compared using the Mann–Whitney *U* test and are presented as the median (IQR). Categorical data were compared using the Chi-squared test and are presented as numbers (%). The matched cohort was generated from the entire cohort using propensity score matching. This was done to balance covariates, including age, gender, surgical approach, and EuroSCORE II, based on findings from published literatures.[9–11]

BMI = body mass index; CABG = coronary artery bypass graft; COPD = chronic obstructive pulmonary disease; CRF = chronic renal failure; ESP = erector spinae plane; EuroSCORE II = European system for cardiac operative risk evaluation; FEV1 = forced expiratory volume in 1 s; FEV1/FVC = proportion of FEV1 to FVC, normal value > 0.75; FVC = forced vital capacity; IQR = interquartile range; MDD = major depression disorder.

Table 2

Intraoperative and postoperative variables in different surgical approaches between the ESP and control groups

	Sternotomy			Thoracotomy		
	ESP (n = 42)	Control (n = 42)	*p*	ESP (n =11)	Control (n = 11)	*p*
Intraoperative						
Propofol, mg	1935.1 (1622.7-2521.5)	2086.2 (1725.1-2459.5)	0.661	2190 (1571-2381.6)	3243.9 (2035.8-4100.2)	0.088
Opioid, μg[a]	232.3 (156.7-680.9)	524 (145.9-985.5)	0.154	199.7 (134.5-299.1)	592.4 (219-1441.9)	0.098
Patients receive remifentanil	17 (40.5)	27 (64.3)	0.029	3 (27.3)	5 (45.5)	0.385
Remifentanil, μg[b]	654.2 (353.1-1222.9)	796.0 (407.9-1280.8)	0.650	296 (134.5-1842.8)	977.9 (621.5-1598.3)	0.297
Remifentanil TWA, μg/kg/min[b]	0.018 (0.013-0.029)	0.021 (0.016-0.028)	0.588	0.010 (0.003-0.049)[b]	0.023 (0.018-0.034)	0.456
Anesthesia duration, h	9.7 (8.2-10.8)	9.0 (7.8-11.5)	0.522	10.9 (10-12.5)	10.6 (10.1-12.8)	0.861
Postoperative						
Pain scale (CPOT)	1.5 (1.2-1.7)	1.6 (1.4-1.7)	0.405	1.3 (1.2-1.5)	1.5 (1.2-1.7)	0.699
Patients receive rescue analgesics	9 (21.4)	14 (33.3)	0.224	3 (27.3)	6 (54.5)	0.203
Length of mechanical ventilation, d	0.7 (0.5-0.8)	0.7 (0.5-0.8)	0.847	0.5 (0-0.6)	0.5 (0.1-0.6)	0.961
Postoperative length of stay, d	10.0 (8.0-14.0)	10.0 (7-14)	0.794	9.0 (7.0-10.0)	8.0 (6.0-16.0)	0.809
Complications						
Composite PPCs, n (%)	21 (50)	30 (71.4)	0.044	3 (27.3)	10 (90.9)	0.003
Respiratory infection, n (%)	4 (9.5)	12 (28.6)	0.024	0 (0.0)	6 (54.5)	0.005
Pleural effusion, n (%)	15 (35.7)	25 (59.5)	0.026	1 (9.1)	8 (72.7)	0.007
Pulmonary edema, n (%)	7 (16.7)	11 (26.2)	0.287	3 (27.3)	3 (27.3)	>0.999
Atelectasis, n (%)	2 (4.8)	5 (11.9)	0.433	0 (0.0)	0 (0.0)	-
Surgical bleeding, n (%)	0 (0.0)	2 (4.8)	0.494	1 (9.1)	0 (0.0)	>0.999
New-onset arrhythmia, n (%)	6 (14.3)	7 (16.7)	0.763	1 (9.1)	2 (18.2)	>0.999
Acute kidney injury, n (%)	0 (0.0)	1 (2.4)	>0.99	0 (0.0)	0 (0.0)	-
Surgical site infection, n (%)	0 (0.0)	1 (1.2)	>0.99	0 (0.0)	1 (9.1)	>0.999
Delirium, n (%)	2 (4.8)	0 (0.0)	0.494	0 (0.0)	0(0.0)	-
Ileus, n (%)	0 (0.0)	1 (2.4)	>0.99	0 (0.0)	0 (0.0)	-

The Mann–Whitney *U* test was used to compare continuous data, which are presented as the median (IQR). The Chi-squared test and the Fisher's exact test were used to compare categorical data, and the results are presented as numbers (%). *p* value comparing ESP vs control group.

CPOT = Critical-Care Pain Observation Tool; ESP = erector spinae plane; IQR = interquartile range; length of mechanical ventilation (d), duration of mechanical ventilation; postoperative length of stay (d), duration of stay in hospital after surgery; TWA = time-weighted average, equals to cumulative remifentanil (μg)/body weight (kg)/anesthesia duration (min).

[a]All intraoperative opioids (remifentanil, alfentanil, and fentanyl) were converted to equivalent intravenous fentanyl doses in a ratio of remifentanil:alfentanil:fentanyl = 1:20:1 (eg, remifentanil 20 μg = alfentanil 200 μg = fentanyl 20 μg). This conversion is based on established opioid equivalency ratios.[14–16]

[b]Data were calculated among patients who received remifentanil and presented as median (IQR). For data with limited cases (eg, only three cases in the cohort), values are presented as median (lowest value-highest value).

intraoperative propofol and opioid use, anesthesia duration, duration of mechanical ventilation, or hospital stay, irrespective of the surgical method used. Additionally, before extubation, both the pain intensity (CPOT) and the need for rescue analgesics showed no statistically significant differences between the ESP and control groups, regardless of whether a sternotomy or thoracotomy approach was employed. The ESP group reported a lower incidence of composite postoperative pulmonary complications (PPCs), a difference particularly noticeable in thoracotomy patients (sternotomy: 50% vs 71.4%, $p = 0.044$, effect size $\phi = 0.22$; Thoracotomy: 27.3% vs 90.9%, $p = 0.003$, effect size $\phi = 0.65$). Other postoperative complications, including bleeding, ileus, postoperative cognitive dysfunction, acute kidney injury, and surgical site infection occurred at similar rates in both groups. No ESP procedure-related complications, such as hematoma or injection site infection, were reported.

Table 3 details a comparison of the primary and secondary outcomes in the ESP and control groups, stratified by surgical approach. The ESP group displayed a significantly reduced cumulative OME dose within the first 72 hours postextubation. Specifically, a median decrease of 113 mg (95% CI: 60-157.5 mg, $p < 0.001$, effect size $r = 0.48$, indicating a medium effect) was observed in sternotomy patients and 172.5 mg (95% CI: 45-285 mg, $p = 0.010$, effect size $r = 0.54$, indicating a large effect) in thoracotomy patients. Patients who underwent sternotomy in the ESP group reported significantly fewer instances of a maximum NRS ≥3 on day 1 (11.9% vs 40.5%, $p = 0.003$, effect size $\phi = 0.32$) and day 3 (9.5% vs 38.1%, $p = 0.002$, effect size $\phi = 0.34$). In the thoracotomy subset, the ESP group had significantly lower instances of NRS ≥3 on day 1 (18.2% vs 72.7%, $p = 0.010$, effect size $\phi = 0.55$) and day 2 (9.1% vs 72.7%, $p = 0.008$, effect size $\phi = 0.65$). While preoperative baseline incentive spirometry volume were comparable between the ESP and control group, the ESP group demonstrated higher incentive spirometry volumes on day 2 and day 3 in sternotomy patients (day 2, 1000 vs 750 mL, $p = 0.024$, effect size $r = 0.26$; day 3, 1250 vs 750 mL, $p = 0.025$, effect size $r = 0.26$) and higher volume on day1 in thoracotomy patients (1000 vs 500 mL, $p = 0.010$, effect size $r = 0.54$). In terms of performance comparison as a percentage of baseline value (spirometry %baseline), the ESP group consistently had a higher incentive spirometry performance as spirometry %baseline, particularly in thoracotomy patients over the first 3 days (day 1, 58.8% vs 25%, $p = 0.002$, effect size $\phi = 0.69$; day 2, 58.8% vs 40%, $p = 0.022$, effect size $\phi = 0.53$; day 3, 60% vs 50%, $p = 0.022$, effect size $\phi = 0.55$).

We performed GEE analysis to adjust temporal factors within 72 hours postextubation and presented in Table 4. The ESP group had a lower risk of reaching a maximum pain scale ≥3 (odds ratio: 0.22, 95% CI: 0.09-0.5, $p < 0.001$ for sternotomy patients; 0.07, 95% CI: 0.02-0.33, $p < 0.001$ for thoracotomy patients). Additionally, the ESP group displayed a higher incentive spirometry volume (mean difference: 149 mL, 95% CI: 25-273 mL, $p = 0.019$ for sternotomy patients; 521 mL, 95% CI: 92-951 mL, $p = 0.017$ for thoracotomy patients), and greater spirometry %baseline (mean difference: 11.5%, 95% CI: 2.3%-20.6%, $p = 0.014$ for sternotomy patients; 26.5%, 95% CI: 12.9%-40.1%, $p < 0.001$ for thoracotomy patients).

Table 3

Subgroup analysis between patients in the ESP group and control group in different surgical approaches for the primary and secondary outcomes

	Sternotomy			Thoracotomy		
	ESP (n = 42)	Control (n = 42)	*p*	ESP (n = 11)	Control (n =11)	*p*
Primary outcome						
Cumulative OME 72 h, mg	105 (58.1-183.8)	225 (148.1-318.8)	<0.001	45 (0-117)	249 (135-360)	0.010
Secondary outcome						
Patients with maximum NRS ≥3, n (%)						
Day 1	5 (11.9)	17 (40.5)	0.003	2 (18.2)	8 (72.7)	0.010
Day 2	6 (14.3)	13 (31.0)	0.068	1 (9.1)	8 (72.7)	0.008
Day 3	4 (9.5)	16 (38.1)	0.002	1 (9.1)	5 (45.5)	0.149
Spirometry, mL						
Baseline	1600 (1250-2000)	1500 (1250-2500)	0.306	2500 (1725-2500)	2000 (1750-2500)	0.629
Day 1	750 (500-1000)	750 (500-900)	0.181	1000 (1000-1500)	500 (250-800)	0.010
Day 2	1000 (750-1250)	750 (500-1000)	0.024	1000 (1000-2250)	875 (500-1313)	0.099
Day 3	1250 (755-1250)	750 (750-1250)	0.025	1500 (1000-2250)	1000 (750-1375)	0.153
Spirometry %baseline, %						
Day 1	50.0 (40-60)	38.8 (25.9-50)	0.038	58.8 (45-60)	25.0 (14.3-36.7)	0.002
Day 2	57.1 (40-68)	47.7 (33.3-59)	0.038	58.8 (44-89.8)	40.0 (28.6-52.5)	0.022
Day 3	65.3 (56.2-82.5)	50.0 (40-66.3)	0.005	60.0 (58-88.8)	50.0 (32.9-64.3)	0.022

The Mann–Whitney *U* test was used to compare continuous data, which are presented as the median (IQR). *p* value comparing ESP vs control group. Baseline, incentive spirometry volume before surgery; day 1, postextubation day 1; day 2, postextubation day 2; day 3, postextubation day 3.

ESP = erector spinae plane; IQR = interquartile range; NRS = numeric rating scale pain score (0-10 scale); OME = oral morphine equivalent; Spirometry %baseline = daily spirometry volume divided by preoperative baseline volume, calculated separately for each postextubation day.

Table 4

GEE analysis for association between ESP and daily maximum NRS ≥3, incentive spirometry volumes within 72 h postextubation

	Sternotomy		Thoracotomy	
	Odds ratio (95% CI)	*p*[a]	Odds ratio (95% CI)	*p*[a]
NRS				
Maximum NRS ≥3, ESP vs control	0.22 (0.09-0.50)	<0.001	0.07 (0.02-0.33)	<0.001
	Coefficient (95% CI)	***p*[a]**	**Coefficient (95% CI)**	***p*[a]**
Incentive spirometry volume				
Spirometry, mL, ESP vs control	149 (25-273)	0.019	521(92-951)	0.017
Spirometry %baseline[a], %, ESP vs control	11.5 (2.3-20.6)	0.014	26.5(12.9-40.1)	<0.001

p value <0.05 represented a significant difference between ESP and control group across postextubation time by the generalized estimating equation.

ESP = erector spinae plane; NRS = numeric rating scale.

[a]Spirometry %baseline, daily spirometry volume divided by preoperative baseline volume, calculated separately for each postextubation day.

Fig. 1 features box-whisker plots comparing incentive spirometry volumes and spirometry %baseline between the ESP and control groups among sternotomy patients (Fig. 1A, C) and thoracotomy patients (Fig. 1B, D). Patients in the sternotomy cohort who received the ESP block exhibited a notable increased incentive spirometry volumes observed on the second and third postextubation days, as demonstrated in Fig. 1A. Thoracotomy patients who were administered the ESP block experienced a marked enhancement in spirometry volumes immediately on the first day postextubation, as shown in Fig. 1B. Spirometry percentages relative to baseline (spirometry %baseline) measurements across both groups from day 1 to day 3 postextubation are detailed in Fig. 1C, D. In both sternotomy (Fig. 1C) and thoracotomy (Fig. 1D) patients, the ESP group maintained a significantly higher spirometry %baseline from postextubation day 1 to day 3. Fig. 1D also illustrated the pairwise comparison results that ESP group held significantly higher spirometry %baseline on postextubation days 1 and 2 after adjusting time effect (day 1, Bonferroni significance < 0.001; day 2, Bonferroni significance = 0.03).

4. DISCUSSION

This study compared the association between ESP block and postoperative opioid requirements, pain scale and respiratory function in patients undergoing open cardiac surgery. Results indicate that the ESP group exhibited lower postoperative morphine needs, less frequent instances of NRS ≥3, and enhanced incentive spirometry performance than the control group.

In our study, the ESP block significantly reduced opioid consumption by 60% and decreased the incidence of patients reporting a maximum NRS ≥3 during the 72-hour postextubation period. To mitigate biases, we matched the control group with the ESP group based on age, gender, and surgical approach, those factors Vasilopoulo et al.[9] linked to increased postoperative pain and opioid use. While earlier studies on cardiac surgeries often used single-shot ESP blocks focusing on early postoperative outcomes,[6,17,18] our approach involved a pre-incision ESP block with analgesia efficacy evaluation for up to 72 hours. Our finding aligns with research groups studying continuous ESP analgesia[19,20] but are distinguished by the noticeable opioid reduction over an extended postoperative

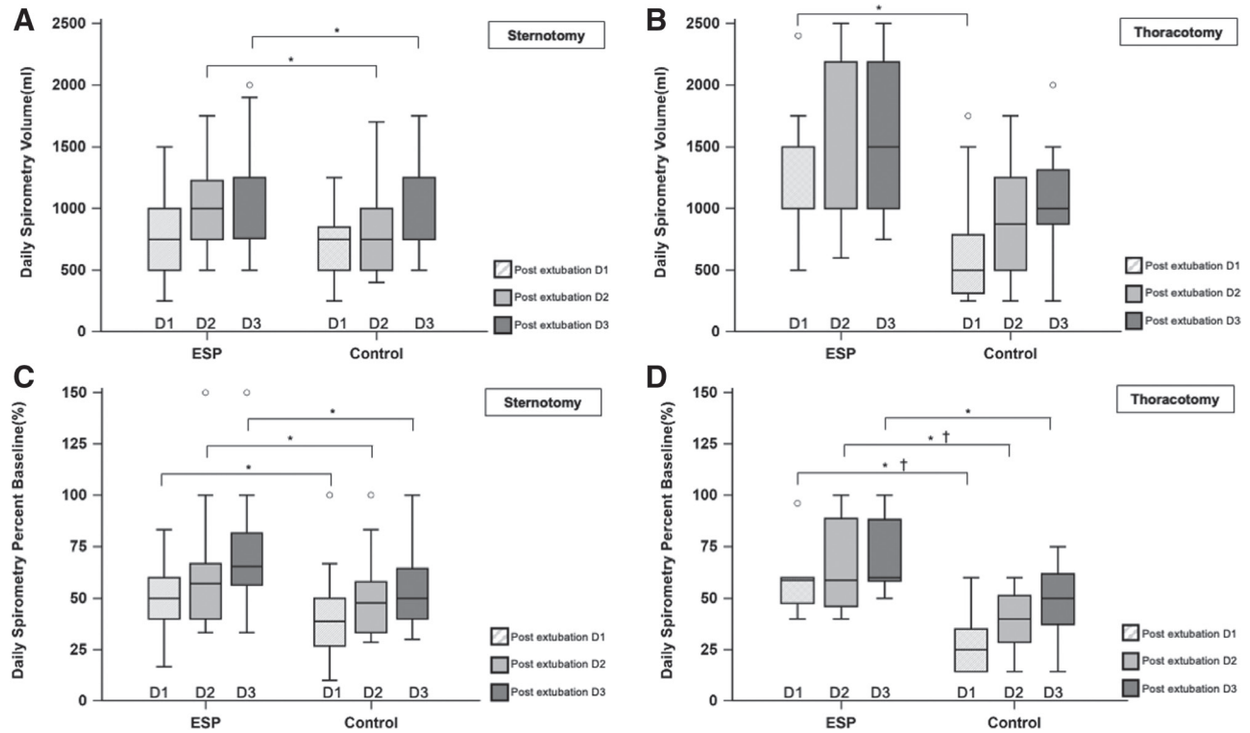

Fig. 1 Box-Whisker plots comparing incentive spirometry volume and spirometry as a percentage of baseline in the ESP group and control groups. The figures depict comparisons between the ESP and control groups among patients undergoing sternotomy (A and C) or thoracotomy (B and D) over the first 3 d postextubation. In the plots, the box denotes the IQR, the line inside the box is the median, whiskers indicate values within 1.5 × IQR, and hollow-circle outside the whiskers are outliers. For sternotomy patients, ESP group showed higher incentive spirometry volumes on postextubation days 2 and 3 (A). In thoracotomy patients, ESP group displayed higher volumes on postextubation day 1 (B). C and D, The comparison of spirometry as a percentage of baseline. In both surgical groups, ESP maintained a higher percentage from postextubation day 1 to 3. After time effect adjustment using the generalized estimating equation, in thoracotomy patients, ESP group had significantly higher percentages on postextubation day 1 and 2 in pairwise comparison (day 1, Bonferroni sig. <0.001; day 2, Bonferroni sig. = 0.03) (D). Statistical significance is indicated on the figure. *$p < 0.05$ in comparisons between the ESP and control groups by the Mann-Whitney *U* test; †$p < 0.05$ in pairwise comparisons by the Bonferroni test after adjusting for time effects with the generalized estimating equation. ESP = erector spinae plane block; IQR = interquartile range; Spirometry %baseline = daily spirometry volume divided by preoperative baseline volume, calculated separately for each postextubation day.

period. We acknowledge the potential variance in intraoperative opioid administration based on anesthesiologists' preferences. Nonetheless, in our study, the time-weighted average (TWA) doses ($\mu g \cdot kg^{-1} \cdot min^{-1}$) of remifentanil—a known factor in acute postoperative pain and opioid-induced hyperalgesia—were consistent across both the ESP and control groups. These TWA doses were below the hyperalgesia-associated thresholds reported in the literature.[21–24] Moreover, we adopted several strategies like TCI mode,[25] propofol-based total intravenous anesthesia,[26] and dexmedetomidine infusion,[27,28] which were known to potentially counteract remifentanil-associated hyperalgesia. Therefore, we believe that remifentanil had marginal effect on postoperative analgesic demands and pain scale in our study.

Additionally, our study demonstrated that patients in the ESP group maintained higher incentive spirometry volumes and a larger percentage of baseline value (spirometry %baseline) across all 3 days postextubation. Also, the ESP group exhibited a reduced rate of composite PPCs. These differences were more distinct in patients who underwent thoracotomy, whereas the effects were limited in sternotomy patients. Incentive spirometry is a clinical tool used to promote alveoli expansion through sustained maximal inspiration following cardiothoracic surgery. It is associated with significant atelectasis reduction, better inspiratory muscle strength recovery, and shortened postoperative fever duration.[29–31] Moreover, incentive spirometry performance has been used as an indicator of regional analgesia efficacy and objective surrogate data for postoperative pain control.[32,33] After cardiac surgery, patients inevitably experience respiratory function decline due to factors such as atelectasis from general anesthesia, ischemia-reperfusion injury, or distressing pain.[34,35] Thus, in our study, we compared the spirometry %baseline (daily volume divided by the baseline volume) instead of the absolute daily incentive spirometry volume. Despite the ESP group having a lower preoperative pulmonary function and similar baseline volumes to the control group, they demonstrated superior individualized performance on incentive spirometry. This supports the hypothesis that ESP recipients may experience better analgesia, resulting in higher diaphragmatic inspiratory strength, leading to increased incentive spirometry volumes despite factors compromising respiratory function recovery.

Another intriguing finding of this study was thoracotomy patients in the ESP group showed more pronounced differences in outcome variables compared with sternotomy patients. Theoretically, thoracotomy approach causes less tissue damage than traditional sternotomy, possibly leading to fewer postoperative complications and a shorter hospital stay.[36,37] However, the intense post-thoracotomy pain, resulting from aggressive rib spreading and excessive rotation of the posterior costovertebral joint, could hinder postoperative pulmonary recovery if not well-managed.[38–40] Recent research demonstrates a possible two-phase local anesthetic (LA) distribution during ESP blocks.[41] Initially, LA infiltrates the retro superior

costotransverse ligament (RetroSCTL) space, impacting the spinal nerve and dorsal root ganglion. It then progresses through slits into the paravertebral space, targeting the ventral ramus and intercostal nerve. While the second phase might not be as extensive due to LA volume and tissue dynamic movement, resulting in uneven block intensity, it potentially provides superior analgesia in thoracotomy patients. These findings may elucidate why in our study, the thoracotomy patients who received ESP blocks exhibited more substantial improvements in incentive spirometry performances.

Meanwhile, in cardiac surgery, particularly for sternotomies, the choice of an ESP block over superficial or deep pectointercostal plane (PIP) blocks is strategic. The ESP block's distal injection site from the surgical field markedly reduces the risk of surgical site infections, a critical consideration for patients undergoing sternotomy. Furthermore, the ESP block provides broader analgesic coverage, extending effectively to the chest drainage area—often a source of significant postoperative pain that PIP blocks may inadequately address. By ensuring adequate LA distribution in the initial phase of the ESP block, we capitalize on its extensive nerve blockade, which encompasses the dorsal root ganglia and spinal nerves, essential for controlling the complex pain patterns following sternotomy.

Our study has several limitations. First, the retrospective and observational design may introduce residual confounding factors that could affect the associations between the continuous ESP block and the outcomes of interest. Second, the choice of a 1:1 propensity score matching ratio, resulting from cases lost during a higher matching attempt (1:2), may limit the accuracy and generalizability of our findings.

In conclusion, our study revealed that patients with ESP block had lower postoperative opioid needs and a better incentive spirometry performance after cardiac surgery. Given the limited sample size in our study, these results are preliminary and require further validation through larger, controlled trials. Future studies should compare single-shot vs catheter insertion, assess time and resource burden of ESP block in cardiac surgery, and identify populations that benefit most.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://links.lww.com/JCMA/A244 and http://links.lww.com/JCMA/A245.

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