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Modified pectoral nerve block versus bi-level erector spinae plane block for postoperative analgesia after radical mastectomy surgery: a prospective, randomized, controlled trial

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Background: Regional anesthesia techniques constitute an important part of successful analgesia strategies in the perioperative care of patients undergoing breast surgery. The advent of ultrasound-guided regional anesthesia has led to the development of fascial plane blocks. The large array of blocks available for postoperative analgesia in breast surgery has increased the accessibility of regional anesthesia but has also created a dilemma of choice. This study compared the analgesic efficacy of the ultrasound-guided modified pectoral nerve (PECS) block and erector spinae plane block (ESPB) in patients undergoing radical mastectomy.

Methods: Seventy women were enrolled in this prospective, double-blind, randomized control trial. After exclusion, 67 female patients who underwent radical mastectomy were finally analyzed. Ultrasound-guided PECS blocks and ESPBs were performed with 30 ml 0.25% bupivacaine. Postoperative morphine and pain scores were compared between the groups.

Results: Postoperative total morphine consumption in the first 24 h was significantly higher in the PECS group ($P < 0.001$). The ESPB group exhibited significantly reduced morphine consumption at all postoperative time points. Numeric rating scale scores were lower in the ESPB group at 6, 12, and 24 h postoperatively at rest and when coughing.

Conclusions: Ultrasound-guided bi-level ESPBs provided better postoperative analgesia than PECS blocks after radical mastectomy surgery.

Keywords: Analgesia; Breast neoplasms; Diagnostic imaging; Local anesthetics; Nerve block; Postoperative pain.

Introduction

Breast cancer is the most prevalent cancer diagnosed in women worldwide [1]. Over one-third of patients who undergo breast cancer surgery experience acute postoperative pain, which may lead to the development of chronic postsurgical pain [2,3]. Although breast surgeries can significantly improve quality of life and can be curative in cases of malignancy, acute and chronic postoperative pain may be severe and cause functional impairment [4]. Therefore, postoperative pain remains a burden for patients and a challenge for surgeons and anesthesiologists [5,6].

The innervation of the breast is complex and thus multiple nerves and interfascial planes are available to target [7]. Various analgesic techniques, such as paravertebral blocks, thoracic epidural anesthesia, pectoral nerve blocks, serratus anterior plane blocks,

and erector spinae plane blocks (ESPBs), have been used to reduce postoperative pain [7,8].

The modified pectoral nerve (PECS) block was first described by Blanco et al. [9] and consists of a PEC I injection plus a second injection under the pectoralis minor muscle at the level of the fourth rib in the anterior axillary line. The PECS block has been shown to provide safe and effective postoperative analgesia in breast surgery [10–12]. The ultrasound-guided ESPB was first described by Forero et al. [13] for the effective management of thoracic wall neuropathic pain in an outpatient setting. The ESPB has since been used as a regional anesthetic technique for thoracic, breast, thoracolumbar spine, and abdominal surgeries [8,14,15].

The primary aim of this study was to compare the analgesic effects of the ultrasound-guided modified PECS block and bi-level ESPB in terms of morphine consumption in the first 24 h postoperatively in patients undergoing breast surgery with axillary lymph node dissection.

Materials and Methods

Study design

This prospective, randomized, controlled, double-blinded trial was approved by the Kocaeli University Ethical Committee (KIA 2018/487). The trial was registered at ClinicalTrials.gov (NCT04689581) and written informed consent was obtained from all participants. This study was conducted in accordance with the ethical principles of the Helsinki Declaration 2013. A Consolidated Standards of Reporting Trials (CONSORT) flow diagram was used for patient enrollment and allocation (Fig. 1). Female patients aged between 18 and 70 years with American Society of Anesthesiologists (ASA) physical status scores I–III scheduled for elective unilateral radical mastectomy surgery with lymph node dissection between January 2020 and January 2021 were included in the study. Exclusion criteria were morbid obesity defined as a body mass index > 40 kg/m^2, infection of the skin at the site of the needle puncture area, coagulopathy, renal insufficiency (preoperative creatinine > 1.5 mg/dl), history of opioid abuse, pregnancy, allergy to the study medications (bupivacaine), inability to comprehend the numeric rating pain scoring system or patient-controlled analgesia (PCA) pump, and COVID-positivity.

Block procedures

The study included two groups of patients, those receiving a modified PECS block (PECS group) and those receiving a bi-level ESPB (ESPB group). Randomization was performed according to
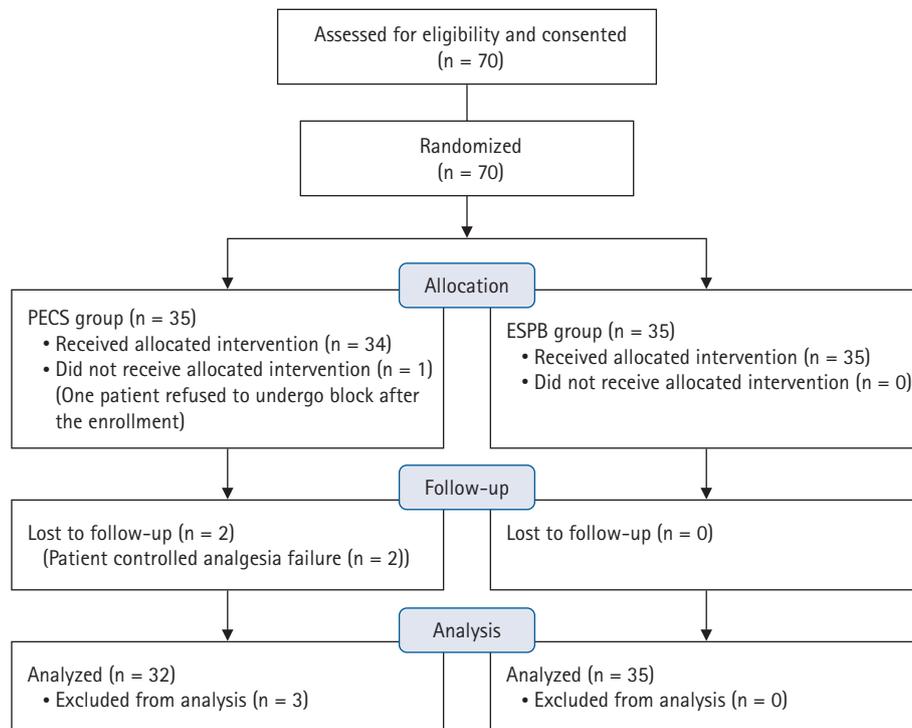

Fig. 1. CONSORT flow diagram of the study. PECS: pectoral nerve block, ESPB: erector spinae plane block.

www.random.org, and patients were allocated using the sealed opaque envelope technique by a researcher (A.K.) who was not involved in the study. The same researcher (A.K.) assigned a random ID to each patient. Preoperatively, all patients were premedicated with midazolam 0.03 mg/kg and fentanyl 1 µg/kg. An experienced anesthesiologist (C.A.), blinded to the data collection until the end of the study, performed all blocks. In the preoperative block room, all patients received standard ASA monitoring (electrocardiogram, pulse oximetry, and non-invasive blood pressure) and oxygen supplementation via a nasal cannula. Blocks were performed approximately 30 min before the induction of general anesthesia. An Esaote MyLab US machine (Esaote, Italy) with a high-frequency linear probe (10–18 MHz) and a 21-gauge, 80-mm, insulated facet type needle (B Braun Sonoplex, Germany) were used for all blocks.

In the PECS group, blocks were performed with the patient in the supine position and the arm abducted to 90°. The ultrasound probe was placed obliquely over the lateral third of the clavicle. Once the axillary artery and vein were identified, the probe was moved laterally until the pectoralis major, minor, and serratus anterior muscles were identified in the same view. After skin infiltration with 1–2 ml 2% lidocaine, the needle was advanced, in the same plane as the probe, from the medial to lateral direction until the tip reached the plane between the pectoralis major and minor muscles, at which point 10 ml 0.25% bupivacaine was injected. Once the local anesthetic had spread to this plane, the needle was

advanced to the fascial plane between the pectoralis minor and serratus anterior muscles, at which point an additional 20 ml 0.25% bupivacaine was administered (Fig. 2A).

In the ESPB group, blocks were performed unilaterally with the patient in the prone position. The ultrasound probe was placed 2–3 cm laterally from the midline at the level of the T4 spinous process using a sagittal approach. After identifying the erector spinae muscle, the needle was inserted in-plane from the cranial to caudal direction deep into the erector spinae muscle. The correct position of the needle tip was controlled with 1–2 ml of isotonic saline solution. Next, 15 ml 0.25% bupivacaine was administered at the T4 level. The same procedure was repeated for the second level (T2 spinous process). The local anesthetic spread in a fascial longitudinal pattern was visualized using ultrasound guidance at the two levels (Fig. 2B).

The sensory level of the block was assessed by another blinded observer (S.A.G.) with cold sensation every 5 min in each dermatomal distribution from T1 to T6. If the ice-cold sensation did not decrease in any segment up to 30 min, it was considered a block failure.

Intraoperative and postoperative management

All patients underwent standardized monitoring (pulse oximetry, electrocardiogram, and non-invasive blood pressure) in the operating room. General anesthesia was induced with an intrave-
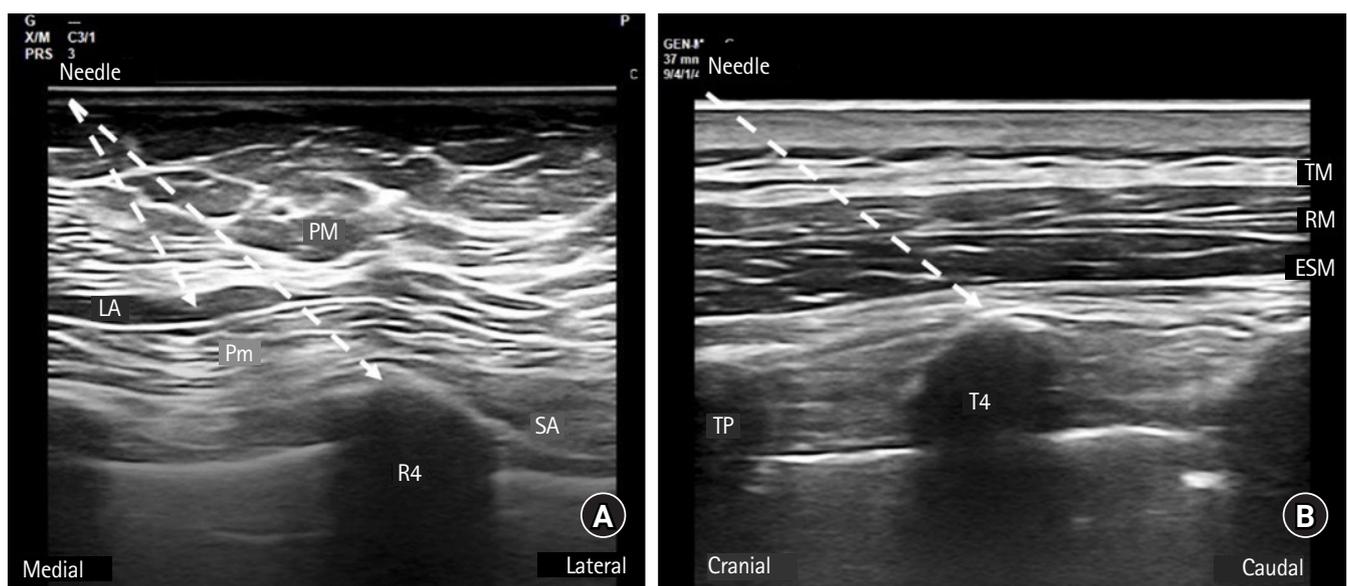
Fig. 2. Ultrasound image of the modified pectoral nerve block and erector spinae plane block. (A) Ultrasound image of the modified pectoral nerve block. (B) Ultrasound image of the erector spinae plane block. PM: pectoralis major muscle, Pm: pectoralis minor muscle, LA: local anesthetic, SA: serratus anterior muscle, R4: fourth rib, TM: trapezius muscle, RM: rhomboid muscle, ESM: erector spinae muscle, TP: transverse process, T4: 4th transverse process.

nous (IV) injection of fentanyl 1 μg/kg followed by propofol 2–3 mg/kg and rocuronium 0.6 mg/kg. Anesthesia was maintained with desflurane in combination with nitrous oxide in oxygen at a ratio of 2 : 1 to maintain a minimum alveolar concentration (MAC) between 1 and 1.3 in 2 L fresh gas flow. One investigator (S.C.) managed the anesthesia according to this protocol. The same surgical team conducted all surgeries; however, the surgeons did not perform local anesthetic wound infiltration. At the end of surgery, tramadol 1 mg/kg and paracetamol 15 mg/kg IV were administered to all patients. Ondansetron 0.1 mg/kg was also administered before completion of surgery. In the recovery room, all patients were given a PCA device containing morphine 0.5 mg/ml, set to deliver a 1-mg bolus dose of morphine, with an 8-min lockout time and 6-mg/h limit. A blinded pain nurse assessed postoperative pain using a numeric rating scale (NRS) ranging from 0 (no pain) to 10 (worst imaginable pain) at 1, 3, 6, 12, and 24 h postoperatively. The first rescue analgesia, IV diclofenac sodium 1.5 mg/kg, was administered in the case of an NRS score ≥ 4 at rest or while coughing. A bolus morphine dose (3 mg) was administered after 30 min if the NRS score remained ≥ 4.

Nausea and vomiting were assessed using four grades: grade 0, no nausea and vomiting; grade 1, mild nausea; grade 2, severe nausea or vomiting once; and grade 3, vomiting more than once. Ondansetron (0.1 mg/kg) was administered every 4 h postoperatively if the score was > 2 points.

Outcome measures

The primary outcome measure of the study was the total morphine consumption within the first 24 h after surgery. A pain nurse blinded to the study recorded the cumulative morphine consumption for each patient using the ID determined by A.K. at 1, 3, 6, 12, and 24 h postoperatively. The secondary outcome measures were the NRS scores at 1, 3, 6, 12, and 24 h postoperatively. The pain nurse also recorded the incidence of nausea and vomiting in the first 24 h. Potential block-related side effects and complications, such as hematoma or infection at the block site, were also recorded.

Statistical analysis

G*Power (version 3.0.10) was used to estimate the sample size (*a priori*). The total overall morphine consumption was used as the primary outcome variable. In a pilot study using 30 ml 0.25% bupivacaine, total morphine consumption in the first 24 h after surgery was 9.30 ± 3.24 mg for the PECS group (n = 7) and 6.18 ±

4.23 mg for the ESPB group (n = 6). Therefore, it was estimated that a sample size of 52 patients (26 per study group) would provide a power of 80%, with an α error of 0.05. We decided to include at least 35 patients per group due to possible patient drop outs.

All statistical analyses were performed using IBM SPSS for Windows (version 20.0; SPSS, USA). The Shapiro-Wilk test was used to assess the assumption of normality. Numerical variables are presented as the mean ± standard deviation (SD) or median (Q1, Q3), according to the normality of the data. Categorical variables are summarized as counts (percentages). Comparisons of numerical variables between groups were carried out using the independent samples t-test or Mann-Whitney *U* test, as appropriate. The association between two categorical variables was examined using the chi-square test. All statistical analyses were carried out with 5% significance, and a two-sided P value < 0.05 was considered statistically significant.

Results

Seventy women were enrolled in this study. One patient from the PECS group refused to undergo the block after enrollment, and two patients from the PECS group were lost during follow-up due to problems with the PCA device. Thus, data from 67 patients were included in the final analyses. No significant differences in demographic data were identified between the two groups (Table 1).

Total morphine consumption in the first 24 h postoperatively was significantly higher in the PECS group (P < 0.001) than in the ESPB group (PECS median, 11.0 mg; ESPB median, 5.0 mg), and morphine consumption was significantly lower at all postoperative time points in the ESPB group (Fig. 3, Table 2). Although rescue analgesia with diclofenac was administered in nine patients in the PECS group and one patient in the ESPB group, none of the patients in both groups require a morphine bolus. The postoperative rescue analgesia requirement was also significantly higher in the PECS group (P = 0.03).

The NRS scores both at rest and while coughing were similar at 1 and 3 h postoperatively. However, NRS scores were lower in the ESPB group than in the PECS group at 6, 12, and 24 h postoperatively both at rest and while coughing (Table 3).

Five patients in the PECS group and seven in the ESPB group experienced postoperative nausea; however, the difference was not statistically significant (P > 0.05).

No block failure or adverse events related to the block procedures, such as pneumothorax, hematoma, or infection at the block site, were observed in any patient.

Table 1. Demographic and Characteristics of Patients

Variable	PECS group (n = 32)	ESPB group (n = 35)	P value
Age (yr)	54.06 ± 10.52	51.05 ± 9.41	0.222
Height (cm)	160.96 ± 3.07	161.51 ± 3.83	0.526
Weight (kg)	71.28 ± 10.33	72.05 ± 12.21	0.880
BMI (kg/m^2)	27.56 ± 4.26	27.74 ± 5.29	0.880
ASA status (I/II/III)	10 (31.3)/21 (65.6)/1 (3.1)	18 (51.4)/17 (48.6)/0 (0.0)	0.141
Duration of surgery (min)	87.34 ± 13.85	78.85 ± 10.78	0.007*

Values are presented as mean ± SD or number (%). BMI: body mass index, ASA: American Society of Anesthesiologists, PECS: modified pectoral nerve block, ESPB: erector spinae plane block. P values marked with the *symbol represents statistically significant difference.

Table 2. Morphine Consumption at 1, 6, 12, and 24 Hours Postoperatively

Morphine consumption (mg)	PECS group (n = 32)	ESPB group (n = 35)	P value
1 h	2.0 (1.0, 3.0)	1.0 (1.0, 2.0)	< 0.001
3 h	5.0 (4.0, 6.7)	3.0 (2.0, 4.0)	< 0.001
6 h	8.0 (6.0, 10.0)	4.0 (3.0, 7.0)	< 0.001
12 h	10.0 (7.0, 13.0)	5.0 (4.0, 6.0)	< 0.001
24 h	11.0 (8.0, 15.0)	5.0 (4.0, 7.0)	< 0.001

Values are presented as median (Q1, Q3). PECS: modified pectoral nerve block, ESPB: erector spinae plane block.
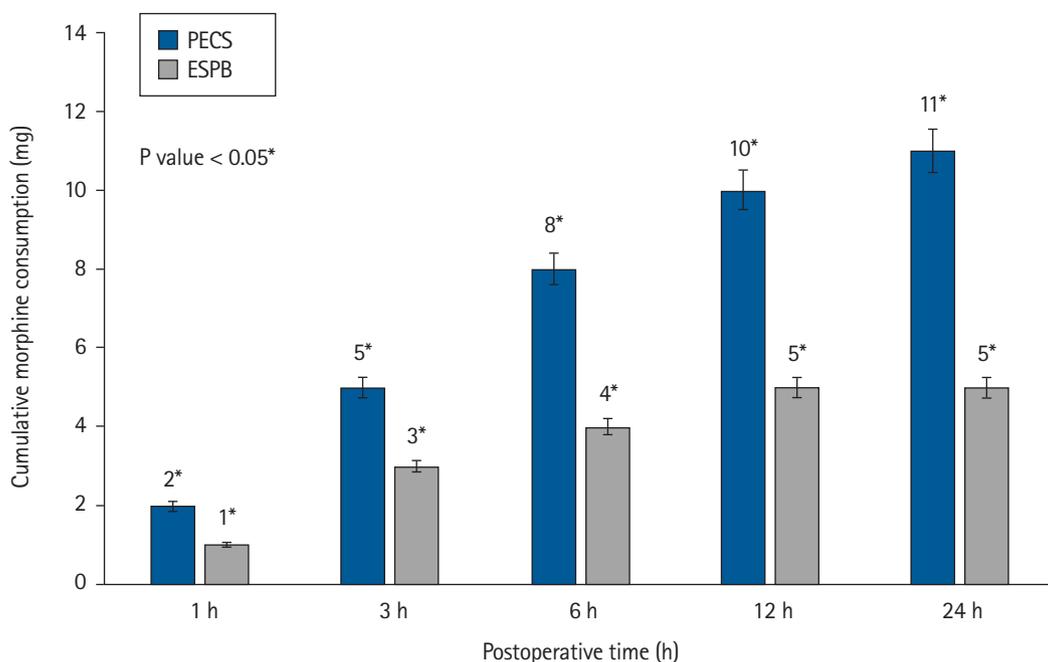

Fig. 3. Bar graph of morphine consumption according to time and group. PECS: modified pectoral nerve block, ESPB: erector spinae plane block. *Statistically significant difference between the PECS and ESPB groups. Values are presented as median (bars) with percentiles 25th–75th (error bars).

Discussion

The findings of the present study show that the ultrasound-guided bi-level (T2–T4). ESPB reduced total morphine consumption in the first 24 h postoperatively significantly more than the modified PECS block. Postoperative pain scores were also significantly lower in the ESPB group.

PECS blocks are superficial interfascial plane blocks that access branches of the brachial plexus, which supplies innervation to the pectoral muscles and upper anterior thoracic wall [10]. Three re-

Table 3. NRS Scores at rest and while Coughing at 1, 6, 12, and 24 Hours Postoperatively

NRS scores	PECS group (n = 32)	ESPB group (n = 35)	P value*
NRS scores at rest			
1 h	3.0 (2.0, 4.0)	3.0 (2.0, 4.0)	0.942
3 h	2.0 (2.0, 3.0)	2.0 (2.0, 3.0)	0.820
6 h	2.0 (1.0, 2.0)	1.0 (0.0, 2.0)	0.003*
12 h	1.0 (0.0, 2.0)	0.0 (0.0, 0.0)	< 0.001*
24 h	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)	0.020*
NRS scores while coughing			
1 h	4.0 (2.0, 4.7)	4.0 (3.0, 6.0)	0.224
3 h	2.5 (2.0, 4.0)	2.0 (2.0, 4.0)	0.744
6 h	2.0 (2.0, 2.7)	2.0 (0.0, 2.0)	0.004*
12 h	1.5 (0.0, 2.0)	0.0 (0.0, 0.0)	< 0.001*
24 h	0.0 (0.0, 0.7)	0.0 (0.0, 0.0)	0.010*

Values are presented as median (Q1, Q3). NRS: numeric rating scale, PECS: modified pectoral nerve block, ESPB: erector spinae plane block. *P < 0.05 (Mann-Whitney U test). P values marked with the *symbol represents statistically significant difference.

cent meta-analyses of randomized controlled trials showed that the PECS block resulted in similar pain scores and opioid consumption to systemic analgesics and thoracic paravertebral blocks (TPVB) for breast surgery [10–12].

Zhao et al. [16] performed a meta-analysis including 993 patients who received PECS blocks for radical mastectomies and recommended PECS-2 as an effective analgesia for early postsurgical pain. Kulhari et al. [17] compared the modified PECS block with the TPVB and reported that the PECS block was superior in terms of postoperative pain and opioid consumption in radical mastectomy. The PECS block may also be a safer alternative to the paravertebral block because it is easier to perform and is associated with a lower risk of pneumothorax. However, one of the most common complications of axillary dissections is trauma to the long thoracic nerve. In most cases, the nerve is stimulated electrically or mechanically for correct identification, but the nerve response has been blocked in more than one case after anesthetic injection, thus preventing identification and facilitating injury [18].

In 2016, Forero et al. [13] described the ultrasound-guided ESPB as a new regional technique in which the local anesthetic is injected into the interfascial plane between the transvers process of the vertebra and the erector spinae muscles. Several cadaveric studies have shown that local anesthetics reach both the ventral and dorsal rami of the spinal nerves, causing a sensory blockade over the anterolateral thorax. Although the debate is still ongoing, the weight of the available evidence suggests that this is the primary mechanism of action. Studies also support the assertion that the ESPB exhibits a significant analgesic effect in patients undergoing breast cancer surgery [19,20].

In a meta-analysis conducted by Leong et al. [21], ESPB was compared with no block in seven studies, the TPVB in four, and the PECS block in three. The analysis revealed that the ESPB reduced opioid consumption in the postoperative period more than systemic analgesics; however, no statistically significant difference was seen in the 24-h opioid consumption compared with the TPVB. Another meta-analysis conducted by Huang et al. [14] reported that the ESPB can be an effective alternative to the TPVB for multimodal analgesia management in thoracic and breast surgeries, which is consistent with the study conducted by Leong et al. Paraspinal facial plane blocks, such as the ESPB, are designed to provide local anesthetic spread into the paravertebral and intercostal spaces without the risks associated with inserting the needle tip into these spaces, hence the nickname paravertebral-by-proxy [22]. Given that the ESPB involves a simpler technique and is associated with a lower risk of serious complications, such as pneumothorax, this block could be a suitable alternative in thoracic and breast surgeries, as suggested by these meta-analyses.

Only three previous studies comparing the PECS block and ESPB have reported that the PECS block provided better pain management; however, the pain scores in the first 24 h were similar between the two blocks in these studies [21,23–25]. Additionally, in the studies by Altıparmak et al. [23] and Gad et al. [24], all blocks were performed after the induction of anesthesia, and the PECS block was administered with the patient in the supine position, while the ESPB was administered using the lateral decubitus position. Studies have suggested that the different positions used in fascial plane blocks may affect the distribution of the local anesthetic [26]. The deep fascia, which is the target of interfascial plane blocks, is composed of multiple layers, and its dynamic

properties depend on numerous factors [27]. One such factor is the mechanism by which muscle contraction creates stretch and movement in the fascia, allowing local anesthetics to spread to low-resistance areas through the pumping mechanism [28,29]. Second, the fascia may contain its own contractile elements that play a role in force generation [30]. Considering the interfascial plane blocks from this perspective, many unanswered questions remain. Although these authors reported that the patients were placed in the supine position as soon as possible after the block to eliminate the positional effect on the local anesthetic distribution, the lack of evaluation of dermatomal spread remains an important limitation. It should also be noted that fascial dynamics, and thus block effects, can be affected by anesthetic depth, muscle relaxation, and patient position.

Additionally, the ESPB was applied at the level of the T4 transverse process in all three studies.

PECS blocks may provide superior postoperative analgesic results owing to better coverage of the axilla and T2 dermatome.

Aksu et al. [20] demonstrated the efficacy of the bi-level ESPB in breast surgery with axillary lymph node dissection. Therefore, the ESPB was employed as a bi-level procedure at the T2 and T4 transverse processes in the present study. The T2 level was selected as the second-level injection point because the origin of pain after axillary surgery involves the lateral cutaneous branch of T2 [31].

Finally, all three studies used more local anesthetic in the PECS block than in the ESPB block (30–35 ml vs. 20 ml, respectively). A previous meta-analysis investigating the analgesic efficacy of the ESPB in breast cancer surgery examined 12 randomized controlled studies involving 699 patients and reported an effective dose of the local anesthetic between 16 ml and 40 ml [32]. The same dose of the local anesthetic (30 ml) was applied for both the ESPB and PECS block in the present study in order to eliminate the potential effects of different doses. The study findings showed that the ultrasound-guided bi-level ESPB is an effective analgesic technique that can be used as part of a multimodal analgesia protocol in patients undergoing radical mastectomy.

The main limitation of this study was the lack of hemodynamic data recorded during the blocks. Second, patient satisfaction scores were not evaluated in this study. Third, the patients' nausea and vomiting symptoms during the postoperative period may not have been correctly evaluated because each patient received routine ondansetron. It is difficult for doctors to blindly treat regional blocks performed using different methods. In a prospective, randomized, controlled, double-blinded trial, considering sedated patients as blinded may be biased.

We used 30 ml 0.25% bupivacaine for both blocks, and lower volumes might produce different results, especially for the bi-level ESPB.

Ultrasound-guided bi-level ESPBs provided better postoperative analgesia than PECS blocks after radical mastectomy. Future studies should investigate the optimum local anesthetic dose for interfascial plane blocks and factors affecting the spread of the local anesthetic.

Funding

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to restrictions of the local ethical committee but are available from the corresponding author on reasonable request.

Author Contributions

Sevim Cesur (Data curation; Methodology; Project administration; Visualization; Writing – original draft; Writing – review & editing)
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