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ORIGINAL ARTICLE / ÖZGÜN MAKALE

Comparison of the postoperative analgesic efficacy of serratus anterior plane block with different types of blocks for video-assisted thoracoscopic surgery: A systematic review and meta-analysis of randomized controlled trials

Video yardımlı torakoskopik cerrahide serratus anterior düzlem blok'unun ameliyat sonrası analjezik etkinliğinin farklı blok tipleri ile karşılaştırılması: Randomize kontrollü çalışmaların sistematik derleme ve meta-analizi

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ABSTRACT

Background: The study aimed to compare the analgesic efficacy of single-shot serratus anterior plane block (SAPB) for video-assisted thoracoscopic surgery (VATS) with other regional block techniques.

Methods: In this meta-analysis, randomized controlled trials published in the PubMed, Scopus, Web of Science, ClinicalKey, and PROSPERO electronic databases between March 24, 2014 and March 24, 2024 comparing the analgesic efficacy of SABP with other regional blocks in adult patients undergoing VATS were reviewed.

Results: Nine randomized controlled trials consisting of a total of 537 participants (287 males, 250 females; mean age: 55.2±13.1 years) were included in this meta-analysis. Serratus anterior plane block was compared with erector spinae plane block (ESPB), local infiltration anesthesia (LIA), and thoracic paravertebral block (TPVB). The postoperative 24-h cumulative opioid consumption was statistically significantly higher in SAPB than in ESPB (standardized mean difference

ÖZ

Amaç: Bu çalışmada, video yardımlı torakoskopik cerrahide (VATS) tek seferlik serratus anterior düzlem blok'unun (SAPB) etkinliği diğer bölgesel blok tekniklerinin analjezik etkinliğiyle karşılaştırıldı.

Çalışma planı: Bu meta-analizde, 24 Mart 2014 - 24 Mart 2024 tarihleri arası yayınlanan ve VATS uygulanan yetişkin hastalarda SABP'nin analjezik etkinliğini diğer rejyonel blokların analjezik etkinliği ile karşılaştıran randomize kontrollü çalışmalar PubMed, Scopus, Web of Science, ClinicalKey, and PROSPERO elektronik veri tabanlarında tarandı.

Bulgular: Toplamda 537 katılımcıyı (287 erkek, 250 kadın; ort. yaş: 55.2±13.1 yıl) içeren dokuz randomize kontrollü çalışma meta-analize dahil edildi. Serratus anterior düzlem blok'u ile erector spinae düzlem blok'u (ESPB), lokal infiltrasyon analjezisi (LIA) ve torasik paravertebral blok (TPVB) karşılaştırıldı. Ameliyat sonrası 24 saatlik kümülatif opioid tüketimi istatistiksel olarak anlamlı bir şekilde SAPB'de ESPB'ye (standardize ortalama fark [SMD]=1.98; %95 güven aralığı [GA], 0.23-3.73;

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[SMD]=1.98; 95% confidence interval [CI], 0.23 to 3.73; Z=2.22; p=0.03; I^2=97%; random effects model) and TPVB (SMD=0.63; 95% CI, 0.31 to 0.96; Z=3.84; p<0.001; I^2=0%; fixed effects model) and lower than in LIA (SMD=–1.77; 95% CI, –2.24 to –1.30; Z=7.41; p<0.001; I^2=0%; fixed effects model). Active pain scores 2 h postoperatively were statistically significantly lower in SAPB than in LIA (SMD=–2.90; 95% CI, –5.29 to –0.50; Z=2.37; p=0.02; I^2=93%; random-effects model). At 12 h postoperatively, both passive pain scores (SMD=0.37; 95% CI, 0.07 to 0.66; Z=2.41; p=0.02; I^2=0%; fixed effects model) and active pain scores (SMD=0.55; 95% CI, 0.25 to 0.85; Z=3.60; p<0.001; I^2=0%; fixed effects model) were statistically significantly lower in ESBP than in SAPB. There was no difference between SAPB and the other groups in terms of the incidence of postoperative nausea and vomiting.

Conclusion: After a comprehensive evaluation of postoperative analgesic effects, it appears that ESBP and TPVB may be better than SABP, and SABP may be better than LIA for analgesia of patients undergoing VATS. Further studies are required to determine the optimal regional analgesia technique in VATS.

Keywords: Postoperatif opioid consumption, serratus anterior plane block, systematic review and meta-analysis, video-assisted thoracoscopic surgery.

Z=2.22; p=0.03; I^2=%97; rastgele etkiler modeli) ve TPVB'ye (SMD=0.63; %95 GA, 0.31-0.96; Z=3.84; p<0.001; I^2=%0; sabit etkiler modeli) kıyasla daha yüksek ve LIA'ya kıyasla daha düşük (SMD=–1.77; %95 GA, –2.24- –1.30; Z=7.41; p<0.001; I^2=%0; sabit etkiler modeli) bulundu. Ameliyat sonrası ikinci saatteki aktif ağrı skorlarının SAPB'de LIA'ya göre istatistiksel olarak anlamlı derecede düşük olduğu tespit edildi (SMD=–2.90; %95 GA, –5.29- –0.50; Z=2.37; p=0.02; I^2=%93; rastgele etkiler modeli). Ameliyat sonrası 12. saatte hem istirahatteki ağrı skorları (SMD=0.37; %95 GA, 0.07-0.66; Z=2.41; p=0.02; I^2=0%; sabit etkiler modeli) hem de aktif ağrı skorlarının (SMD=0.55; %95 GA, 0.25-0.85; Z=3.60; p<0.001; I^2=%0; sabit etkiler modeli) ESBP'de SAPB'ye kıyasla istatistiksel olarak anlamlı olarak düşük olduğu bulundu. Ameliyat sonrası mide bulantısı ve kusma insidansı açısından ise SAPB ile diğer gruplar arasında fark yoktu.

Sonuç: Ameliyat sonrası analjezik etkilerin kapsamlı bir değerlendirmesinden sonra VATS uygulanan hastalarda, ESBP ve TPVB'nin SABP'ye kıyasla, SABP'nin ise LIA'ya kıyasla analjezide daha iyi olabileceği görülmektedir. Video yardımlı torakoskopik cerrahide optimal bölgesel analjezi tekniğinin belirlenebilmesi için daha fazla çalışmaya ihtiyaç vardır.

Anahtar sözcükler: Ameliyat sonrası opioid tüketimi, serratus anterior düzlem blok'u, sistematik derleme ve meta-analiz, video yardımlı torakoskopik cerrahi.

Patients undergoing thoracic surgery often experience acute and chronic postoperative pain.[1] Thoracic surgery is considered the most painful surgical procedure regardless of its invasiveness.[2] Video-assisted thoracoscopic surgery (VATS), performed through a smaller incision, is not only less invasive than open thoracotomy but also leads to less postoperative pain.[3] Despite smaller incisions, lack of rib retraction, and less tissue damage, some patients undergoing VATS experience moderate to severe pain after surgery; therefore, achieving adequate postoperative analgesia is challenging.[4]

Inadequate postoperative pain control may delay the recovery of respiratory functions by preventing deep breathing and coughing, which leads to complications such as atelectasis, hypoxia, and pneumonia.[5] Additionally, ineffective and inadequate treatment of acute postoperative pain may alter the risk of chronic pain development.[6] Therefore, postoperative acute pain management is a significant issue. Opioids are one of the most commonly used drugs in postoperative pain management.[7] However, opioid-related side effects should not be underestimated.[8] A multimodal perioperative analgesia model combining intravenous analgesia and regional nerve blocks has been proposed to reduce postoperative opioid consumption and provide better pain control.[9]

The most commonly used techniques to reduce pain after thoracic surgery are thoracic epidural analgesia (TEA) and thoracic paravertebral block (TPVB).[10,11] However, these are technically challenging, and they are associated with some important complications, such as pneumothorax, dural puncture, hematoma, infection, and nerve injury.[12] This is the point where the need for less invasive techniques may arise. Serratus anterior plane block (SAPB), erector spinae plane block (ESPB), and intercostal nerve block (ICNB) are among the common regional block techniques used currently for pain in thoracotomy. Ultrasound-guided SAPB is a promising interfascial plane block with the potential to provide adequate analgesia for such cases.[13,14] First proposed by Blanco et al.,[15] SAPB is performed by injecting a local anesthetic into the interfascial plane above or below the serratus anterior muscle using ultrasound guidance. This regional technique blocks the lateral cutaneous branches of the intercostal nerves, providing a broader nerve block effect that generally extends between the second and ninth thoracic dermatomes, and is associated with fewer complications.[16] Serratus anterior plane block has been shown to improve postoperative pain management and reduce postoperative opioid consumption following thoracotomy, breast surgery, and rib fracture surgery.[17,18] Hence, SAPB appears as an easy-to-implement, effective, and safe regional

block technique. Although there are reports of systematic review and meta-analysis studies of existing randomized controlled trials (RCTs) attempting to evaluate the analgesic efficacy of SAPB after VATS,[19,20] there is still limited data comparing the analgesic efficacy of SAPB after VATS with other blocks. In this systematic review and meta-analysis, RCTs comparing the analgesic efficacy of SAPB after VATS with the analgesic efficacy of other blocks were evaluated.

MATERIALS AND METHODS

Literature search

This systematic review and meta-analysis of RCTs was performed in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The PRISMA checklist is displayed in Supplementary Table 1. The protocol was registered by the authors in the International Prospective Register of Systematic Reviews (CRD42024523185). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The electronic databases PubMed, Scopus, Web of Science, ClinicalKey, and PROSPERO were searched to identify studies comparing the analgesic efficacy of SABP with the analgesic efficacy of other blocks in patients undergoing VATS. The literature search was conducted between March 24, 2014 and March 24, 2024. Search terms consisted of medical subject headings and keywords. Our search strategy for each database was as follows: ("video-assisted thoracoscopic surgery" OR "video-assisted" OR "VATS") AND ("serratus anterior plane block" OR "Serratus plane block" OR "SAP" OR "SAPB"). All the included studies were RCTs. Additional articles were obtained by manually checking the reference lists of the appropriate studies and reviews on the subject.

Study selection

Three independent researchers filtered the articles obtained from the literature review by viewing the titles and abstracts and elected the matching studies by reading the full texts. The selected studies were included using the PICOS criteria: Population (P), adult patients aged 18 years and older undergoing any type of VATS; Intervention (I), single-shot SAPB; Control (C), other regional analgesia blocks; Outcome (O), postoperative opioid consumption, passive (at rest) and active (at movement) postoperative pain scores, postoperative nausea and vomiting (PONV), time to first analgesic requirement; Study design (S), RCTs published in the last 10 years. Retrospective studies, observational cohort studies, case reports with insufficient data, letters to the editor, review articles, animal studies, and articles that were not full-length, studies comparing SAPB with epidural analgesia, no block, placebo, or combined blocks, or studies using continuous nerve block, and studies published in a language other than English were excluded.

Outcomes

The primary outcome of the present meta-analysis was the total opioid consumption in the first 24 h postoperatively in adult patients undergoing VATS with SAPB and other blocks. Secondary outcomes were passive and active pain scores 2, 6, 12, and 24 h postoperatively and PONV.

Data extraction

After identifying studies that met the inclusion criteria, two members of our team independently reviewed and evaluated each of the included studies. Any disagreement regarding the studies was planned to be resolved by a third author or by contacting the corresponding author. The following information was also collected: first author, year of the study, total number of patients per group, age, American Society of Anesthesiologists (ASA), body mass index, dose and type of local anesthetic used, postoperative opioid analgesia, total opioid dosage consumed in the first 24 h postoperatively, postoperative passive and active pain scores, and PONV. All differential opioid consumption data were converted to oral morphine equivalents using the conversion tool from the GlobalRPh website (https://www.globalrph.com/narcotic), assuming 0% incomplete cross tolerance.

For studies reporting medians, interquartile ranges, or minimum and maximum values, the mean and standard deviation were estimated according to appropriate formulas.[21] If the results were presented only as figures, Graphreader (https://www.graphreader.com) was used to digitize and extract numerical data.

Risk of bias assessment and quality assessment

The risk of bias regarding the included RCTs was evaluated using the Cochrane risk of bias assessment method.[22] Based on the risk of bias assessment items, two researchers evaluated the following criteria: "Random sequence generation (selection bias)," "Allocation concealment (selection bias)," "Blinding of participants and personnel (performance bias): All outcomes," "Blinding of outcome assessment (detection bias): All outcomes," "Incomplete outcome

data (attrition bias): All outcomes," "Selective reporting (reporting bias)," and "other bias." A determination of "low risk of bias," "high risk of bias," or "unclear risk of bias" was made for every item. A summary of each study's evaluation findings is represented in Figure 1.

The quality of included studies was assessed using the Jadad scale.[23] The Jadad scale assigned scores of 0, 1, or 2 to three domains regarding randomization, blinding, and withdrawals and dropouts according to the description and appropriateness of these domains. A study with a total score of 3 to 5 was considered high quality; otherwise, it was considered low quality.

Statistical analysis

The meta-analysis was performed using Review Manager version 5.4.1 (Nordic Cochrane Centre, Copenhagen, Denmark).[24] The summary data were presented as the mean ± standard deviation (SD), mean difference (MD), and 95% confidence intervals (CIs). For continuous data Visual Analog Scale (VAS), the combined MD was calculated with 95% CI, and heterogeneity was estimated based on the study by Higgins et al.[25] Heterogeneity was assessed using the I^2 test and the chi-square test. When I^2 was ≤50% and p was ≥0.10, the fixed effects model was utilized; otherwise, the random effects model was employed.[25] All results were presented with a forest plot. Publication bias was assessed using funnel plots. A p-value <0.05 was considered statistically significant, and 95% CIs were preferred between studies.

RESULTS

The literature search yielded 328 articles from electronic databases. After removing duplicates, 78 articles remained. Twenty-five articles were assessed for further examination after inspecting their titles, abstracts, and full texts. Of the remaining 25 articles, 16 were excluded for the following reasons: six did not meet the outcome measure, three compared a combination of blocks, five compared no block, one compared SAPB, and one compared continuous SAPB. As shown in Figure 2, a total of nine RCTs, including 537 participants (287 males, 250 females; mean age: 55.2±13.1 years), were included in the meta-analysis.[26-34] Of the patients included in the analyses, 50.09% received SAPB, while 49.91% received other blocks. Table 1 shows the characteristics of the nine included studies.

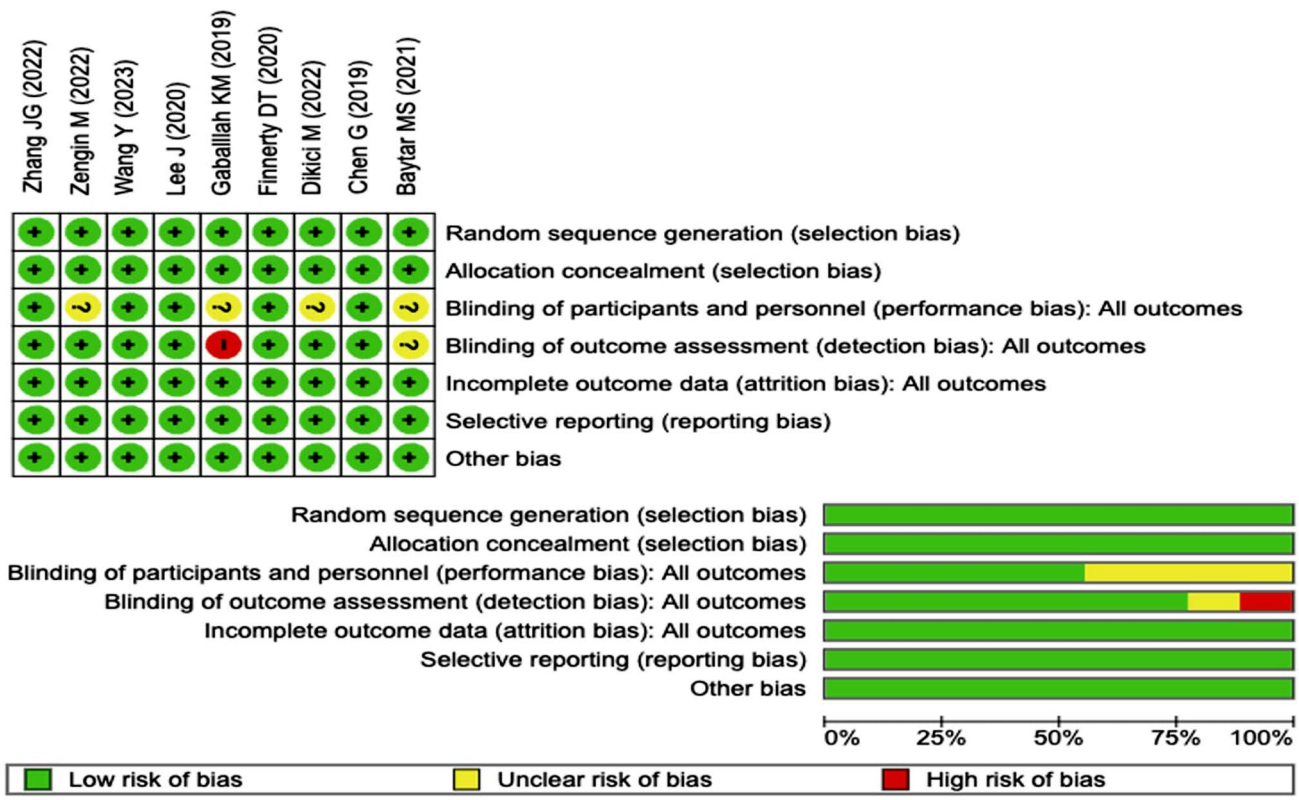

Figure 1. Risk of bias graph.

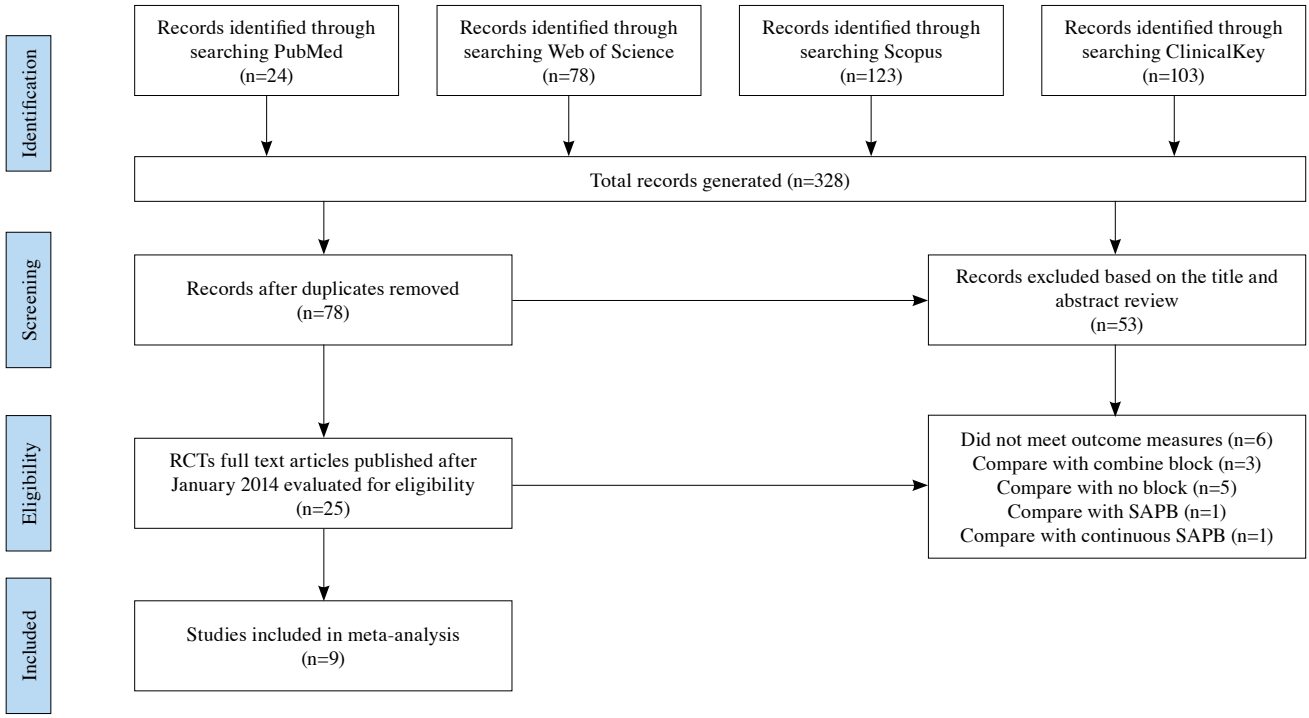

Figure 2. Flowchart of the literature search.
RCTs:Randomized controlled trials; SAPB: Serratus anterior plane block.

Risk of bias and quality of study

All nine studies reported appropriate randomization procedures and allocation concealment. The blinding method for participants and personnel was unclear in four trials.[26,30-32] In one study, investigators assessing postoperative parameters had a high risk of bias in group assignment.[26] In one study, researchers evaluating postoperative parameters had a high risk of bias in group assignment.[30] Taken together, eight studies had low risk of bias in all domains.[27-34] One study had high risk of bias.[26] The risk of bias assessment is summarized in Figure 1. According to the Jadad scale, one study with a score of 2 was considered to have low quality,[26] and the others with scores of 3 to 5 had high quality.[27-34]

Outcomes

The results of all outcomes are summarized in Figure 3. Cumulative opioid consumption in the first 24 h in patients in the SAPB group (n=269) was shown in the nine randomized clinical trials we included in the meta-analysis. As a result of the analysis, it was determined that an mean of 100 mg oral morphine equivalent (95% CI, 58.8 to 142.0; I^2=100; p<0.001) was used.

The cumulative opioid consumption of patients in the SAPB (n=119) and ESPB (n=118) groups 24 h postoperatively were evaluated in four studies.[26,28,31,33] The 24-h cumulative opioid consumption was found to be statistically significantly higher in the SAPB group than in the ESPB group (standardized MD [SMD]=1.98; 95% CI, 0.23 to 3.73; Z=2.22; p=0.03; I^2=97%; random effects model; Figure 4).

The opioid consumption 24 h postoperatively was provided in two studies for the SAPB (n=50) and local anesthetic (LA) (n=50) groups.[27,32] The analysis displayed that the 24-h cumulative opioid consumption was statistically significantly lower in the SAPB group than in the LA group (SMD=–1.77; 95% CI, –2.24 to –1.30; Z=7.41; p<0.001; I^2=0%; fixed effects model; Figure 4).

The opioid consumption 24 h postoperatively was provided in two studies for the SAPB (n=77) and TPVB (n=77) groups.[30,34] The 24-h cumulative opioid consumption was found to be statistically significantly higher in the SAPB group than in the TPVB group (SMD=0.63; 95% CI, 0.31 to 0.96; Z=3.84; p<0.001; I^2=0%; fixed effects model; Figure 4).

To evaluate the passive pain scores 2 h after surgery, the results of the SAPB (n=90) and ESPB (n=90)

Table 1. Characteristics of included studies, including opioid consumption, VAS, verbal rating scale, or numeric rating scale scores, time to first analgesia administration, and PONV

Study	Years of publication	Interventions	The number of participants	Dose and type of local anesthetic used	Postoperative opioid analgesia	ASA (1/2/3)	Outcome	Age (year)	BMI
Gaballah et al.[26]	2019	SSAPB / ESBP	30/30	20 mL of 0.25% bupivacaine / 20 mL of 0.25% bupivacaine	VAS was ≥4, pethidine	-	1, 2, 3	41.53±8.86 / 41.20±8.51	-
Chen et al.[27]	2019	SSAPB / LA	20/20	0.4 mL/kg 0.25% ropivacaine / 10 -17 mL 0.25% ropivacaine	PCA of sufentanil. Tramadol when VAS >4. Morphine when VAS >5.	10/10/0; 13/7/0	1, 2, 4	58.9±5.7 / 57.1±6.2	-
Finnerty et al.[28]	2020	DSAPB / ESPB	30/30	0.25% 30 mL Levobupivakain / 0.25% 30 mL Levobupivakain	Oxycodone as a rescue analgesic when needed	7/11/12; 1/15/14	1, 2, 3, 4	53.1 (20) / 58.8 (13)	25.9 (7.4) / 28.6 (9.5)
Lee et al.[29]	2020	SSAPB / ICNB	23/23	20 mL %0.375 ropivakain / 20 mL %0.375 ropivakain	The PCA of fentanyl. If a patient required additional analgesics fentanyl was administered iv NRS score ≥6.	1/21/1; 2/19/2	1, 2, 4	68 (57-75) / 67 (58-74)	-
Baytar et al.[30]	2021	DSAPB / TPVB	31/31	0.25% bupivacaine 0.4 mL/kg (max. 20 mL) / 0.25% 0.4 mL/kg (max. 20 mL)	PCA of tramadol iv	1/30/0; 3/28/0	1, 2, 3, 4	47.6±16.9 / 51.2±19.3	26.3±6.0 / 27.2±5.3
Zengin et al.[31]	2022	C-SAPB / ESPB	30/30	20 mL of 0.25% bupivacaine	PCA of morphine as a rescue analgesic agent, tramadol iv when the VAS score at rest was ≥4.	4/14/12; 3/16/11	1, 2, 4	57.50 (28.0) / 58.00 (23.00)	23.72±3.24 / 25.49±4.62
Dikici et al.[32]	2022	DSAPB / LA	30/30	Bupivacaine 0.25% dose of 0.25 mL/kg Bupivacaine 0.25% dose of 0.5 mL/kg	PCA of morphine to give tramadol as the second rescue analgesic when VAS ≥4 persisted.	8/22; 10/20	1, 2, 3, 4	53.2±14.5 / 52.4±14.3	26.0±4.5 / 28.0±5.9
Zhang et al.[33]	2022	DSAPB / ESPB / RIB	29/28/29	20 mL 0.4% ropivakain / 20 mL 0.4% ropivakain / 20 mL 0.4% ropivakain /	PCA of sufentanil	0/27/2; 0/27/1; 0/28/1	1, 2, 3, 4	61.7±6.8 / 55.6±12.9 / 59.1±10.1	23.4±3.5 / 23.8±4.0 / 24.0±3.1
Wang et al.[34]	2023	SSAPB TPVB	46/46l	0.375% ropivacaine at 3 mg/kg / 0.375% ropivacaine at 3 mg/kg	PCA of sufentanil	0/21/25; 0/23/23	1, 2, 3, 4	59.0±10.1 / 58.3±11.4	-

VAS: Visual analog scale; PONV: Postoperative nausea and vomiting; BMI: Body mass index; SSAPB: Superficial serratus anterior plane block; ESPB: Erector spinae plane block; LA: Local anesthetic; PCA: Patient-controlled analgesia; DSAPB: Deep serratus anterior plane block; VRS: Verbal rating scale; ICNB: Intercostal nerve block; NRS: Numeric rating scale; iv: Intravenous; TPVB: Thoracic paravertebral block; C-SAPB: Combined deep and superficial; RIB: Rhomboid intercostal block.

		SAPB-ESPB	SAPB-LA	SAPB-TPVB
24th Hour Opioid Consumption		**SAPB>ESPB (p=0.030)**	**SAPB<LA (p<0.001)**	**SAPB>TPVB (p<0.001)**
Rest	2th Hour rest VAS	SAPB=ESPB (p=0.090)	SAPB=LA (p=0.100)	
	6th Hour rest VAS	SAPB=ESPB (p=0.430)		SAPB=TPVB (p=1.000)
	12th Hour rest VAS	**SAPB>ESPB** (p=0.020)		SAPB=TPVB (p=1.000)
	24th Hour rest VAS	SAPB=ESPB (p=0.890)	SAPB=LA (p=0.880)	SAPB=TPVB (p=0.290)
Active	2th Hour rest VAS	SAPB=ESPB (p=0.760)	**SAPB<LA** (p=0.020)	
	6th Hour rest VAS	SAPB=ESPB (p=0.340)		SAPB=TPVB (p=1.000)
	12th Hour rest VAS	SAPB>ESPB (P<0.001)		SAPB=TPVB (p=1.000)
	24th Hour rest VAS	**SAPB=ESPB** (p=0.260)	SAPB=LA (p=0.080)	SAPB=TPVB (p=0.380)
	PONV	SAPB=ESPB (p=0.620)	SAPB=LA (p=0.080)	SAPB=TPVB (p=0.830)

Figure 3. Summary of results.

SAPB: Serratus anterior plane block; ESPB: Erector spinae plane block; VAS: Visual Analog Scale; LA: Local anesthetic; TPVB:Thoracic paravertebral block; PONV: Postoperative nausea and vomiting.

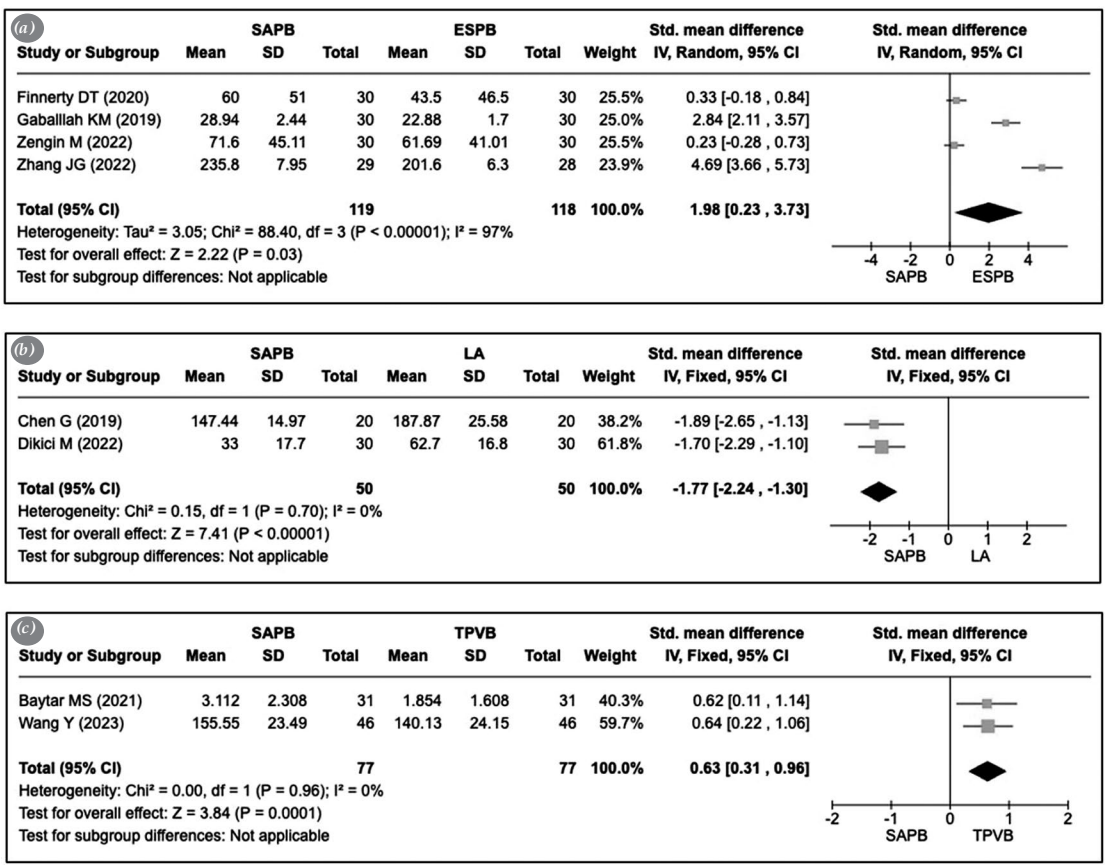

Figure 4. Comparison of 24-hour opioid consumption between SAPB and **(a)** ESPB, **(b)** LA and **(c)** TPVB groups.

ESPB: Erector spinae plane block; SAPB: Serratus anterior plane block; SD: Standard deviation; CI: Confidence interval; LA: Local anesthetic; TPVB:Thoracic paravertebral block.

groups were compared in three studies,[26,28,31] and the SAPB (n=40) and LA (n=40) groups were compared in two studies.[27,32] No statistically significant difference was found between the passive pain scores at 2 h in the SAPB and ESPB groups (SMD=–0.26; 95% CI, –0.55 to 0.04; Z=1.72; p=0.09; I^2=17%; fixed effects model; Figure 5) and the SAPB and LA groups (SMD=–3.32; 95% CI, –7.23 to 0.60; Z=1.66; p=0.10; I^2=96%; random effects model; Figure 5).

To evaluate the active pain scores 2 h after surgery, the results of the SAPB (n=90) and ESPB (n=90) groups were compared in three studies,[26,28,31] and the SAPB (n=40) and LA (n=40) groups were compared in two studies.[27,32] No statistically significant difference

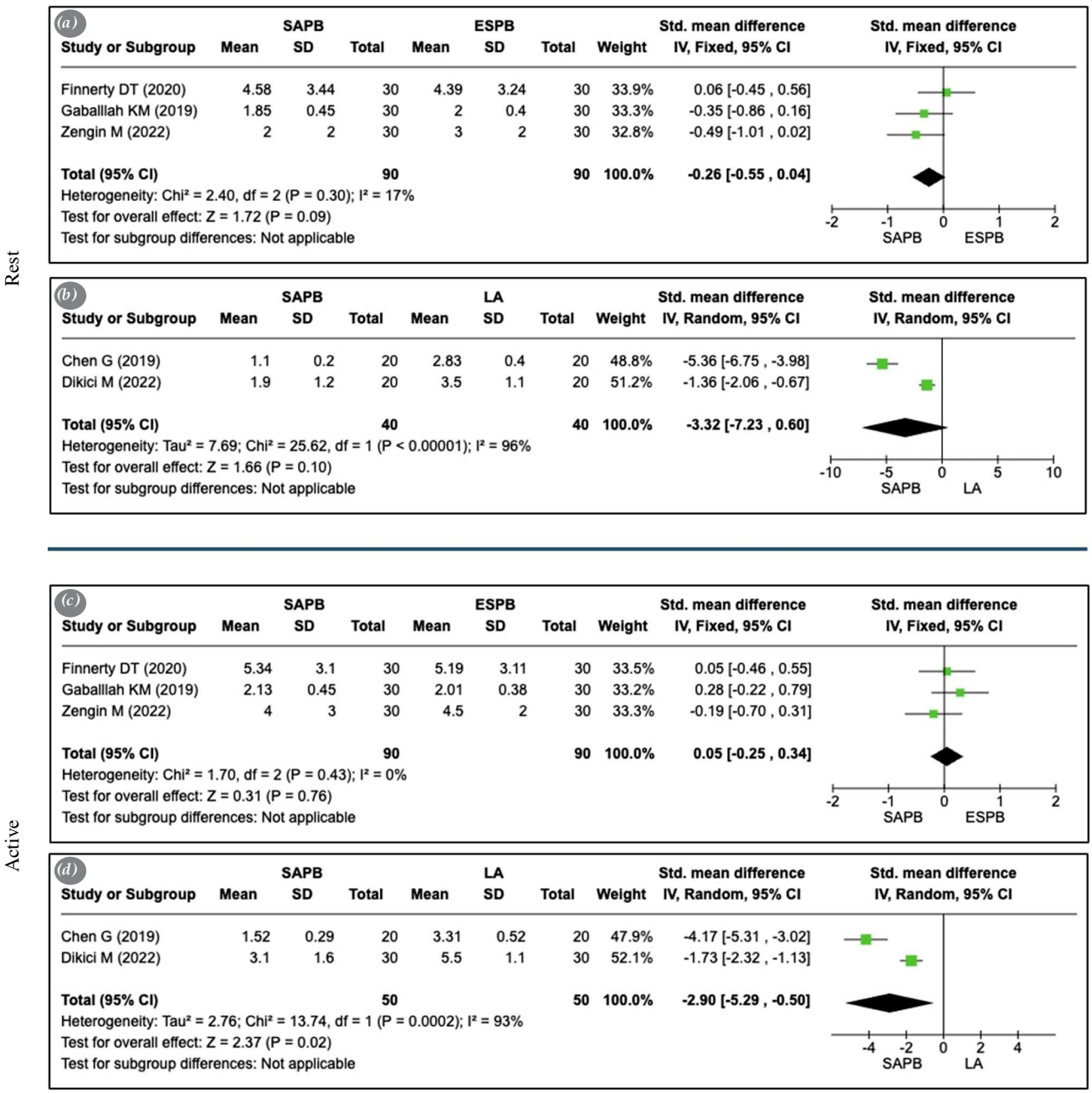

Figure 5. Comparison of postoperative 2 h passive pain scores between SAPB and **(a)** ESPB **(b)** LA and postoperative 2 h active pain scores between SAPB and **(c)** ESPB **(d)** LA groups.

SAPB: Serratus anterior plane block; ESPB: Erector spinae plane block; SD: Standard deviation; CI: Confidence interval; LA: Local anesthetic.

was found between the SAPB and ESPB groups (SMD=0.05; 95% CI, –0.25 to 0.34; Z=0.31; p=0.76; I^2=0%; fixed effects model; Figure 4) in terms of active pain scores at 2 h. However, the active pain score at 2 h postoperatively was found to be statistically significantly lower in the SAPB group than in the LA group (SMD=–2.90; 95% CI, –5.29 to –0.50; Z=2.37; p=0.02; I^2=93%; random effects model; Figure 5).

To evaluate the passive pain scores 6 h postoperatively, the results of the SAPB (n=59) and ESPB (n=58) groups were compared in two studies,[26,33] and the SAPB (n=77) and TPVB (n=77) groups were compared in two studies.[30,34] No statistically significant difference was found between the passive pain scores at 6 h in the SAPB and ESPB groups (SMD=–0.37; 95% CI, –1.30 to 0.56; Z=0.78;

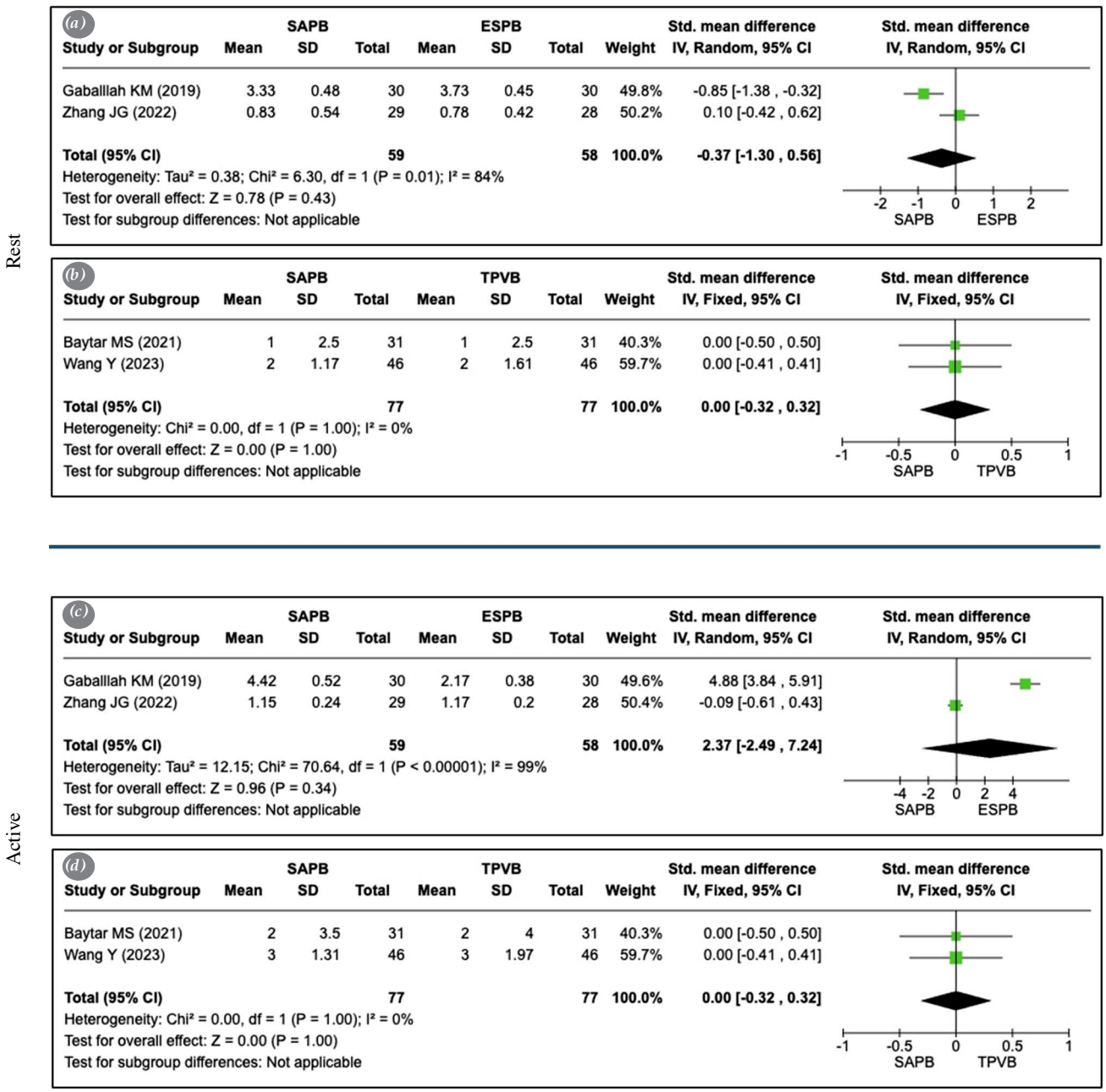

Figure 6. Comparison of postoperative 6 h passive pain scores between SAPB and **(a)** ESPB **(b)** TPVB and postoperative 6 h active pain scores between SAPB and **(c)** ESPB **(d)** TPVB groups.

SAPB: Serratus anterior plane block; ESPB: Erector spinae plane block; SD: Standard deviation; CI: Confidence interval; TPVB: Thoracic paravertebral block.

p=0.43; I^2=84%; random effects model; Figure 6) and the SAPB and TPVB groups (SMD= –0.00; 95% CI, –0.32 to 0.32; Z=0.00; p=1.00; I^2=0%; fixed effects model; Figure 6).

To evaluate active pain scores at 6 h postoperatively, the results of the SAPB (n=59) and ESPB (n=958) groups were compared in two studies,[26,33] and the SAPB (n=77) and TPVB (n=77) groups were compared in two studies.[30,34] No statistically significant difference was found between the active pain scores at 6 h in the SAPB and ESPB groups (SMD=2.37; 95% CI, –2.49 to 7.24; Z=0.96; p=0.34; I^2=99%; random effects model; Figure 6) and the SAPB and TPVB groups (SMD= –0.00; 95% CI, –0.32 to 0.32; Z=0.00; p=1.00; I^2=0%; fixed effects model; Figure 6).

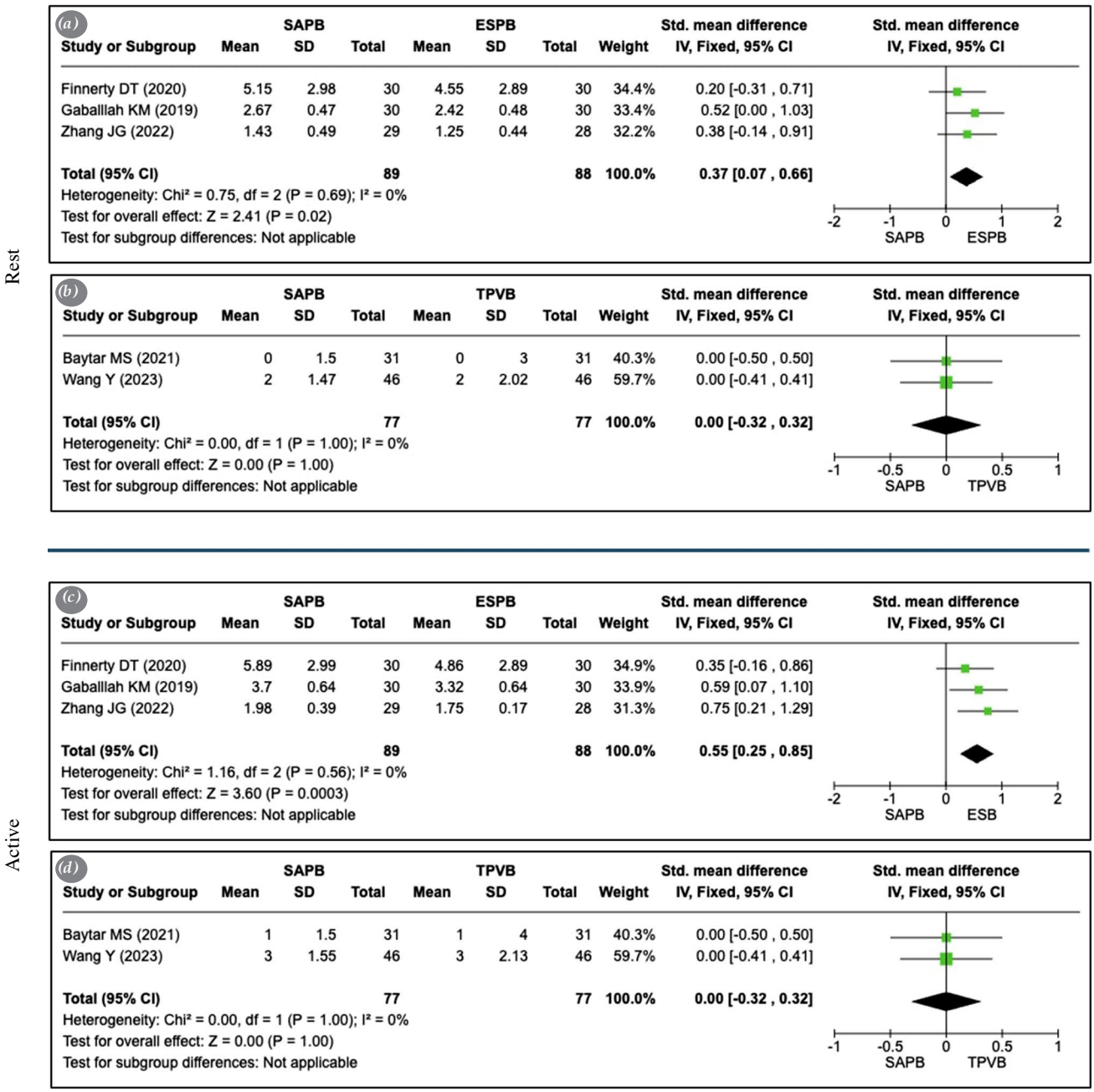

Figure 7. Comparison of postoperative 12 h passive pain scores between SAPB and **(a)** ESPB **(b)** TPVB and postoperative 12 h active pain scores between SAPB and **(c)** ESPB **(d)** TPVB groups.

SAPB: Serratus anterior plane block; ESPB: Erector spinae plane block; SD: Standard deviation; CI: Confidence interval; TPVB: Thoracic paravertebral block.

To evaluate the passive pain scores 12 h postoperatively, the results of the SAPB (n=89) and ESPB (n=88) groups were compared in three studies,[26,28,33] and the SAPB (n=77) and TPVB (n=77) groups were compared in two studies.[30,34] Passive pain scores at 12 h were found to be statistically significantly lower in the ESPB group than in the SAPB group (SMD= 0.37; 95% CI, 0.07 to 0.66; Z=2.41; p=0.02; I^2=0%; fixed effects model; Figure 7). However, no statistically significant difference was found between

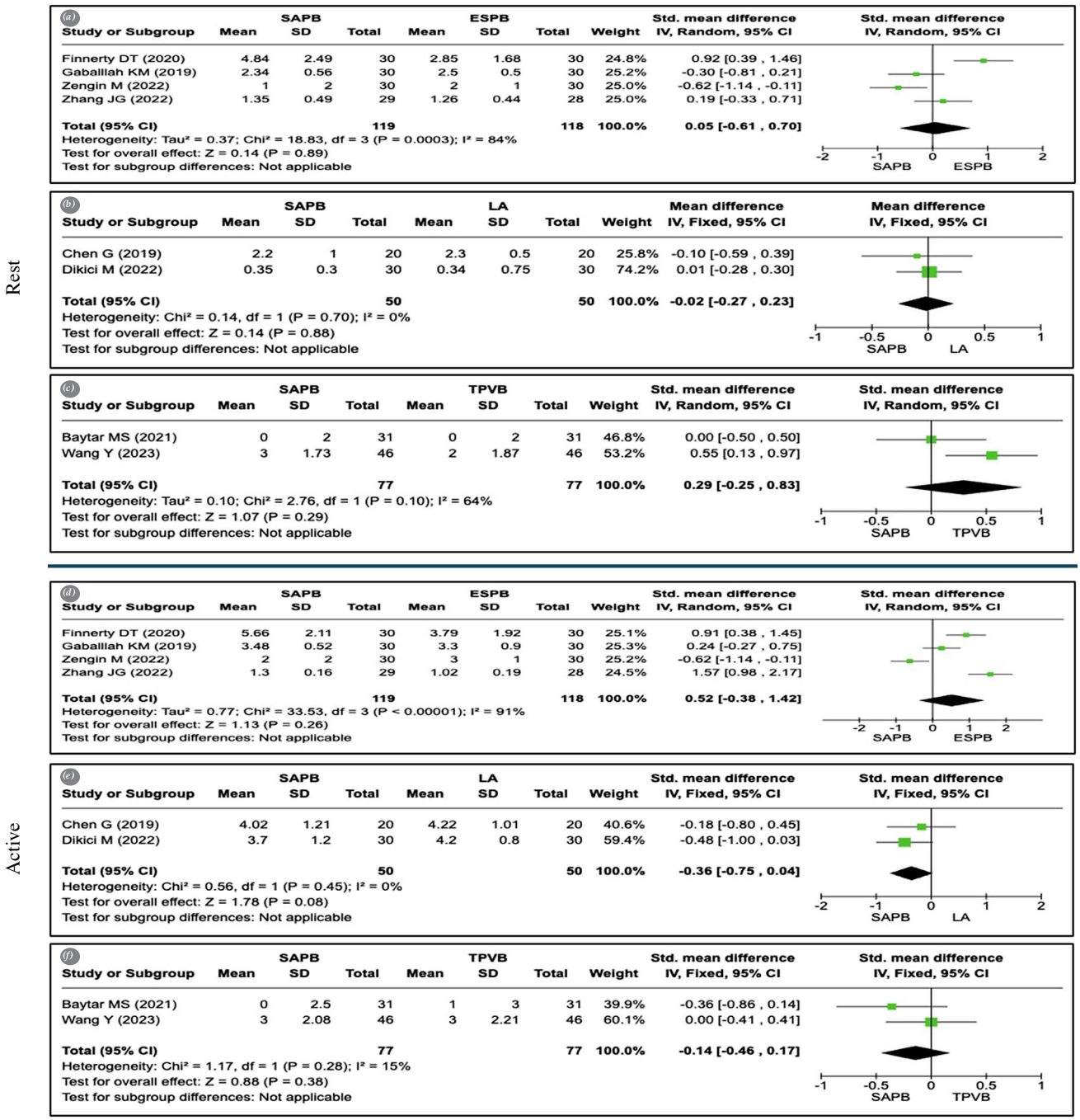

Figure 8. Comparison of postoperative 24 h passive pain scores between SAPB and **(a)** ESPB **(b)** LA **(c)** TPVB and postoperative 24 h active pain scores between SAPB and **(d)** ESPB **(e)** LA **(f)** TPVB groups.

SAPB: Serratus anterior plane block; ESPB: Erector spinae plane block; SD: Standard deviation; CI: Confidence interval; LA: Local anesthetic; TPVB: Thoracic paravertebral block.

the passive pain scores at 12 h in the SAPB and TPVB groups (SMD= –0.00; 95% CI, –0.32 to 0.32; Z=0.00; p=1.00; I^2=0%; fixed effects model; Figure 7).

To evaluate active pain scores 12 h postoperatively, the results of the SAPB (n=89) and ESPB (n=88) groups were compared in three studies,[26,28,33] and the SAPB (n=77) and TPVB (n=77) groups were compared in two studies.[30,34] Active pain scores at 12 h were found to be statistically significantly lower in the ESPB group than in the SAPB group (SMD= 0.55; 95% CI, 0.25 to 0.85; Z=3.60; p<0.001; I^2=0%; fixed effects model; Figure 7). However, no statistically significant difference was found between the active pain scores at 12 h in the SAPB and TPVB groups (SMD=–0.00; 95% CI, –0.32 to 0.32; Z=0.00; p=1.00; I^2=0%; fixed effects model; Figure 7).

To evaluate the passive pain scores 24 h postoperatively, the results of the SAPB (n=119) and ESPB (n=118) groups were compared in four studies,[26,28,31,33] the SAPB (n=50) and LA (n=50) groups were compared in two studies,[27,32] and the SAPB (n=77) and TPVB (n=77) groups were compared in two studies.[30,34] No statistically significant difference was found between the passive pain scores at 24 h in the SAPB and ESPB groups (SMD= 0.05; 95% CI, –0.61 to 0.70; Z=0.14; p=0.89; I^2=84%; random effects model; Figure 8), the SAPB and LA groups (SMD= –0.02; 95% CI, –0.27 to 0.23; Z=0.14; p=0.88; I^2=0%; fixed effects model; Figure 8), and the SAPB and TPVB groups (SMD=0.29; 95% CI, –0.25 to 0.83; Z=1.07; p=0.29; I^2=64%; random effects model; Figure 8).

To evaluate active pain scores 24 h postoperatively, the results of the SAPB (n=119) and ESPB (n=118) groups were compared in four studies,[26,28,31,33] the SAPB (n=50) and LA (n=50) groups were compared in two studies,[27,32] and the SAPB (n=77) and TPVB (n=77) groups were compared in two studies.[30,34] No statistically significant difference was found between the active pain scores at 24 h in the SAPB and ESPB groups (SMD=0.52; 95% CI, –0.38 to 1.42; Z=1.13; p=0.26; I^2=91%; random effects model) and the SAPB and LA groups (SMD= –0.36; 95% CI, –0.75 to 0.04; Z=1.78; p=0.08; I^2=0%; fixed effects model) and the SAPB and TPVB groups (SMD=–0.14; 95% CI: –0.46 to 0.17; Z=0.88; p=0.38; I^2=15%; fixed effects model; Figure 8).

PONV

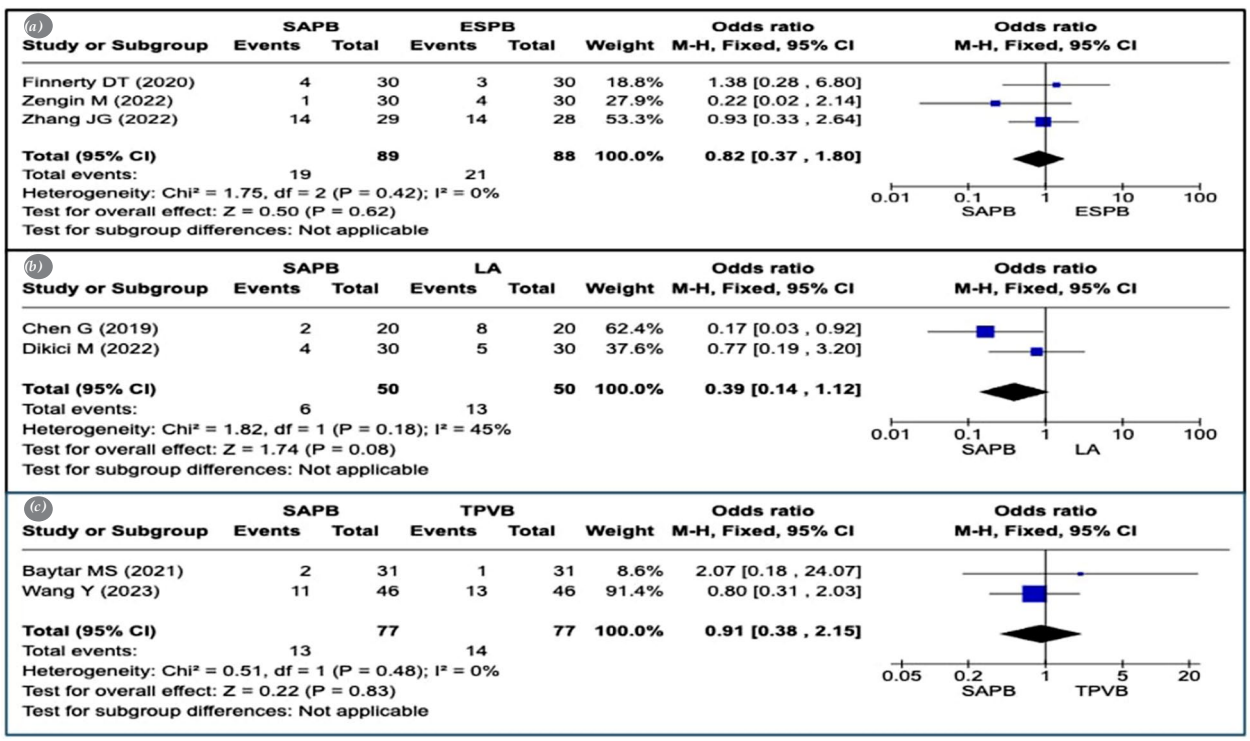

Figure 9. Comparison of PONV between SAPB and **(a)** ESPB **(b)** LA **(c)** TPVB.

PONV: Postoperative nausea and vomiting; SAPB: Serratus anterior plane block; ESPB: Erector spinae plane block; CI: Confidence interval; LA: Local anesthetic; TPVB: Thoracic paravertebral block.

The incidence of PONV was reported in eight studies,[27-34] and one of the studies did not include data on PONV.[26] The overall incidences of PONV were 16.7% (40 out of 239) in the SAPB group, 24.0% (21 out of 88) in the ESPB group, 26.0% (13 out of 50) in the LA group, and 18.18% (14 out of 77) in the TPVB group. According to the results of PONV comparison in the SAPB and ESPB groups in three studies,[28,31,33] no statistically significant difference was found in terms of PONV risk between the SAPB and ESPB groups (odds ratio [OR]=0.82; 95% CI, 0.37 to 1.80; Z=0.50; p=0.62; I^2=0%; fixed effects model; Figure 9). According to the results of two studies[27,32] comparing PONV in the SAPB and LA groups, no statistically significant difference was found in terms of PONV risk between the SAPB and LA groups (OR=0.39; 95% CI, 0.14 to 1.12; Z=1.74; p=0.08; I^2=45%; fixed effects model; Figure 9). According to the results of PONV comparison in the SAPB and TPVB groups in two studies,[30,34] no statistically significant difference was found in terms of PONV risk between the SAPB and TPVB groups (OR=0.91; 95% CI, 0.38 to 2.15; Z=0.22; p=0.83; I^2=0%; fixed effects model; Figure 9).

Publication bias

Despite the lack of clear asymmetry upon visual inspection, a definitive interpretation of the funnel plots was not possible due to the paucity of studies (Supplementary Figure 1; funnel plot).

DISCUSSION

This meta-analysis showed that in patients undergoing VATS, opioid consumption in the first 24 h after the operation was higher with single-shot SAPB than ESBP and TPVB and lower than LA. Passive and active pain scores at 12 h postoperatively were significantly higher with SAPB than ESPB, and active pain scores at 2 h postoperatively were lower with SAPB than LA (Figure 3). There was no difference in both passive and active pain scores between SAPB and ESPB, TPVB, and LA at other time points. Furthermore, there was no significant difference in the incidence of PONV between SAPB and ESPB, TPVB, and LA. In this meta-analysis, opioid consumption in the first 24 h, passive and active pain scores, and PONV odds ratios were calculated to evaluate analgesic effects and the incidence of side effects.

With the development of regional block techniques, the number of studies investigating the effects of regional nerve blocks on postoperative analgesia in VATS is growing. However, which of these blocks is a better choice in VATS is still controversial.[20]

Serratus anterior plane block is an easy-to-apply nerve block technique. In two meta-analyses performed on patients undergoing VATS, it was shown that single-shot SAPB can effectively relieve postoperative pain and reduce postoperative opioid consumption and PONV. In one of these meta-analyses, SAPB was compared with general anesthesia alone without any regional blockade,[19] and in the other, it was compared with control (no block, placebo, or local infiltration).[20]

Apart from SAPB, there are also different block options such as TPVB, ESBP, or LA. Thoracic paravertebral block is performed by injecting local anesthetics into the paravertebral space and has an analgesic effect similar to TEA.[35,36] In a randomized study comparing the analgesic efficacy of TPVB, ESPB, and ICNB in thoracoscopic surgery, TPVB was favored because it provided more successful analgesia and required less morphine consumption.[37]

However, meta-analyses conducted on this subject present different results. In a network meta-analysis (NMA) conducted by Luo et al.[38] comparing the analgesic efficacies of regional block techniques in breast surgery and VATS, it was reported that the SAPB group was the best group in terms of opioid consumption and static pain scores, while TPVB provided significant advantages when active pain scores were evaluated.

In another NMA performed on VATS, it was observed that there was little difference between regional analgesia techniques other than epidural anesthesia.[39] They concluded that TPVB was superior to SABP and other blocks in terms of resting VAS scores in the early postoperative stages and opioid consumption at 24 h postoperatively. The authors also stated that the analgesic effect of ESPB had no advantage over SAPB, ICNB, and other techniques.

Erector spinae plane block is an important component of multimodal analgesia for patients undergoing VATS. Interfascial plane blocks are clinically safe and technically easier to perform than TEA or TPVB since they are remote from the spinal cord. A study on the mechanism of action of ESPB[40] demonstrated that ESPB provides visceral and somatic analgesia by local anesthetics spreading to both transforaminal and epidural spaces.

In a meta-analysis by Koo et al.[41] investigating the analgesic efficacy of ESPB in VATS and thoracotomy, it was shown that postoperative opioid consumption was statistically significantly higher in the ESPB group compared to the TPVB group and lower than in the

SAPB group. It was found that there was no significant difference between ESPB and SAPB in terms of passive pain scores at 24 h postoperatively, and active pain scores were significantly lower in the ESPB group than in the SAPB group. In another NMA, it was shown that intravenous morphine consumption at 24 h postoperatively was lower in TPVB than in ESPB, and passive pain scores at 24 h postoperatively were lower in ESPB than in SAPB.[42]

The majority of our findings in the current meta-analysis are consistent with the findings in the aforementioned literature. It was determined that ESBP and TPVB were significantly better than SAPB in terms of postoperative opioid consumption, while SAPB was better than LA. In terms of pain scores, although the active and passive pain scores were significantly lower in ESBP than in SAPB at the 12th postoperative hour, and the active pain score at 2 h was lower in SAPB than in LA, no difference was found between the blocks at other time points. These differences may be due to the epidural spread of local anesthetics in ESBP and TPVB being a block close to the central. Our results confirm the analgesic effect of TPVB and ESBP. Since only one study included in the meta-analysis compared SAPB with ICNB, a pairwise comparison could not be made.[29]

Four of the studies included in the meta-analysis used 0.25% bupivacaine,[26,30-32] one used 0.25% levobupivacaine,[28] one used 0.375% ropivacaine,[34] one used 0.25% ropivacaine,[27] and another used 0.4% ropivacaine.[33] Different concentrations and volumes of local anesthetics used in these studies involving SAPB may have introduced bias into our results.

Although there appears to be little difference in analgesic effects among the various regional nerve block techniques, technique performance, failure rate, and the possibility of side effects or complications are factors to consider when selecting the most appropriate regional nerve block technique for the patient.

Thoracic paravertebral block is a difficult block to perform. The success rate decreases as the difficulty increases. Blocking the sympathetic nerves is also beneficial for analgesia.[40] However, even if TPVB is performed under ultrasound guidance, postoperative complications such as pneumothorax, hematoma, hemodynamic compromise, and total spinal anesthesia may occur.[43] Compared with TPVB, ESPB can achieve a higher success rate.[44]

Serratus anterior plane block is a promising alternative to the other mentioned analgesia methods due to its safety and relative simplicity.[45] The location of the SPAB block is far from the intervertebral foramen, local anesthetics are unlikely to penetrate the epidural space, and the incidence of hypotension due to the block is low.[46] In addition, it can be performed with the patient in supine position and under general anesthesia, with low risk of pleural puncture or spinal cord injury.[45] It has a higher safety margin in patients receiving anticoagulants since the injection site is relatively shallow, compressible, and away from areas susceptible to expanding hematomas.[46] For all these reasons, we believe that SAPB is a block that should be preferred in VATS.

In addition to the analgesic effect, we also evaluated nausea and vomiting, which are among the most common postoperative complications in our study. Postopeartive nausea and vomiting may impair patient comfort and satisfaction and increase postoperative pain. In the current meta-analysis, we could not find any difference in the results of pairwise comparisons, but in the comparison of LA and SAPB, the incidence of nausea and vomiting was higher than in the SAPB group. This result could be due to the difference in 24-h opioid consumption between LA and SAPB, which is greater than the difference between SAPB and ESPB, as well as TPVB.

There are several limitations to our study. First, subgroup analysis could not be performed due to the heterogeneity of the blocks performed in the included studies. Second, different surgical techniques, particularly the number and location of ports, anesthesia and perioperative multimodal analgesic management, and the use of different concentrations and volumes of local anesthetics may influence the analgesic efficacy of the blocks. Third, the sample size of each study and the meta-analysis was relatively small, suggesting that statistical power may be insufficient. Fourth, the opioid dose used during surgery may change the amount of opioid consumption after surgery and the incidence of side effects. Finally, excluding studies not published in English may also represent a limitation.

In conclusion, it was shown that single-shot SAPB in VATS resulted in higher postoperative opioid consumption than TPVB and ESPB and lower than LA. Active and passive pain scores at 12 h postoperatively were higher in SAPB than in ESBP, active pain scores at 2 h postoperatively were lower in SAPB than in LA. There was no difference between the blocks in terms of PONV incidence. It can be said that TPVB

and ESPB provides better pain control than SAPB in VATS. Moreover, SABP is better than LA in pain relief. Randomized controlled trials with larger sample sizes are needed to increase the strength of evidence, confirm the findings, and determine the optimal regional analgesia technique in VATS.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Conception, design, drafted the manuscript: A.D.; Performed literature search: K.K., I.I., H.B.O.; Data extraction: M.A.Y., M.C.; Participated in the statistical analyses: K.K., Y.A.; Supervision, critical review: A.B.U., A.E., M.S.O., H.E.

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