Erector Spinae Plane Block versus Transversus Abdominis Plane Block for Postoperative Analgesia in Abdominal Surgery: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Regional anesthesia technique has been reported to exert excellent analgesic efficacy for various surgeries. Erector spinae plane block (ESPB) and transversus abdominis plane (TAP) block are good ways to relieve postoperative pain after abdominal surgery. However, the analgesic efficacy between them remains controversial. This meta-analysis evaluated the analgesic effect between these two blocks in abdominal surgery with statistical and clinical interpretation.

Methods: PubMed, Web of Science, the Cochrane Library, ClinicalTrials.gov register, and Embase databases were systematically searched by two independent investigators from the inception to December 2021.

Results: 10 randomized controlled trials (RCTs) comprising 570 patients were included in the final meta-analysis. Meta-analysis revealed that ESPB decreased the opioid consumption and improved the pain scores during the first 24 postoperative hours compared with TAP groups statistically, while the magnitude of this difference did not reach the clinically significant threshold (10 mg of intravenous morphine consumption and 1.3 cm on the VAS scale). In addition, ESPB prolonged blockade duration and decreased the occurrence of postoperative nausea and vomiting (PONV). However, it did not improve the patients’ satisfaction.

Conclusions: Although ESPB does not provide better clinical analgesia than the TAP block, it could be a comparable nerve block technique for abdominal wall analgesia.

Introduction

Owing to the advanced surgical techniques, abdominal surgery has been increasing worldwide [1,2]. However, approximately 80% of patients suffered from mild to severe postoperative pain following open abdominal surgery or laparoscopic surgery [3,4]. With the growing emphasis on perioperative pain control, regional block techniques have been rapidly developed and promoted as well [5]. The erector spinae plane block (ESPB) is a newly introduced interfascial plane block that needs physicians to inject the local anesthetic into the fascial plane underneath the erector spinae muscles over the vertebral transverse process [6]. It is supposed to inhibit somatic and visceral pain probably through transforaminal and epidural spreading [7–9]. ESPB has gained popularity in various surgical procedures such as the abdominal [10], lumbar spine [11], breast [12], and thoracic surgery for its wide analgesia dermatomes (from T1 to L3) [13,14]. The previous meta-analysis has demonstrated the analgesic efficacy between ESPB and non-block care in abdominal surgery, but few systematic and persuasive study has been presented to compare it with other local anesthesia blocks. The transversus abdominis plane (TAP) block has been developed for over two decades and is considered the gold standard analgesic technique for abdominal surgery [9]. Nowadays, TAP block and its derivatives [subcostal TAPB (STAPB) and oblique subcostal TAPB (OSTAPB)] are widely applied by practitioners in abdominal surgery for their favorable analgesic efficacy [5]. Therefore, we aim to synthesize available evidence to identify whether the analgesic efficacy of ESPB is superior to TAP block or not, with statistical conclusions and clinical interpretations.

Methods

This systematic review and meta-analysis was executed based on the criteria of the Preferred Reporting Items for
Systematic Reviews and Meta-Analyses (PRISMA) guidelines [15]. The predesigned protocol of this study was registered in advance at the Prospective Register of Systematic Reviews (PROSPERO) database with No.CRD42021292568. This article was conducted on published literature and did not need ethical review and approval.

**Search strategy**

We searched several databases such as PubMed, Web of Science, the Cochrane Library, Embase, and ClinicalTrials.gov register for existing literature from the inception of the databases to December 2021 without restriction on language. The following search syntax was used: (((erector spinae plane block) OR (ESPB)) OR (ESP)) AND (((transversus abdominis plane block) OR (subcostal transversus abdominis plane block)) OR (oblique subcostal transversus abdominis plane block)) OR (TAP) OR (TAP block)) AND (((abdominal surgery) OR (abdominal)) OR (laparotomy)) OR (open surgery)) OR (laparoscopic surgery)) OR (Laparoscopy)). Considering that TAP block has several derivatives and abdominal surgery includes many operation types, we adopted a detailed search strategy. The gray literature also had been searched by supplementary hand searching.

**Study selection criteria**

Two investigators carried out the search process independently. If there were any disagreements between investigators, we would discuss them with a senior investigator. Studies that met the following criteria were included: a. were RCTs; b. compared the analgesic efficacy between ESPB and TAP block; c. included patients undergoing abdominal surgery; d. adults aged 18 years or older. Non-RCT studies, ongoing trials, conference reports, case reports, and articles that did not contain relevant outcomes or failed to obtain data from the author were excluded.

**Data extraction**

The relevant information was extracted as follows: name of the first author, year of publication, the Jadad score, age, number of participants, type of surgery performed, block location, type of TAP block, anesthesia technique, time to perform blocks, patient-controlled intravenous analgesia (PCIA), and the primary outcome. In this meta-analysis, we regarded the 24-hour postoperative opioid usage as the primary outcome [12]. Other measures such as the 24-hour postoperative pain scores during rest or movement, time to the first rescue analgesia, rate of nausea and vomiting, and patients’ satisfaction were considered as the secondary outcomes [16].

If continuous data such as opioid consumption, pain score, and time of first rescue analgesia were described as medians and interquartile range (IQR), they would be converted into means and corresponding standard deviation approximations according to the methods presented in the Cochrane Handbook for Systematic Reviews of Interventions [17,18]. When standard deviations were not reported and could not be converted from available values, we would send emails to the author for the raw data. In the absence of data from the author, we would estimate the SD with the pooled SD of other studies included in this systematic review using the formula below [19]:

\[
SD = \sqrt{\frac{\text{summation}}{N-1} \cdot \text{SD}^2}
\]

Web Plot Digitizer was used to extract numerical data from figures [20]. We converted all opioid doses into intravenous morphine equivalents for data synthesis and evaluation according to a standard conversion table [21,22]. Two methods that assessed the pain, namely VAS and NRS, were converted to a 0–10 cm scale for comparison [23].

**Quality and risk assessment**

The Cochrane's Risk-of-Bias Assessment Tool [24], the modified Jadad Score [25], and the Grading of Recommendations Assessment Development and Evaluation (GRADE) methodology [26] (the GRADEprofiler software, version3.6.1) were conducted by two independent and blinded researchers to evaluate the quality of included studies and the certainty of evidence. Any disagreements would be negotiated with a senior researcher. The Cochrane's Risk-of-Bias Assessment Tool assessed the quality according to the randomization process, allocation concealment, blinding of patients, researchers, outcome assessor, incomplete data, reporting bias, and other biases. Each item was rated at three levels (low risk, unclear risk, and high risk). The modified Jadad Score scale (total 1–7 points) was based on four criteria: randomization generation (0–2 points), allocation concealment, double-blinding (0–2 points), and statements of possible withdrawals (0–1 point). Studies scoring more than 3 points were deemed as high quality; otherwise, they would be regarded as low quality. Finally, evidence was classified by the GRADE methodology into five categories: high risk of bias, inconsistent results, indirect evidence, imprecision, and publication bias.

**Statistical analysis**

We utilized the Review Manager Version5.3 (RevMan, The Cochrane Collaboration, Copenhagen, Denmark, 2014) to perform this meta-analysis. The mean difference (MD) with the corresponding 95% confidence intervals (CI) was calculated for continuous data; risk ratio (RR) with the corresponding 95% CI was used for dichotomous data with the Mantel-Haenszel method. Heterogeneity was examined by I² statistics. When I²>50%, which indicated the heterogeneity was significant [27], a random effects model was chosen; otherwise, a fixed effects model was selected. Besides, sensitivity analysis and subgroup analysis (long duration surgery group vs. short duration surgery group) was undertaken to explore the source of huge heterogeneity. Funnel plot and Egger's linear and trim-and-fill analysis were performed to
assess the publication bias by STATA (version 16.0, StataCorp, College Station, TX). P value <0.05 with 95% CI was considered statistically significant.

Results

Literature search results

According to our search strategy, 152 relevant studies were initially included from the databases. After removing 40 duplications and 89 studies with irrelevant titles and abstracts, 23 articles were left. 10 RCTs [28–37] were finally included in the current meta-analysis after reading the full text. The detailed literature selection process is presented in the PRISMA statement flowchart (Figure 1). The pooled risk of bias summary and risk of bias graph of included ten articles are shown in Figure 2.

Study characteristics

Articles incorporated in the current study were published between 2019 and 2021, and the sample sizes were small (including 570 patients in total and 285 patients in each group). The studies varied in several aspects like the types of surgery and local analgesics injected, anesthesia method, and background analgesia administration. The type of surgery includes hysterectomy, sleeve gastrectomy, cesarean section, colorectal surgery, and laparoscopic cholecystectomy. Four studies [28,30,31,35] addressed open surgery, and six studies [29,32–34,36,37] involved laparoscopic surgery. Seven [28–30,32–35] studies chose bupivacaine as the local anesthetic, while the remaining three [31,36,37] used ropivacaine. Eight studies [28,29,32–37] were performed using general anesthesia, and the other two [30,31] used spinal anesthetic. Four studies [30,32,34,37] used postoperative controlled analgesia to relieve postoperative pain. Three articles [29,33,35] compared ESPB with TAP as well as no-block treatment (opioid analgesia, trocar-site infiltration, or placebo, respectively). All blocks were guided by ultrasound and injected bilaterally. Every study was registered at the clinicaltrials.gov prospectively. Hassan’s [35] study was a completed clinical trial but has not been published yet. The quality and characteristics of the enrolled ten studies are summarized in Table 1.

Outcomes

Primary outcomes

24-Hour postoperative opioid consumption

Across all studies, nine studies recorded total opioid doses in the first 24 hours after surgery. This meta-analysis demonstrated that the consumption of morphine was significantly decreased in ESPB groups compared with the TAP groups (−7.78 mg; 95% CI: −11.67 to −3.89; p < 0.001; $I^2 = 99\%$) (Figure 3). For the high heterogeneity, we divided the studies into two groups for subgroup analysis: long duration surgery group and short duration surgery group (we regarded LC and the cesarean section as short time surgeries and the remaining operations as long time surgeries). In the former group, four studies with 216 participants were analyzed (−5.22 mg; 95% CI: −9.02 to −1.43; $p = 0.007; I^2 = 93\%$); in the latter group, five studies with 294 patients were examined (−9.83 mg; 95% CI: −18.02 to −1.65; $p = 0.02; I^2 = 95\%$).
99%) (Table 2). Notably, more reduction in opioid consumption has been seen with ESPB in the short duration surgery group.

Secondary outcomes

Time of first rescue analgesia

It was defined as the time of patients’ first requirement for rescue analgesia. Seven studies included 380 patients compared this indicator between patients receiving ESPB and TAP treatment. Synthesized results revealed that patients who received ESPB had a longer blockage duration after abdominal surgery compared to those in the TAP group (9.54 h; 95% CI: 4.93 to 14.14; \( p < 0.0001; F^2 = 100\% \)) (Figure 4).

24-Hours postoperative pain scores during rest and movement

The meta-analysis assessed the pain scores at 2h, 4h, 6h, 8h, 12h and 24h after surgery during rest and movement (Figure 5 ABC). Pain scores were slightly lower in ESPB group during rest at several time points postoperatively (4h: -0.60 cm; 95% CI: -0.98 to -0.22; \( p = 0.002; F^2 = 91\% \); 6h: -0.81 cm; 95% CI: -1.28 to -0.34; \( p = 0.0007; F^2 = 86\% \)); 8h: -0.97 cm; 95% CI: -1.70 to -0.25; \( p = 0.008; F^2 = 93\% \); 12h: -1.08 cm; 95% CI: -1.78 to -0.38; \( p = 0.002; F^2 = 97\% \); 24h: -0.40 cm; 95% CI: -0.70 to -0.10; \( p = 0.008; F^2 = 88\% \)). There was no difference at 2h between the two groups (2h: -0.42 cm; 95% CI: -1.05 to -0.22; \( p = 0.20; F^2 = 95\% \)). The ESPB improved pain scores at movement as well, compared with the TAP group (2h: -0.42 cm; 95% CI: -0.79 to -0.05; \( p = 0.03; F^2 = 68\% \); 4h: -0.62 cm; 95% CI: -1.12 to -0.11; \( p = 0.02; F^2 = 88\% \); 6h: -1.04 cm; 95% CI: -2.05 to -0.03; \( p = 0.04; F^2 = 94\% \); 12h: -0.87 cm; 95% CI: -1.73 to -0.02; \( p = 0.04; F^2 = 96\% \); 24h: -0.50 cm; 95% CI: -0.86 to -0.14; \( p = 0.007; F^2 = 88\% \)), except at 8h (8h: -1.27 cm; 95% CI: -2.72 to 0.18; \( p = 0.09; F^2 = 95\% \)).

Side effects and patients’ satisfaction

Five articles included 282 patients reported data about postoperative nausea, and four included 222 patients recorded data on the occurrence rate of postoperative vomiting. Since the heterogeneity between the included articles was small, we used the fixed effects model to analyze the
Table 1. The characteristics of included studies: ESPB vs TAP.

| Reference     | Jadad score | Age (years) | Type of surgery          | Anesthesia technique | Time to perform blocks | No. of patient | Location | Local anesthetic dose               | No. of patient | type | Postoperative analgesic | Primary outcome                                                                 |
|---------------|-------------|-------------|---------------------------|----------------------|------------------------|-----------------|----------|-------------------------------------|----------------|------|---------------------------|--------------------------------------------------------------------------------|
| Alshaimaa 2020 | 6           | 40 ~ 60     | Open total abdominal hysterectomy | GA                   | After surgery          | 24              | T9       | 20 mL 0.375% bupivacaine           | 24             | TAP  | IV morphine + pethidine   | Pain score at 24 postoperative hours; The time of the first request for analgesia; Opioid consumption at 24 postoperative hours |
| Bassant 2020   | 7           | 18 ~ 59     | Laparoscopic sleeve gastrectomy | GA                   | Before surgery         | 22              | T9       | 15 mL 0.25% bupivacaine           | 22             | STAP | IV paracetamol + pethidine | Pain score at 24 postoperative hours |
| Maged 2020     | 6           | 18 ~ 40     | Cesarean section           | SA                   | After surgery          | 30              | T9       | 20 mL 0.25% bupivacaine           | 30             | TAP  | Tramadol PCA + IV paracetamol 1gm 8th hourly and IV ketorolac 30mg 12th hourly | Pain score at 24 postoperative hours; The time of the first request for analgesia |
| Aman 2020      | 6           | pregnant woman | Cesarean section           | SA                   | After surgery          | 30              | T9       | 0.2ml/kg 0.2% ropivacaine         | 30             | TAP  | IV diclofenac               | The time of the first request for analgesia |
| Başak 2019     | 6           | 18 ~ 70     | LC                         | GA                   | Before surgery         | 34              | T7       | 20 mL 0.375% bupivacaine          | 34             | OSTAT | Tramadol PCA + IV morphine    | Opioid consumption at 24 postoperative hours |
| Mohamed 2020   | 7           | 20 ~ 60     | LC                         | GA                   | Before surgery         | 21              | T8       | 20 mL 0.25% bupivacaine           | 21             | OSTAT | IV fentanyl or morphine or pethidine | Opioid consumption at 24 postoperative hours |
| Halime 2021    | 4           | 18 ~ 64     | LC                         | GA                   | Before surgery         | 32              | T7       | 10 mL 0.25% bupivacaine and 10 mL 2% prilocaine | 32             | STAP  | Tramadol PCA + IV paracetamol 15mg/kg 6th hourly | Pain score at 24 postoperative hours |
| Hassan 2020    | 5           | 18 ~ 70     | Laparotomy                  | GA                   | Before surgery         | 31              | T7       | 20 mL 0.25% bupivacaine           | 31             | TAP  | IV fentanyl + IV paracetamol 1 gm 6th hourly | Opioid consumption at 24 postoperative hours; The time of the first request for analgesia |
| Lingaraj 2021  | 6           | 18 ~ 70     | LC                         | GA                   | Before surgery         | 30              | T7       | 20 mL 0.2% ropivacaine and 4mg dexamethasone solution | 30             | OSTAT | IV paracetamol 1 gm 6th hourly + IV tramadol or diclofenac | Opioid consumption at 24 postoperative hours; Pain score at 24 postoperative hours |
| Shen 2021      | 6           | >65          | Laparoscopic Colorectal surgery | GA                   | Before surgery         | 31              | T9       | 20 mL 0.25% ropivacaine           | 31             | OSTAT | Sufentanil PCA              | Pain score at 24 postoperative hours |

Abbreviations: LC, laparoscopic cholecystectomy; GA, general anesthesia; SA, spinal anesthetic; T, thoracic vertebra; ESPB, erector spinae plane block; TAP, transversus abdominis plane block; STAP, subcostal transversus abdominis plane block; OSTAT, oblique subcostal transversus abdominis plane block; PCA, patient-controlled analgesia; IV, intravenous injection.
pooled results. The forest plot shown that ESPB reduced the rate of postoperative nausea (RR 0.65; 95%CI 0.43 to 0.98; \( p = 0.04; I^2 = 38\% \) (Figure 6A) and postoperative vomiting (OR 0.35; 95%CI 0.13 to 0.91; \( p = 0.03; I^2 = 0\% \)) (Figure 6B). Two articles included 108 patients assessed the patients’ satisfaction; however, there were statistically insignificant between the ESPB and TAP groups (RR 1.16; 95%CI 1.00 to 1.34; \( p = 0.05; I^2 = 0\% \)) (Figure S1). Additionally, a study by Lingaraj [36] reported that patients that received ESPB treatment were more satisfied with the improvement of pain, whereas patients that received TAP treatment were more satisfied with the process of performance. Only one study [34] assessed the lengths of PACU and hospital stay [mean ± SD: 25.2 ± 2.5 min vs.13.9 ± 2.2 min and 27.3 ± 3.2h vs.24.2 ± 0.5h, respectively, \( p < 0.0001 \)], and time to achieve unassisted walking [mean ± SD: 168.4 ± 11.8 min vs.126.3 ± 13.9 min, respectively, \( p < 0.0001 \)]. All results were significantly shorter in the ESPB group. No ESPB-related and TAP-related complications such as bleeding or infection of puncture point, local anesthetic intoxication, and bowel perforation were described in the included studies.

Figure 3. Forest plot for the comparison of intravenous morphine equivalents (mg) in the first 24h after surgery.

Table 2. Results of the subgroup analysis.

| Outcomes                  | Subgroup (the duration of surgery) | Participants (studies) | Effect SD (95%CI) | P     | \( \nu \) |
|---------------------------|-----------------------------------|------------------------|-------------------|-------|--------|
| 24-hour postoperative     | Long                              | 216 (4)                | −5.22 (9.02,−1.43)| 0.007 | 93%    |
| opioid consumption        | Short                             | 294 (5)                | −9.83 (−18.02,−1.65) | 0.02 | 99%    |
| Time of first rescue      | Long                              | 154 (3)                | 10.19 (2.24,18.13) | 0.01 | 98%    |
| analgesia                 | Short                             | 226 (4)                | 9.05 (3.20,14.90)  | 0.002 | 100%   |
| Pain scores at rest at 2h | Long                              | 154 (3)                | −0.36 (−1.77,1.05) | 0.62 | 98%    |
|                           | Short                             | 226 (4)                | −0.46 (−0.89,−0.02) | 0.04 | 75%    |
| Pain scores at rest at 4h | Long                              | 154 (3)                | −0.33 (−0.65,−0.01) | 0.04 | 68%    |
|                           | Short                             | 286 (5)                | −0.77 (−1.32,−0.22) | 0.006 | 92%    |
| Pain scores at rest at 6h | Long                              | 92 (2)                 | −0.50 (−0.89,−0.11) | 0.01 | 0%     |
|                           | Short                             | 226 (4)                | −0.94 (−1.54,−0.33) | 0.002 | 90%    |
| Pain scores at rest at 8h | Long                              | 154 (3)                | −0.40 (−0.63,−0.18) | 0.0004 | 0%    |
|                           | Short                             | 120 (2)                | −1.76 (−2.28,−1.25) | <0.00001 | 64% |
| Pain scores at rest at 12h| Long                              | 154 (3)                | −0.85 (−1.16,−0.55) | <0.00001 | 43% |
|                           | Short                             | 286 (5)                | −1.21 (−2.29,−0.13) | 0.03 | 98%    |
| Pain scores at rest at 24h| Long                              | 154 (3)                | −0.43 (−0.74,0.11)  | 0.007 | 66%    |
|                           | Short                             | 286 (5)                | −0.40 (−0.86,0.07)  | 0.09 | 92%    |

Figure 4. Forest plot for the comparison of the time of first rescue analgesia.
Publication bias
Since the heterogeneity was distinct in this analysis, we further conducted a sensitivity analysis by systematically removing articles to explore the source of heterogeneity. However, no significant changes have been seen in pooled effect, which indicates the pooled results were stable (Figure S2). Taking into consideration that the duration of the surgery is a potential factor influencing the analgesic efficacies of nerve blocks, we performed a subgroup analysis based on it to explore the heterogeneity. The results showed that the heterogeneity of postoperative pain scores at rest was significantly reduced (Table 2).

The funnel plot (Figure S3) showed some asymmetry through visual inspection, implicating the existence of publication bias, which was constructed with 24-hour postoperative opioid consumption for the ESPB versus TAP. Egger’s regression also showed a publication bias for a small-study effect ($P=0.001$) (Figure S4). We utilized the trim-and-fill analysis to handle the asymmetry of the funnel plot, and it predicted three theoretical missing studies (Figure S5). After being trimmed and filled, the overall effect measure did not change significantly. The level of certainty of the evidence is presented in Table 3.

Discussion
Postoperative pain is still a challenge today. Pain after abdominal surgery usually derives from incisional pain, visceral pain, tissue trauma, shoulder pain from CO$_2$ insufflation, and phrenic nerve irritation [38]. This means that
patients are experiencing both visceral and somatic pain. Adequate analgesia can increase patient satisfaction, hasten rehabilitation and functional recovery, shorten the length of hospital stay and decrease the chance of venous thrombosis [39]. Previous studies have proved that both ESPB and TAP can improve the postoperative pain of abdominal surgery. However, in theory, the ESPB has a great advantage of providing somatic and visceral analgesia compared to the TAP block, which only addresses the somatic pain [5]. As far as we know, this was the first meta-analysis conducted on RCTs to compare the analgesic efficacy of ESPB with that of TAP in patients following abdominal surgery so far. The most valuable finding of the current investigation was that ESPB could provide positive clinical analgesic efficacy, which is equivalent to the TAP block. Statistically, it reduced the opioid consumption in the first 24 hours postoperatively, improved pain scores and prolonged the blockage time, and reduced the occurrence of PONV compared to TAP.

Nevertheless, there was no significant clinical difference in two results. Reductions equivalent to 30 mg oral morphine [16] in the first 24 hours postoperatively, improved pain scores and prolonged the blockage time, and reduced the occurrence of PONV compared to TAP. Nevertheless, there was no significant clinical difference in two results. Reductions equivalent to 30 mg oral morphine [16] in the first 24 hours after surgery and 1.3 cm [40, 41] on the VAS scale were regarded as the minimum clinically important difference. As mentioned before, 30 mg of oral morphine is approximately equal to 10 mg of intravenous morphine. In this system review, ESPB reduced the 24-hour morphine consumption; however, the importance of the statistical benefits disappeared when putting the difference of 7.78 mg into the clinical background.

In terms of the pain severity, the most significant pain score reduction on the VAS scale was 1.08 cm, which failed to reach the clinically meaningful threshold. Therefore, these two outcomes were statistically significant but clinically unimportant. This may explain why no significant change was observed in patient satisfaction between these two technologies.

What is worth mentioning is that the ESPB prolonged the time to the first analgesic need significantly compared to the TAP block. The difference of 9.54 h was not only statistically significant but also clinically meaningful [34].

As described before, ESPB was considered to act on the ventral and dorsal rami ventral of spinal nerves to provide adequate somatic and visceral analgesia, which was an advantage over the TAP block. However, how the local anesthetic (LA) acts and spreads remains unclear. A vivo MRI study suggested that LA spreads anteriorly and laterally, entering the transforaminal, circumferential epidural, and intercostal space so as to extend the dermatomal coverage [10, 42].

The subgroup analysis based on the duration of surgery decreased the I² of postoperative pain scores at rest. However,
the sources of high heterogeneity of two other outcomes (24-hour postoperative opioid consumption and the time of first rescue analgesia) have not been detected by the sensitivity analysis and subgroup analysis. Many variables caused the existence of heterogeneity. For instance, the supplementary analgesics (paracetamol or diclofenac); intraoperative opioid administration (fentanyl, sufentanil, or remifentanil); the application of different procedures (OSTAP, STAP, and TAP); the type of surgery (open surgery or Laparoscopic surgery); the blocking locations (T7 or T9); the types of local anesthetics (ropivacaine or bupivacaine) and the adjunct (adrenaline or dexamethasone). Indeed, it has been proved that the analgesic efficacy of OSTAP is superior to other derivatives [43]. Besides, conducting nerve block preoperatively can provide better analgesia than the same block performed postoperatively during the early postoperative period [44]. The nature of surgical procedures (types of surgery, pathologies, surgical approaches, and extent of procedure) can also add extra heterogeneity. Moreover, heterogeneity prevailed since we used the transformed means and standard deviations and converted data.

Several complications related to ESPB have been described in previous studies. Hamilton [45] reported one case of pneumothorax following ESPB; Elkoundi [46] described a priapism; O Selvi [47] reported an unexpected case of motor weakness; Karaca [48] described a LAST (local anesthetic systemic toxicity) following high dose lumbar erector spinae plane block. A retrospective review [49] revealed that 4 of the 182 patients experienced side effects. In these four complications, one case was perhaps related to the spread of...
the LA to the lumbar plexus, and three cases were considered to be associated with the LA toxicity possibly. Although no major LAST complications such as seizures have been observed, the rate of the LA toxicity was a little high. There is, therefore, a significant need to determine the effective and safe volume and concentration of the local anesthetic.

In this meta-analysis, no complications like local anesthetic toxicity, bleeding or infection of puncture point, or nerve injury were reported among the 285 patients in the ESPB group. Because of the injection location of ESPB (which is away from the vital structures) as well as the prevalence of ultrasound, procedure-related complications like pneumothorax and nerve injury are remarkably decreased [50]. Another advantage of the ESPB is that the block is considered easy to be learned due to the simplicity of its landmarks on ultrasound [51].

Generally speaking, ESPB is a relatively safe technique. It would be a proper choice for the abdominal operation, given its analgesic efficacy, lower associated risk, and strong operability. It is worth noting that performing ESPB requires

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**Table 3. Results of the main outcomes and quality of evidence (GRADE).**

| Outcome                                | Patients (studies) | Effect SD (95%CI) | P value | Heterogeneity | Quality of evidence (GRADE) |
|----------------------------------------|-------------------|-------------------|---------|---------------|-----------------------------|
| 24-hour postoperative opioid consumption | 502 (9)           | −7.78 mg (−11.67 to −3.89) | <0.0001 | <0.00001 (99%) | ⊕⊕⊕⊝ moderate^b |
| Pain scores at rest                    |                   |                   |         |               |                             |
| 2 h                                    | 380 (7)           | −0.42 cm (−1.05 to 0.22) | 0.20    | <0.00001 (95%) | ⊕⊕⊕⊕low^a,b |
| 4 h                                    | 440 (8)           | −0.60 cm (−0.98 to −0.22) | 0.002   | <0.00001 (91%) | ⊕⊕⊕⊕low^a,b |
| 6 h                                    | 318 (6)           | −0.81 cm (−1.28 to −0.34) | 0.0007  | <0.00001 (86%) | ⊕⊕⊕⊕low^a,b |
| 8 h                                    | 274 (5)           | −0.97 cm (−1.70 to −0.23) | 0.008   | <0.00001 (93%) | ⊕⊕⊕⊕low^a,b |
| 12 h                                   | 440 (8)           | −1.08 cm (−1.78 to −0.38) | 0.002   | <0.00001 (97%) | ⊕⊕⊕⊕low^a,b |
| 24 h                                   | 440 (8)           | −0.40 cm (−0.70 to −0.10) | 0.008   | <0.00001 (88%) | ⊕⊕⊕⊕low^a,b |
| Pain scores at movement                |                   |                   |         |               |                             |
| 2 h                                    | 296 (5)           | −0.42 cm (−0.79 to −0.05) | 0.03    | 0.02 (68%)    | ⊕⊕⊕⊕low^a,b |
| 4 h                                    | 268 (5)           | −0.62 cm (−1.12 to −0.11) | 0.02    | <0.00001 (88%) | ⊕⊕⊕⊕low^a,b |
| 6 h                                    | 166 (3)           | −1.04 cm (−2.05 to −0.03) | 0.04    | <0.00001 (94%) | ⊕⊕⊕⊕low^a,b |
| 8 h                                    | 122 (2)           | −1.27 cm (−2.72 to 0.18) | 0.09    | <0.00001 (85%) | ⊕⊕⊕⊕low^a,b |
| 12 h                                   | 356 (6)           | −0.87 cm (−1.73 to −0.02) | 0.04    | <0.00001 (96%) | ⊕⊕⊕⊕low^a,b |
| 24 h                                   | 356 (6)           | −0.50 cm (−0.86 to −0.14) | 0.007   | <0.00001 (88%) | ⊕⊕⊕⊕low^a,b |
| Time for requirement of first rescue analgesia | 380 (7)              | 9.54 h (4.93 to 14.14) | <0.0001 | <0.00001 (100%) | ⊕⊕⊕⊕low^a,b |
| Nausea                                 | 282 (5)           | 0.65 (0.43 to 0.98)  | 0.04    | 0.17 (38%)    | ⊕⊕⊕⊕⊕ high |
| Vomiting                               | 222 (4)           | 0.35 (0.13 to 0.91)  | 0.03    | 0.39 (0%)     | ⊕⊕⊕⊕⊕ high |
| Satisfaction of analgesia              | 108 (2)           | 1.16 (1.00 to 1.34)  | 0.05    | 0.68 (0%)     | ⊕⊕⊕⊕⊕ high |

^aQuality was rated down for using estimation formulas.
^bQuality was rated down for very high statistical heterogeneity.
the lateral, prone, or sitting position, which is a little bit restricted compared to the TAP block, which only requires the supine position.

Although the results of this systematic review were desirable, some limitations should be noted. Firstly, due to the relatively small sample size of the studies included (the largest experimental group consisted of 34 patients), the treatment effect could be overestimated. Secondly, we did not perform a quantitative analysis comparing ESPB with TAP because of the limited number of RCTs. Thirdly, because we only chose articles conducted on abdominal surgery, selection bias may exist. Fourthly, even though we conducted a comprehensive and exhaustive literature search on plenty of databases, there is still a possibility of missing relevant articles or gray literature that meet our criteria. Fifthly, significant heterogeneity was observed in most analyses, and the potential sources were discussed earlier. Lastly, age is an important factor impacting pain sensation or expression. The elderly are relatively insensitive to pain. However, only two articles included assessed the pain in elderly patients, which makes it impossible for us to carry out an analysis on age. Thus, further studies with age-stratified analysis are essential.

Overall, figuring out the mechanism of action of ESPB could help physicians apply this block better. This is an area that requires further exploration in the future, and more robust evidence is required to guide clinical practice.

**Conclusion**

Compared with TAP block, ESPB has exhibited statistically better and clinically equivalent analgesic efficacy in this systematic review. Besides, ESPB showed a longer blockade duration, a lower incidence of PONV, and equal patient satisfaction. Overall, these results provided novel evidence to support incorporating the ESPB into the multimodal analgesic management, which suggests that ESPB could be a suitable alternative to the abdominal analgesia. However, the moderate-to-low quality of evidence impacted the findings. Therefore, further high-quality RCTs related to the ESPB are still needed to evaluate the safety and analgesic efficacy.

**Disclosure statement**

The authors report no conflicts of interest.

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