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ORIGINAL ARTICLE

Bilateral ultrasound-guided erector spinae plane block versus wound infiltration for postoperative analgesia in lumbar spinal fusion surgery: a randomized controlled trial

Zhen Zhang[1] · Ran-Lyu Zhu[2] · Lei Yue[2] · Xue Li[1] · Jia-Hui Ma[1] · Hao Kong[1] · Chun-de Li[2] · Hong Zhang[1] · Dong-Xin Wang[1,3]

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Abstract

Purpose Both erector spinae plane block and wound infiltration are used to improve analgesia following spinal fusion surgery. Herein, we compared the analgesic effect of bilateral erector spinae plane block with wound infiltration in this patient population.

Methods In this randomized trial, 60 patients scheduled for elective open posterior lumbar interbody fusion surgery were randomized to receive either ultrasound-guided bilateral erector spinae plane block before incision ($n=30$) or wound infiltration at the end of surgery ($n=30$). Both groups received standardized general anesthesia and postoperative analgesia, including patient-controlled analgesia with sufentanil and no background infusion. Opioid consumption and pain intensity were assessed at 2, 6, 12, 24, and 48 h after surgery. The primary outcome was cumulative opioid consumption within 24 h after surgery.

Results All 60 patients were included in the intention-to-treat analysis. The equivalent dose of sufentanil consumption within 24 h was significantly lower in patients given erector spinae plane block (median 11 μg, interquartile range 5–16) than in those given wound infiltration (20 μg, 10 to 43; median difference − 10 μg, 95% CI − 18 to − 3, $P=0.007$). The cumulative number of demanded PCA boluses was significantly lower with erector spinae plane block at 6 h (median difference − 2, 95% CI − 3 to 0, $P=0.006$), 12 h (− 3, 95% CI − 6 to − 1, $P=0.002$), and 24 h (− 5, 95% CI − 8 to − 2, $P=0.005$) postoperatively. The proportion given rescue analgesia was also significantly lower in patients given erector spinae plane block group within 48 h (relative risk 0.27, 95% CI 0.07 to 0.96, $P=0.037$). There were no statistical differences in pain intensity at any timepoints between groups. No procedure-related adverse events occurred.

Conclusions Compared with wound infiltration, bilateral ultrasound-guided erector spinae plane block decreases short-term opioid consumption while providing similar analgesia in patients following lumbar spinal fusion surgery.
Chinese Clinical Trial Registry: ChiCTR2100053008.

Keywords Spinal fusion · Analgesia · Postoperative period · Nerve block · Erector spinae plane block · Wound infiltration

Introduction

Spine fusion surgery can cause severe postoperative pain because of damage to the skin, subcutaneous tissues, ligaments, and bones. According to a large prospective cohort study involving 50,523 patients with 179 kinds of surgical procedures, those following spinal fusion had a median worst pain score of 7 based on an 11-point numeric rating scale within 24 h and ranked top 4 (1 to 2 segments) and 6 (3 or more segments) among the most painful procedures [1]. Severe pain is associated with delayed postoperative recovery, reduced satisfaction with surgery, and even increased

Zhen Zhang and Ran-Lyu Zhu contributed equally to this work.

✉ Hong Zhang
zhanghong40@hotmail.com

✉ Dong-Xin Wang
dxwang65@bjmu.edu.cn; wangdongxin@hotmail.com

[1] Department of Anesthesiology and Critical Care Medicine, Peking University First Hospital, No. 8 Xishiku Street, Xicheng District, Beijing 100034, China

[2] Orthopedic Department, Peking University First Hospital, Beijing, China

[3] Outcomes Research Consortium, Cleveland, OH, USA

risk of persistent pain [2–4]. Although opioids are the most commonly used analgesics for postoperative analgesia, they bring side effects such as dizziness, pruritus, nausea, vomiting, and respiratory depression [5]. Therefore, the better way is to improve analgesia while reducing opioid consumption.

Various non-opioid methods are available for postoperative pain management in these patients, one of which is wound infiltration with local anesthetics. Several studies reported that wound infiltration may reduce opioid consumption after spine surgery [6–9]. A peripheral nerve block can also be a component of multimodal pain management [10, 11]. Such techniques have a high success rate, especially when applied under ultrasound guidance which improves visualization and thereby reduces potential complications. The erector spinae plane (ESP) block was first described by Forero and colleagues in 2016 [12]. In this technique, a local anesthetic solution is injected into the plane between the deep fascia of the erector spinae muscle and the vertebral transverse process. This block is a paraspinal inter-fascial plane block targeting the ventral and dorsal rami of the spinal nerves and is safe and easy to perform under ultrasound guidance. Previous studies showed that ultrasound-guided ESP block provides effective analgesia following spinal surgery [10, 13, 14].

In this study, we compared the analgesic efficacy of ultrasound-guided ESP block with local anesthetic wound infiltration following spinal fusion surgery. The primary endpoint was cumulative opioid consumption within 24 h after surgery.

Methods

Study design and participants

This randomized trial was conducted in a tertiary hospital in Beijing, China. The study protocol was approved by the local Biomedical Research Ethics Committee (2021–414) and was registered prior to patient enrollment at the Chinese Clinical Trial Registry (http://www.chictr.org.cn, ChiCTR2100053008; 8 November 2021). Written informed consent was obtained from each participant.

We enrolled patients who were (1) aged 18–70 years, (2) diagnosed with degenerative lumbar spine disease not responsive to non-surgical treatments including medication, physical therapy, and epidural steroid injection for at least 6 months, and (3) scheduled for elective open posterior lumbar interbody fusion (PLIF) surgery. We excluded those who underwent corrective surgery for degenerative scoliosis and kyphosis, revision lumbar surgery, or surgery involving the thoracic vertebra. Other exclusion criteria included the following: (1) severe renal (serum creatinine > 442 μmol/L or requiring renal replacement therapy) or liver (Child–Pugh grade C) insufficiency, or ASA class IV or higher; (2) chronic opioid dependence or use of painkillers for more than 3 months; (3) inability to communicate due to severe dementia, language barrier, or end-stage disease; (4) comorbidity of the central and/or peripheral nervous system; or (5) allergy to local anesthetics.

Randomization and blinding

Random numbers were generated by a statistician using the SAS statistical package version 9.3 (SAS Institute, Cary, NC, USA) in a 1:1 ratio with a block size of 4. The generated random numbers were sealed in sequentially numbered opaque envelopes and kept by a study coordinator. On the day of surgery, the envelopes were opened in the operating room after general anesthesia according to the recruitment sequence. Patients were randomized to receive either ESP block which was performed by experienced anesthesiologists (ZZ and XL) before surgery, or wound infiltration which was performed by attending surgeons before the end of surgery. Anesthesiologists and surgeons were aware of the study intervention. However, all patients, investigators in charge of postoperative following-ups (ZRL and YL), and other healthcare team members were masked to group assignments.

Anesthesia, surgery, and perioperative care

No pre-anesthesia medication was administered. Intraoperative monitoring was per ASA guidelines and usually included intraarterial blood pressure monitoring. General anesthesia was induced with midazolam, sufentanil, propofol and/or etomidate, and rocuronium, and maintained with propofol infusion, remifentanil infusion and/or sufentanil injection, and muscle relaxants (rocuronium or cisatracurium), with or without sevoflurane inhalation. Anesthesia depth was targeted to a bispectral index between 40 and 60. Mechanical ventilation was established with an oxygen–air mixture. Fluid therapy was provided according to routine practice. Vasoactive drugs were administered when necessary to maintain mean arterial pressure and heart rate within 20% from baseline. Glucocorticoids were administered at the discretion of surgeons.

Patients were placed in prone position under general anesthesia. For patients assigned to ESP block, a curvilinear ultrasound probe (3–5 MHz, GE Healthcare, Boston, Massachusetts, USA) was used to identify the target spinous process by paramedian sagittal scan starting from the sacral regions; the probe was then moved 2 to 3 cm lateral to the midline to identify the tip of the corresponding transverse process. The target spinous process was determined according to the level of lumbar surgery, i.e., intermediate one for surgical level(s) of odd number or the upper or second one

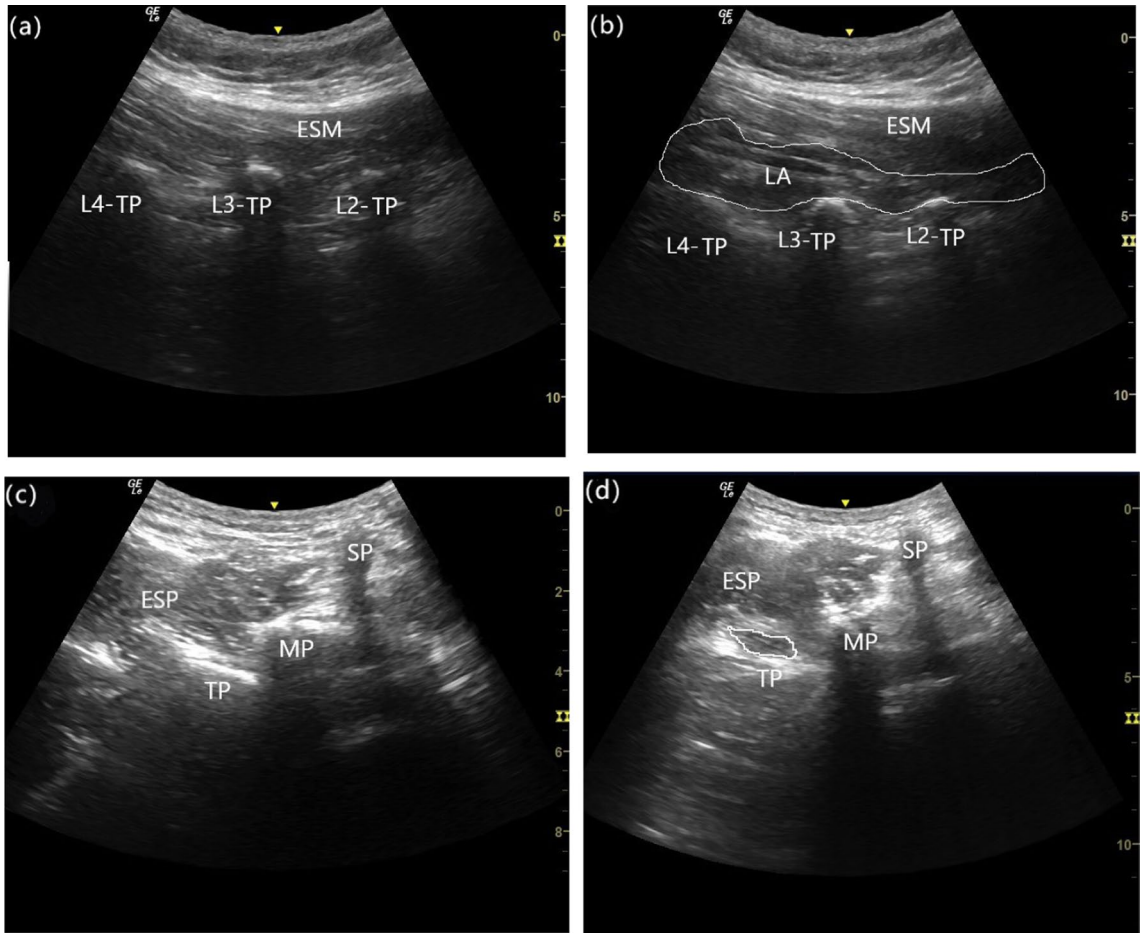

Fig. 1 Sonographic anatomy of the erector spinae plane (**A**, longitudinal; **C**, transverse) and erector spinae plane block (**B**, out-of-plane approach longitudinally; **D**, in-plane approach transversely). The area within the white line indicates local anesthetic (LA) spreading deep to the erector spinae muscle. ESM, erector spinae muscle; TP, transverse process; MP, mammillary process; SP, spinous process

for surgical levels of even number. An 8-cm 21-gauge block needle (Stimuplex D, B.Braun, Melsungen, Germany) was inserted in an out-of-plane mode until it contacted the transverse process. After verifying the position of the needle tip with 2 mL normal saline, 20 mL 0.375% ropivacaine was injected (Fig. 1). The procedure was repeated on the contralateral side. For patients assigned to wound infiltration, 40 mL of 0.375% ropivacaine was infiltrated along each side of the wound edges after closure.

For the open PLIF procedure, a midline incision was made, paravertebral muscle was dissected to expose the spinous process and laminae, and pedicle screws were inserted. After a standard laminotomy and discectomy, the autologous bone was implanted into the disk space, and an appropriate size cage packed with bone autograft was inserted. Bilateral pedicle screws were then connected with elongated screw rods and fixed with nuts. A drainage tube was placed in the wound, and the incision was closed.

At 30 min before the expected end of the surgery, 50 mg flurbiprofen axetil was administered (in patients without contraindications) for supplemental analgesia and 5 mg tropisetron was administered for prophylaxis of nausea and vomiting. At the end of the surgery, 2 mg neostigmine and 1 mg atropine were used to antagonize neuromuscular blockade. Patients were extubated in the operating room, monitored in the post-anesthesia care unit for at least 30 min, and transferred to the general wards when the modified Aldrete Score reached 10; otherwise, they were transferred to the intensive care unit.

All patients were provided with a patient-controlled analgesia (PCA) pump for postoperative analgesia. The pump was established with 100 ml of 1.25 μg/ml sufentanil and programmed to deliver 2 mL boluses at an 8-min lockout interval without a background infusion. As a routine practice, 50 mg flurbiprofen axetil was given intravenously twice daily whenever possible. Other analgesics were prescribed when necessary. The target was to maintain the Numerical Rating Scale for pain intensity (an 11-point scale where 0 = no pain and 10 = the worst imaginable pain) at a rest of less than 4.

Data collection

Baseline data included demographics, comorbidities, and American Society of Anesthesiologists classification. Preoperative evaluations were performed. Among these, anxiety and depression were assessed with the Hospital Anxiety and Depression Scale (score ranges from 0 to 21 for either anxiety or depression, with a higher score indicating more severe anxiety or depression status) [15]; pain intensity was assessed with the Numeric Rating Scale; sleep quality was assessed with the Pittsburgh Sleep Quality Index (score ranges from 0 to 21, with a higher score indicating worse sleep quality) [16]; low back pain related disability was assessed with the Oswestry Disability Index (percentage ranges from 0 to 100%, with a higher percentage indicating more severe spinal dysfunction) [17].

Intraoperative data were collected and included the durations of anesthesia and surgery, medications and fluid infusion during anesthesia, estimated blood loss, transfusion of blood products, and number of fused levels.

Postoperative follow-ups were performed by investigators who were not involved in anesthesia and surgery and were blinded to the study group assignment. Our primary outcome was cumulative opioid consumption within the first 24 h after surgery and calculated as sufentanil equivalent [11, 18]. Among secondary outcomes, pain intensity both at rest and with movement was assessed with the Numeric Rating Scale at 2, 6, 12, 24, and 48 h after surgery; sleep quality during the night of surgery was assessed with the Richards-Campbell Sleep Questionnaire (overall score ranges from 0 to 100, with a higher score indicating better sleep quality) [19]; quality of recovery at 24 h was assessed with the Quality of Recovery-15 scale (overall score ranges from 0 to 150, with a higher score indicating better postoperative recovery) [20]; postoperative complications were generally defined as new-onset medical conditions that were harmful to patients' recovery and required therapeutic intervention, i.e., grade II or higher on the Clavien–Dindo classification [21]. Other outcomes including opioid consumption between 24 and 48 h, required bolus via patient-controlled analgesia pump, supplemental analgesics, and Oswestry Disability Index at 30 days were also collected.

Adverse events were monitored from the beginning of anesthesia until 24 h after surgery. Specifically, hypotension was defined as systolic blood pressure < 90 mmHg or a decrease of > 30% from baseline; hypertension as systolic blood pressure > 180 mm Hg or an increase of > 30% from baseline; bradycardia as heart rate < 50 beats/min or a decrease of > 30% from baseline; tachycardia as heart rate > 100 beats/min or an increase of > 30% from baseline; respiratory depression as spontaneous breathing rate < 8 breaths/min; desaturation as pulse saturation < 90% in room air and required supplemental oxygen; and nausea and vomiting as any retching, vomiting, or requirement for antiemetics [22].

Statistical analysis

Sample size estimation

In our pilot study, the cumulative sufentanil consumption within the first 24 h after spinal fusion surgery was (mean ± SD) 16.2 ± 6.7 μg in 5 patients with wound infiltration and 10.0 ± 4.7 μg in 5 patients with ESP block. We expected the same difference and a standard deviation (SD) of 6.7. With the significance level set as $\alpha = 0.05$ and power set as $1-\beta = 90\%$ on a two-sided t test, the sample size required to detect difference was 52 patients (26 in each group). Taking into account the dropout rate, we planned to enroll 60 patients. Sample size calculation was performed with the PASS 15.0 software (Stata Corp. LP, College Station, Texas, USA).

Data analysis

Outcome analysis was performed in the intention-to-treat population. Continuous data were evaluated for normality using the Shapiro–Wilk test and Q–Q plots. Variables with normal distribution were expressed as mean ± SD and compared with the independent t test; otherwise, they were expressed as median (interquartile range) and compared with Mann–Whitney U test. Differences between the two medians (and 95% CIs) were calculated with Hodges–Lehmann estimators. Repeatedly measured variables (scores of pain intensity, cumulative sufentanil consumption, and cumulative number of demanded PCA bolus) were compared with the generalized estimating equation method; the significance criterion for each comparison was $P < 0.01$ (0.05/5) after Bonferroni correction. For categorical variables, data were expressed as n (%), and inter-group differences were analyzed using the chi-squared or Fisher's exact tests. Relative risks (and 95% CIs) were provided. For the 2 × 2 table containing at least one zero cell, we used "modified Haldane-Anscombe" correction by adding 0.5 to all cells to calculate the relative risk [23]. Considering the possible relationship between pain and hypertension [24], adjustment via multiple linear regression model was performed in our primary outcome analysis. Missing data were not replaced. Generally, a two-sided $P < 0.05$ was considered statistically significant unless otherwise indicated. Statistical analysis was performed with SPSS 25.0 (IBM, New York, USA).

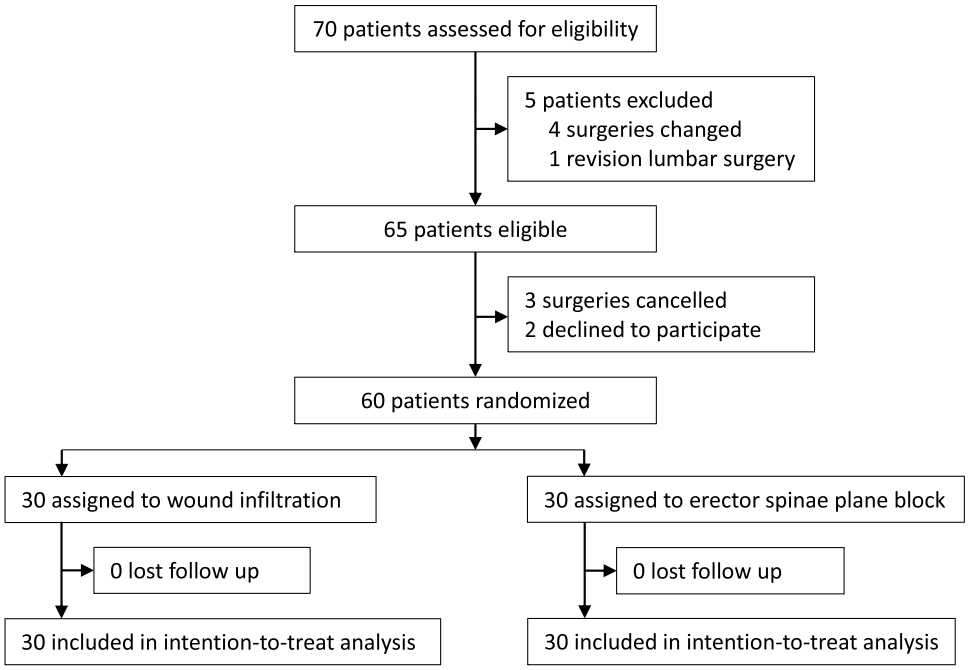

Fig. 2 Flow diagram

Results

From December 9, 2021, to March 20, 2022, 70 patients were screened for eligibility. Among these, 65 patients were eligible and 60 were enrolled and randomized to receive either ESP block ($n=30$) or wound infiltration ($n=30$). All patients completed the study and were included in the final intention-to-treat analysis (Fig. 2).

Baseline data were well balanced between the two groups, except that the proportion with preoperative hypertension was higher in patients given ESP block (Table 1) and was adjusted in the primary outcome analysis. Intraoperative data were comparable between the two groups (Table 2).

Efficacy outcomes

The equivalent dose of sufentanil consumption within 24 h was significantly lower in patients given ESP block (median 11 μg, interquartile range 5–16) than in those given wound infiltration (median 20 μg, interquartile range 10–43; median difference − 10 μg, 95% CI − 18 to − 3, $P=0.007$). The generalized estimating equation analysis showed that there was a significant interaction between group assignment and time after surgery for the equivalent dose of cumulative sufentanil consumption ($P=0.021$). Apart from that at 24 h, the equivalent doses of cumulative sufentanil consumption were also significantly lower in the ESP block group than in the wound infiltration group at 6 h (median difference − 3, 95% CI − 8 to 0, $P=0.007$) and 12 h (− 8, 95% CI − 13 to − 3, $P=0.005$) postoperatively (Table 3; Fig. 3A). Multiple linear regression model analysis showed that group assignment ($P=0.004$) but not preoperative hypertension ($P=0.500$) had a statistically significant effect on the equivalent dose of sufentanil consumption within 24 h after surgery ($F=4.608$, $P=0.014$) (Supplemental Table 1).

The method of generalized estimating equation revealed that there were no significant interactions between group assignment and time after surgery for pain intensity both at rest ($P=0.561$) and with movement ($P=0.827$). There were no statistical differences in pain intensity either at rest or with movement at any timepoint postoperatively between the two groups (Fig. 3B, C; Supplemental Table 2). Other secondary outcomes including sleep quality, quality of recovery, length of hospital stay after surgery, and complications during hospital stay did not differ between the two groups (Table 3).

The method of generalized estimating equation revealed that there was a significant interaction between group assignment and time after surgery for the number of PCA bolus demands after surgery ($P=0.006$). The cumulative number of demanded PCA boluses was significantly lower in the ESP block group than in the wound infiltration group at 6 h (median difference − 2, 95% CI − 3 to 0,

Table 1 Baseline data

	Wound infiltration ($n=30$)	Erector spinae plane block ($n=30$)	P value
Age (years)	60 ± 8	61 ± 9	0.449
Male sex	10 (33.3%)	14 (46.7%)	0.292
Body mass index ($kg \cdot m^{-2}$)	26.2 ± 2.8	27.0 ± 2.9	0.291
Comorbidities			
Hypertension	10 (33.3%)	19 (63.3%)	0.020*
Diabetes mellitus	3 (10.0%)	7 (23.3%)	0.166
Coronary heart disease	4 (13.3%)	4 (13.3%)	> 0.999
Atrial fibrillation	1 (3.3%)	0 (0.0%)	> 0.999
Hyperlipemia	1 (3.3%)	1 (3.3%)	> 0.999
ASA classification			0.776
I	1 (3.3%)	2 (6.7%)	
II	24 (80.0%)	25 (83.3%)	
III	5 (16.7%)	3 (10.0%)	
Preoperative evaluation			
Anxiety (point)[a]	2 (1, 5)	3 (1, 4)	0.946
Depression (point)[a]	4 (2, 7)	3 (2, 5)	0.271
Pain intensity (point)[b]	7 (5, 8)	7 (5, 8)	0.893
Sleep quality (point)[c]	10 (5, 14)	10 (8, 12)	0.683
Oswestry Disability Index (%)[d]	(48.8 ± 18.8) % [2]	(43.2 ± 18.7) %	0.265

Data are mean ± SD, *n* (%), or median (interquartile range). Number in square bracket indicates patients with missing data

ASA, American Society of Anesthesiologists

[a]Assessed with the Hospital Anxiety and Depression Scale (score ranges from 0 to 21 for either anxiety or depression, with a higher score indicating more severe anxiety or depression status) [15]

[b]Assessed with the Numeric Rating Scale (score ranges from 0 to 10, with 0 indicating no pain and 10 the worst pain)

[c]Assessed with the Pittsburgh Sleep Quality Index (score ranges from 0 to 21, with a higher score indicating worse sleep quality) [16]

[d]Percentage ranges from 0 to 100%, with higher percentage indicating more severe spinal dysfunction.[17]

$P=0.006$), 12 h (− 3, 95% CI − 6 to − 1, $P=0.002$) and 24 h (− 5, 95% CI − 8 to − 2, $P=0.005$) postoperatively (Fig. 3D). The proportion given rescue analgesia was significantly lower in the ESP block group than in the wound infiltration group within 48 h postoperatively (relative risk 0.27, 95% CI 0.07 to 0.96, $P=0.037$) (Table 3).

Safety outcomes

There were no significant differences between the two groups regarding safety outcomes (Table 4). No adverse events related to either the ESP block or wound infiltration were observed, including local anesthetic intoxication and hematoma.

Discussion

Our results showed that, compared with wound infiltration, bilateral ultrasound-guided ESP block significantly decreased the 24-h opioid consumption by 45% following spinal fusion surgery; it also decreased the cumulative opioid consumption at 6 h and 12 h, the cumulative PCA bolus demands at 6 h, 12 h, and 24 h, and the proportion requiring rescue analgesics within 48 h after surgery.

For patients undergoing complex spine surgery, a multimodal analgesia regime is recommended and should include paracetamol and nonsteroidal anti-inflammatory drugs or cyclooxygenases-2 specific inhibitors, with opioids used for rescue analgesia [25, 26]. Wound infiltration with local

Table 2 Intraoperative data

	Wound infiltration ($n=30$)	Erector spinae plane block ($n=30$)	P value
Duration of anesthesia (min)	274 (242,334)	303 (270,350)	0.258
Medications during anesthesia			
Use of midazolam	6 (20.0%)	5 (16.7%)	0.739
Midazolam (mg)[a]	0 (0, 0)	0 (0, 0)	0.677
Propofol (mg)[a]	1052 (733, 1493)	1003 (855, 1282)	0.994
Use of etomidate	30 (100%)	26 (86.7%)	0.121
Etomidate (mg)[a]	10 (10, 12)	11 (10, 14)	0.465
Use of sufentanil	30 (100%)	30 (100%)	> 0.999
Sufentanil (μg)[a]	40 (35, 46)	45 (40, 83)	0.053
Use of remifentanil	24 (80.0%)	19 (63.3%)	0.152
Remifentanil (μg)[a]	1175 (206, 1605)	1260 (0, 1955)	0.788
Rocuronium[a]	80 (60, 100)	78 (50, 96)	0.737
Use of cisatracurium	3 (10.0%)	7 (23.3%)	0.166
Cisatracurium[a]	0 (0, 0)	0 (0, 1)	0.136
Use of sevoflurane	29 (96.7%)	28 (93.3%)	> 0.999
Use of glucocorticoids	19 (63.3%)	12 (40.0%)	0.071
Methylprednisolone equivalent (mg)	120 (0, 120)	0 (0, 120)	0.087
Fluid infusion			
Crystalloid fluid (mL)	1800 (1300, 2313)	1950 (1600, 2525)	0.254
Use of colloid fluid	25 (83.3%)	28 (93.3%)	0.421
Colloid fluid (mL)	500 (500, 500)	500 (500, 500)	0.518
Estimated blood loss (mL)	300 (250, 530)	300 (238, 500)	0.761
Autologous blood transfusion (mL)	145 (125, 263)	150 (122, 251)	0.711
Duration of surgery (min)	191 (167, 267)	206 (170, 263)	0.420
Number of fused levels			0.262
Two	15 (50.0%)	16 (53.3%)	
Three	14 (46.7%)	9 (30.0%)	
Four	1 (3.3%)	4 (13.3%)	
Five	0 (0.0%)	1 (3.3%)	

Data are median (interquartile range) or *n* (%)

[a]Data of all patients

anesthetics is also recommended in this patient population [6–9, 26, 27]. In a randomized trial of 71 patients following thoracolumbar spinal surgery, continuous wound infusion with 0.33% ropivacaine provided similar analgesic effects but less adverse events when compared with intravenous flurbiprofen axetil and pentazocine [28]. A meta-analysis also showed that wound infiltration prolonged time to first rescue analgesia and reduced postoperative opioid demand [29]. However, controversies still exist [7, 27]. A systematic review of trials comparing wound infiltration with local anesthetics versus placebo only revealed a small or modest reduction in pain intensity immediately after surgery and a minor reduction in opioid consumption with questionable clinical significance [30].

Lumbar spinal nerve roots emerge from the intervertebral foramina in proximity to the anterior surface of the transverse processes and split into ventral and dorsal rami. ESP block is conducted by injecting local anesthetics into the plane between the deep fascia of the erector spinae muscle and the vertebral transverse process. By blocking the ventral and dorsal rami of the spinal nerves, ESP block has been successfully used for analgesia following various procedures including cardiac surgery, thoracic surgery, breast surgery, percutaneous nephrolithotomy, ventral hernia repair, cesarean section, bariatric surgery, cholecystectomy, and hip surgery [31].

The paraspinal muscles, bony tissues, and back skin are innervated by the dorsal rami of spinal nerves [32].

Table 3 Postoperative outcomes

	Wound infiltration ($n=30$)	Erector spinae plane block ($n=30$)	Median difference or relative risk (95% CI)[a]	*P* value
Primary outcome				
Sufentanil equivalent within 24 h (μg)[b]	20 (10, 43)	11 (5, 16)	−10 (−18, −3)	0.007*
Secondary outcomes				
Sleep quality during night of surgery (point)[c]	44 (0, 69)	33 (0, 58)	−4 (−22, 4)	0.411
Quality of recovery at 24 h (point)[d]	103 (93, 113)	104 (97, 110)	0 (−7, 7)	0.994
Length of hospital stay after surgery (day)	7 (6, 7)	7 (6, 8)	0 (−1, 1)	0.963
Complications during hospital stay[e]	2 (6.7%)	0 (0.0%)	RR = 0.23 (0.01, 5.40)	0.472
Other outcomes				
Number of required PCA bolus within 48 h	11 (6, 23)	8 (2, 19)	−4 (−10, 1)	0.105
Use of flurbiprofen axetil within 48 h	30 (100.0%)	30 (100.0%)	–	–
Use of rescue analgesics within 48 h[f]	11 (36.7%)	4 (13.3%)	RR = 0.27 (0.07, 0.96)	0.037*
Oswestry Disability Index at 30 days (%)[g]	44% (36%, 51%)	42% (36%, 51%)	−2% (−9%, 5%)	0.575
Decrease from baseline[h]	12% (−13%, 22%)	3% (−9%, 15%)	−4% (−16%, 11%)	0.600

Data are median (interquartile range) or *n* (%)

RR, relative risk

[a]Calculated as the erector spinae plane block group vs. or minus the wound infiltration group

[b]Including the consumption during post-anesthesia care unit stay, dosage administered by patient-controlled analgesia, and rescue analgesics (Tylox tablets), calculated as sufentanil equivalent. One Tylox tablet (containing 4.5 mg oxycodone) = 6.7 μg sufentanil [11, 18]

[c]Assessed with the Richards-Campbell Sleep Questionnaire which contains five visual analogue scales evaluating perceptions of depth of sleep, sleep onset latency, number of awakenings, time spent awake, and overall sleep quality. The scores range from 0 to 100, with a higher score indicating better sleep quality. The average score is presented [19]

[d]Assessed with the Quality of Recovery-15 scale (QoR-15) which contains 15 items. The score ranges from 0 to 150, with a higher score indicating better postoperative recovery [20]

[e]Generally defined as new-onset medical conditions that were harmful to patients' recovery and required therapeutic intervention, i.e., grade II or higher on the Clavien–Dindo classification [21]

[f]Oral Tylox tablet; one tablet contains 4.5 mg oxycodone and 325 mg paracetamol

[g]The index ranges from 0 to 100%, with higher percentage indicating more severe spinal dysfunction [17]

[h]Calculated as postoperative value minus preoperative value

Therefore, ESP block is also increasingly used in patients undergoing spinal surgery [10, 13, 14, 33, 34]. In a meta-analysis of six trials with 360 patients following lumber spinal surgery, combined use of ESP block reduced opioid consumption and improved analgesia for up to 24 h postoperatively [35]. However, studies comparing ESP block with other types of regional block analgesia remain limited [35]. Two recent small sample size trials compared the effects of bilateral ESP block with wound infiltration in patients undergoing spinal surgery; both reported improved analgesia, decreased opioid consumption, and shortened hospital stay after surgery in those given ESP block [36, 37]. In line with the above results, our trial also found that ESP block compared with wound infiltration significantly reduced the opioid consumption, PCA bolus demands, and use of rescue analgesics in patients following spinal surgery.

In the present study, we did not find differences in pain intensity at any postoperative timepoints. This could be attributed to the use of PCA pump with sufentanil and no background infusion, which might have improved analgesia on an individual basis [38, 39]. We did not find a significant difference in cumulative opioid consumption at 2 h after surgery. The phenomenon could be explained by the effect of wound infiltration which was performed at the end of surgery [30] and the residual effect of intraoperative sufentanil [40]. We also did not find a statistical difference in cumulative opioid consumption at 48 h, possibly due to the limited sample size.

Poorly controlled postoperative pain is associated with delayed functional recovery, worsened sleep quality, and increased morbidity [41, 42]. Whereas effective pain relief is a prerequisite for enhanced recovery [43]. In our results, the quality of sleep and recovery as well as complications during hospital stay did not differ between the two groups. This is understandable considering the comparable intensity of postoperative pain between the two groups; furthermore,

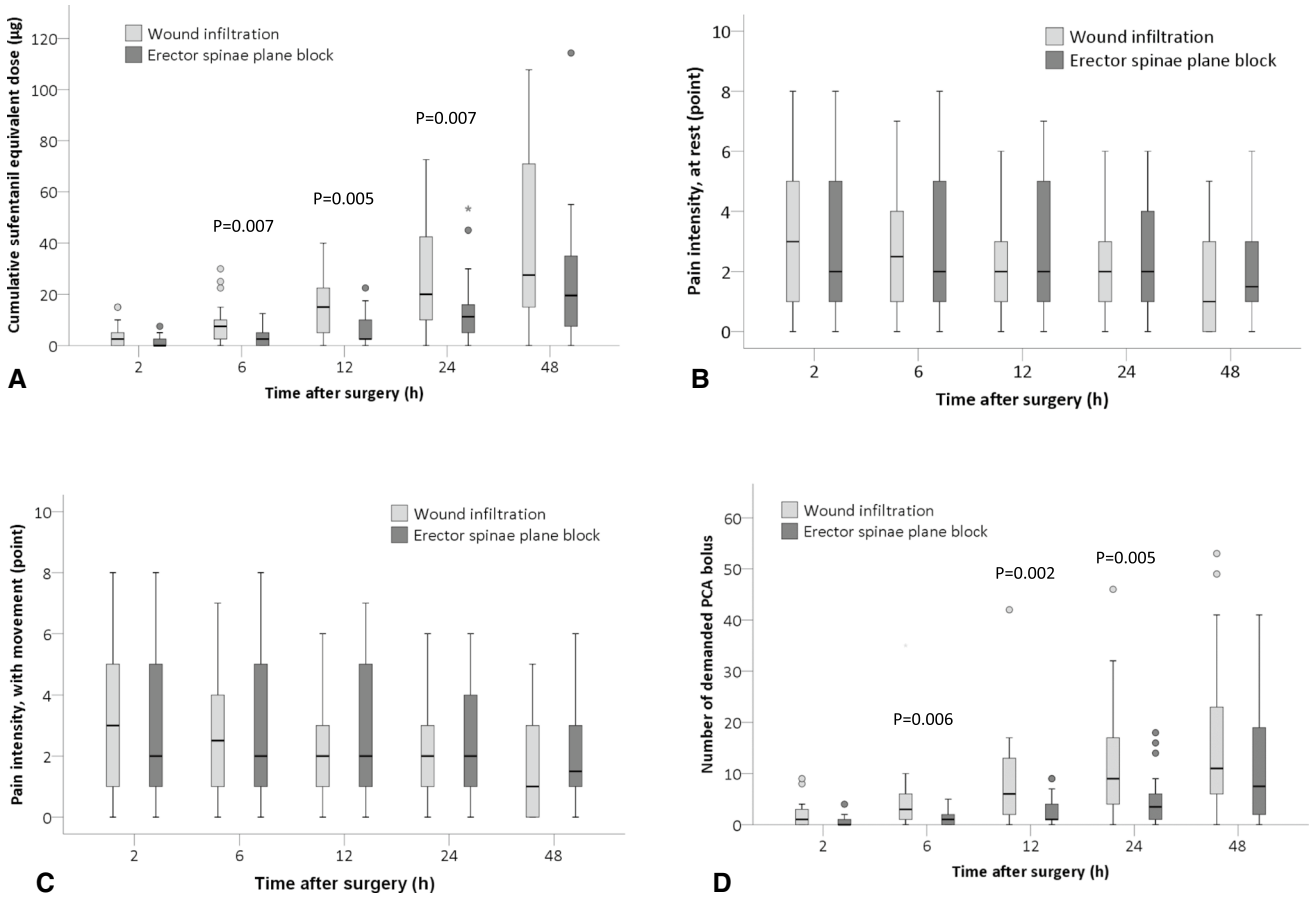

Fig. 3 Cumulative sufentanil equivalent dose (**A**), pain intensity at rest (**B**), pain intensity with movement (**C**), and the number of demanded PCA bolus (**D**) at 2, 6, 12, 24, and 48 h after spinal surgery. Pain intensity was assessed with the numeric rating scale, an 11-point scale where 0 indicates no pain or the best sleep and 10 indicates the worst pain or the worst sleep. The box and whisker plots show medians, interquartile ranges and outer ranges; individual points indicate mild outliers (○, outside 1.5 times of interquartile range) and extreme outliers (*, outside 3 times of interquartile range). $P < 0.01$ was considered statistically significant after Bonferroni correction. Also see Supplemental Table 2

our sample size was not calculated to detect differences in these secondary outcomes.

Under the guidance of ultrasonography, ESP block can be performed easily and safely. Few procedure-related complications were reported in the literature, including in patients undergoing spinal surgery [35, 44]. Consistent with the available studies, we did not observe any procedure-specific adverse events in our patients, such as local anesthetic intoxication or hematoma. Safety outcomes were similar between the two groups.

Our study has some limitations. First, we did not determine the dermatomal extent of the sensory block because the ESP block was performed after the general anesthesia induction. Second, for pragmatic reasons, anesthesiologists and surgeons were not masked from trial intervention. However, investigators responsible for postoperative assessment as well as patients and other healthcare providers were blinded. Third, intraoperative opioids might interfere with the outcome assessment. But this does not seem to last for more than 4 h considering the pharmacokinetic profile of sufentanil [40]. Fourth, given the likely limited effect of nerve blocks on long-term pain outcomes [45], we did not perform a follow-up longer than one month after surgery. Fifth, we did not evaluate the cost-effectiveness of the ESP technique versus wound infiltration.

Table 4 Safety outcomes

	Wound infiltration ($n=30$)	Erector spinae plane block ($n=30$)	*P* value
Hypotension[a]	9 (30.0%)	7 (23.3%)	0.559
Hypertension[b]	2 (6.7%)	1 (3.3%)	> 0.999
Bradycardia[c]	7 (23.3%)	5 (16.7%)	0.519
Tachycardia[d]	1 (3.3%)	1 (3.3%)	> 0.999
Respiratory depression[e]	1 (3.3%)	0 (0.0%)	> 0.999
Desaturation[f]	1 (3.3%)	0 (0.0%)	> 0.999
Nausea and vomiting[g]	5 (16.7%)	4 (13.3%)	> 0.999
Dizziness	0 (0.0%)	1 (3.3%)	> 0.999
Fever[h]	1 (3.3%)	0 (0.0%)	> 0.999

Data are *n* (%)

[a]Defined as systolic blood pressure < 90 mmHg or a decrease in systolic blood pressure of more than 30% from baseline level (average value in the ward) and required intervention

[b]Defined as systolic blood pressure > 180 mmHg or an increase of more than 30% from baseline

[c]Defined as heart rate < 50 beats/min or a decrease of > 30% from baseline

[d]Defined as heart rate > 100 beats/min or an increase of > 30% from baseline

[e]Defined as spontaneous breathing rate < 8 breaths/min

[f]Defined as pulse saturation < 90% in room air and required supplemental oxygen

[g]Patients who experienced at least one episode of nausea, vomiting or retching, or any combination of these during the first 24 h after surgery [22]

[h]Defined as an elevation of body temperature to greater than 38.3° C within 24 h after surgery

In conclusion, compared with wound infiltration, bilateral ultrasound-guided ESP block decreases short-term opioid consumption while providing similar analgesia in patients following lumbar spinal fusion surgery. A bilateral ESP block may be recommended in these patients considering its opioid-sparing effects.

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Declarations

Conflicts of interest The authors report no conflicts of interest in this work.

Ethics approval The study protocol was approved by the local Biomedical Research Ethics Committee (2021-414) and was registered prior to patient enrollment at the Chinese Clinical Trial Registry (http://www.chictr.org.cn, ChiCTR2100053008; 8 November 2021).

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