European Review for Medical and Pharmacological Sciences 2024; 28: 3120-3134

The impact of ultrasound-guided erector spinae plane block on hemodynamic stability and postoperative pain in patients undergoing modified radical mastectomy for breast cancer

A. NIKOLIĆ[1,2], M. STOŠIĆ[1,3], J. ŽIVADINOVIĆ[1,2], M. GMIJOVIĆ[1,4], M. ĐORĐEVIĆ[1,5], R. JANKOVIĆ[1,2], A. KARANIKOLIĆ[1,5], B. STOŠIĆ[1,2]

[1]Faculty of Medicine, University of Niš, Niš, Serbia
[2]Anesthesia and Intensive Therapy Clinic, University Clinical Center of Niš, Niš, Serbia
[3]Cardiac Surgery Clinic, University Clinical Center of Niš, Niš, Serbia
[4]Digestive Surgery Clinic, University Clinical Center of Niš, Niš, Serbia
[5]Endocrine Surgery Clinic, University Clinical Center of Niš, Niš, Serbia

Abstract. – OBJECTIVE: Breast cancer, a prevalent global malignancy in women, necessitates a comprehensive treatment approach, with surgery playing a crucial role. Severe acute pain is common post-radical breast cancer surgery, emphasizing the significance of hemodynamic stability and postoperative pain control for optimal outcomes. This study evaluates the impact of ultrasound-guided erector spinae plane block (ESPB) on these parameters in ASA scores 1-2 patients undergoing modified radical breast cancer surgery with general anesthesia.

PATIENTS AND METHODS: Forty-eight patients were divided into two groups: a general anesthesia group, with erector spinae plane block (GA+ESPB), and a control group receiving only general anesthesia (GA). Hemodynamic parameters were continuously monitored, and postoperative pain was assessed using the visual analog scale (VAS) at various time points.

RESULTS: Ultrasound-guided ESPB effectively maintained hemodynamic stability and reduced postoperative pain in breast cancer surgery patients. Statistically significant differences were observed in heart rate, systolic and diastolic blood pressure, and mean arterial pressure between the GA and GA+ESPB groups at multiple time points ($p < 0.05$). VAS scores showed a significant interaction time*group ($p < 0.001$), with consistent differences between the groups at all time points ($p \leq 0.001$).

CONCLUSIONS: Ultrasound-guided ESPB application proved effective in preserving hemodynamic stability and managing postoperative pain in modified radical breast cancer surgery. The technique demonstrates promise in minimizing complications related to hemodynamic variations and postoperative pain, contributing to a comprehensive approach to breast cancer surgical treatment.

Key Words:
Erector spinae plane block, Regional anesthesia, Ultrasonography, Hemodynamic stability, Postoperative pain control, Breast cancer surgery.

Introduction

Breast cancer represents the most common form of malignant tumor among women worldwide. This complex disease requires a comprehensive approach to treatment, with surgical intervention standing as a key component of therapy[1,2]. Surgical procedures often induce varying levels of pain during the operation and in the postoperative period, with approximately 60% of women undergoing radical surgery for breast cancer experiencing intense acute pain[3]. Ignoring or lacking proper treatment for this pain may open the door to long-term chronic pain that persists for years[4,5]. The lack of effective pain control during surgery and the recovery period is a significant factor directly influencing the increased incidence of postoperative complications[6]. Opioid analgesics alleviate pain but, on the other hand, come with undesirable side effects such as nausea, vomiting, drowsiness, and respiratory depression. Therefore, the combination of general and regional anesthesia as additional multimodal analgesia for controlling intraoperative and postoperative pain is considered more effective compared to using only general anesthesia for breast cancer surgeries[7].

In the context of surgical treatment for breast cancer, various regional anesthesia techniques are widely applied to reduce intraoperative and post-

Corresponding Author: Aleksandar Nikolić, MD; e-mail: draleksandarnikolic@hotmail.com; aleksandar.nikolic@medfak.ni.ac.rs

operative pain[8]. These techniques include epidural, paravertebral, and intercostal blocks, but each carries certain risks and drawbacks[9-11]. In contrast, the erector spinae plane block provides adequate analgesia for multiple dermatomes with just one needle puncture and the application of local anesthetic, with minimal risk of complications. The first described technique, namely the erector spinae plane block (ESPB), dates back to 2016 by Forero et al[12], presenting an innovative method of interfascial block carefully performed under ultrasound guidance. Initially used for thoracic neuropathic pain, ESPB is now increasingly applied in surgeries on the chest and abdomen. This block involves the precise application of local anesthetic between the transverse processes of the vertebrae and the erector spinae muscle. Compared to similar techniques, ESPB stands out for its simple education, application, low risk of complications, prolonged analgesia of up to 24 hours, and good patient tolerance[12-15]. A meta-analysis[16] involving 85 publications with a total of 242 patients confirmed all these advantages of ESPB when performed as part of multimodal analgesia for surgical interventions on the chest and abdomen. In addition to the ESPB block, PECS 1 (pectoralis major and minor muscle block) and PECS 2 (modified PECS 1 block) blocks are becoming more prevalent in their application as components of multimodal analgesia during breast cancer surgeries. PECS blocks have demonstrated[17] exceptional effectiveness in pain control, both when used independently and in conjunction with general anesthesia.

Hemodynamic stability and adequate fluid therapy during surgical interventions are crucial for optimal postoperative outcomes[18,19]. Hemodynamic instability is a relatively common clinical occurrence during surgical procedures, and pronounced hypotension can lead to organ ischemia, increasing the risk of postoperative complications[20,21].

Maintaining stability in blood pressure, pulse, and other hemodynamic parameters directly influences the reduction of risks associated with intraoperative and postoperative complications[22]. Hemodynamic control not only improves patient safety during the surgical procedure but also contributes to faster recovery after surgery. Previous experiences highlight significant challenges during the intraoperative and postoperative periods in patients undergoing breast surgeries without adequate analgesia. Analyzing these challenges has made it clear that providing adequate analgesia during and after the surgical procedure is necessary to enhance the overall well-being of patients. While there is literature support for the effectiveness of ESPB in pain control, studies examining the impact of ESPB on hemodynamic stability during breast surgeries are scarce in the literature. The lack of analysis on this topic creates a gap in knowledge. Nevertheless, it is presumed that the application of ESPB could contribute to better hemodynamic stability during breast surgeries due to the reduction of surgical stress. Our research on this correlation is challenging due to the limited number of relevant studies in literature.

The study aimed to evaluate the effects of ultrasound-guided erector spinae plane block (ESPB) on hemodynamic stability and postoperative pain control in patients undergoing modified radical surgery for breast cancer under general anesthesia. Additionally, it aimed to investigate the impact of ESPB on perioperative opioid and anesthetic consumption.

Patients and Methods

Study Design

In our prospective comparative study, 48 female patients aged 50-65 undergoing modified radical surgery for breast cancer due to a breast tumor were included. Limiting the sample to the age group of 50-65 was aimed at reducing variability among participants, striving to achieve homogeneity in biological and physiological characteristics, including hormonal status related to the population. The study was conducted at the Clinic for Anesthesia and Intensive Therapy and the Clinic for Endocrine Surgery at the University Clinical Center in Niš. This study was conducted in accordance with the 2013 Helsinki Declaration; the study protocol was approved by the Ethics Committee of the University Clinical Center Niš, with reference number 35797/4, and registered with ISRTN reference number ISRCTN16469348. Written informed consent was obtained from all patients at least 24 hours prior to participation. A consecutive series of patients operated on from January 2023 to October 2023 were included in the study after signing informed consent forms.

Study Groups

The study included two groups. Patients were randomly assigned to two groups in an alternate sequence 1, 2. The first group (GA group) un-

derwent general anesthesia during the surgical procedure, while the second group (GA+ESPB), in addition to general anesthesia, received an ultrasound-guided erector spinae plane block before the induction of anesthesia.

Inclusion and Exclusion Criteria

Inclusion criteria for the study were as follows: female patients with confirmed breast cancer aged 50 to 65 years, indication for radical surgery for breast cancer, and an American Society of Anesthesiologists (ASA) score of 1-2. Exclusion criteria included the refusal of the patient to participate in the study, unsuccessful administration of the erector spinae plane block (ESPB), known allergy to the used drugs, local infection at the injection site, who were unable to cooperate, or who were deemed to have mental deficits and morbid obesity (BMI > 40 kg/m^2).

Anesthesia

Before the induction of anesthesia, one group of patients received the erector spinae plane block under ultrasound guidance. Patients in the group receiving the ESPB were positioned on the operating table in a seated position, as instructed by the anesthesiologist. The ESPB procedure was performed under ultrasound guidance using the SonoScape P10 ultrasound system (SonoScape Medical Corp, Shanghai, China), with the ultrasound probe longitudinally oriented at the level of the spinous process of T4 after moving the probe 3 cm laterally from the midline. Ultrasound landmarks included the transverse process of the T4 vertebra and the erector spinae muscle. After ultrasound orientation in aseptic conditions, the UPB 50 block needle, 22 G (0.70 mm) x 50 mm (Temena Group, Felsberg, Hessen, Germany), was inserted at an angle of 30-45° in the cranio-caudal direction until the needle tip contacted the transverse process of the T4 vertebra. After hydrodissection with 2 ml of isotonic saline, the correct needle position was confirmed, and then the anesthesiologist injected 30 ml of 0.25% Levobupivacaine deep into the erector spinae muscle. After the injection of 30 ml of 0.25% Levobupivacaine, anechoic fluid was detected by the ultrasound probe, separating the erector spinae muscle from the transverse process of T4, confirming the successful execution of the erector spinae plane block. In both groups, target-controlled infusion (TCI) of intravenous hypnotic TCI Propofol, together with TCI Remifentanil, was used for general anesthesia. The Schneider model effect site concentration for TCI Propofol was set at 5 μg/ml during induction, 2-3 μg/ml during maintenance, and reduced to 0.5 μg/ml during emergence from anesthesia. For TCI Remifentanil, the Minto model effect site concentration was used, with a concentration of 6 ng/ml during induction and 3-5 ng/ml during anesthesia maintenance. Twenty-five minutes before the completion of the breast cancer surgery and awakening from anesthesia, patients received 1 g of paracetamol and 30 mg of ketorolac. Five minutes before awakening, the TCI remifentanil infusion was discontinued. The same non-depolarizing neuromuscular relaxant, rocuronium bromide, was used for intubation at a dose of 0.6 mg/kg BW and a maintenance dose of 0.15 mg/kg BW. After the completion of radical breast cancer surgery, 0.035 mg/kg neostigmine and 0.015 mg/kg atropine were administered for the antagonism of any residual neuromuscular block. In both groups, monitoring for the assessment of the depth of anesthesia (PSi) and the patient's state index was used to ensure an equal depth of anesthesia. The RD SedlineTM EEG Adult Sensor and Massimo Root Platform Radical 7 (Root® Platform, Irvine, California, USA) were used for this purpose. Mechanical ventilation was performed using the Drager Perseus® anesthesia machine (Dragerwerk AG&Co, Lübeck, Germany) for all patients. TCI was executed using AlarisTM PK Plus MK4 infusion pumps (CareFusion, Basingstoke, Hampshire, UK). Intraoperative monitoring included an electrocardiogram (lead II and V5), non-invasive blood pressure measurement, pulse oximetry-oxygen saturation, and end-tidal carbon dioxide.

The study involved modified radical breast surgeries conducted by the same experienced surgical team. The administration of the erector spinae plane block (ESPB) in each patient was carried out by the same skilled anesthesiologist.

Outcomes

Hemodynamic parameters (heart rate, systolic, diastolic, and mean arterial pressure) were continuously monitored using the Mindray iPM 12 monitor (Mindray Bio Medical Electronics Co, Shenzhen, Guangdong, China) and recorded in 10 time intervals: T0 –baseline values, T1 – before induction of anesthesia, T2 – after induction of anesthesia, T3 – before surgical incision, T4 – 5 minutes after incision, T5 – 15 minutes after incision, T6 – 25 minutes after incision, T7 – 35 minutes after incision, T8 – before the conclusion of the operation, T9 – after awakening from

anesthesia. The percentage deviation from baseline values was calculated for each patient, and the frequency of variations exceeding 20% from baseline values was registered. Cardiovascular system stability was assessed as follows: Grade I – 0-10% deviation from baseline values; Grade II – 11-20%; Grade III – 21-30%; Grade IV – more than 30% deviation from baseline values. To assess the degree of pain in the postoperative period, a visual analog scale (VAS) for pain was used, and the VAS score was recorded. VAS scores were measured at 5 time intervals: first in the post-anesthesia care unit 30 minutes after waking up and completing the surgery, then at 2, 6, 12, and 24 hours after waking up and completing the surgery. In the postoperative period, NSAIL (non-steroidal anti-inflammatory drugs) were not regularly prescribed to the patients. However, if the VAS score was higher than 4 during any of these five time intervals, NSAIL were administered to the patients, and Tramadol was available for breakthrough pain. Importantly, no patient received opioids postoperatively.

Sample Size Calculation

The sample size calculation was performed using the G-Power 3.1.9.2 package (Heinrich Heine Universität Düsseldorf, Düsseldorf, Germany), where initial parameters were defined for the margin of error of 5% and the power of the study at 95%. Based on the average VAS score values (from the experimental and control groups measured postoperatively after 6 hours) based on a previous study[23], a minimum representative sample size of 26 subjects, i.e., 13 in each group, was calculated. Due to the possible dropouts, 24 patients per group were included.

Statistical Analysis

The data analysis was conducted using the Statistical Package for the Social Sciences version 16 program (SPSS Inc., Chicago, IL, USA). Mean values and standard deviations were calculated for each hemodynamic parameter. The normality of data distribution was assessed using the Kolmogorov-Smirnov test. Continuous variable comparison was performed using the *t* if the data distribution was normal. In cases where the data distribution was not normal, the comparison of values between two groups was conducted using the Mann-Whitney test. The analysis of the studied parameters in repeated measurements was tested using repeated measures ANOVA. In the analysis of repeated measurements, the following effects were interpreted: the overall effect of time, the overall effect of groups, and the interaction effect of time and groups. If the analysis of repeated measurements indicated a statistically significant interaction, the main effect was examined. In other words, the values of the studied variables between groups were compared at individual time points. The hypothesis was tested with a significance threshold of $p < 0.05$.

Results

The study included 48 patients undergoing modified mastectomy, with an average age of 59.73 ± 6.18 years. Patient age and body mass index (BMI) were compared between groups ($p = 0.171$ and $p = 0.456$, respectively). The distribution of ASA scores and the frequency of patients with arterial hypertension did not show statistically significant differences between groups ($p = 0.456$ and $p = 1.000$, respectively). The duration of anesthesia and surgical intervention was uniform across the examined groups ($p = 0.926$ and $p = 0.935$, respectively), as well as intraoperative blood loss ($p = 0.209$). The total intraoperative administration of anesthetics was significantly higher in the GA group ($p = 0.012$), while the total intraoperative administration of opioids did not show a statistically significant difference ($p = 0.248$) between the control (GA) and experimental (GA+ESPB) groups (Table I).

Different levels of cardiovascular instability of heart rate were found to be statistically significantly different between groups at all time points T1-T9 ($p < 0.001$, $p < 0.001$, $p = 0.015$, $p = 0.007$, $p = 0.030$, $p = 0.040$, $p = 0.021$, $p = 0.004$, $p < 0.001$) (Table II, Figure 1). In both groups, the frequency of levels of cardiovascular instability of heart rate changed significantly ($p = 0.024$ and $p = 0.007$).

Different levels of cardiovascular instability in systolic blood pressure were statistically significantly different between groups at all time points T1-T8 ($p < 0.001$, $p < 0.001$, $p = 0.047$, $p < 0.001$, $p < 0.001$, $p < 0.001$, $p < 0.001$, $p < 0.001$), except the last one T9 (Table III, Figure 2). Different levels of cardiovascular instability in diastolic blood pressure were found to be statistically significantly different between groups at T1, T2, and T4 ($p < 0.001$, $p = 0.001$, $p = 0.049$) (Table III, Figure 3). Different levels of cardiovascular instability in mean arterial pressure (MAP) were statistically significantly different between groups at all time points T1-T8 ($p < 0.001$, $p < 0.001$, $p = 0.006$, $p =$

3123

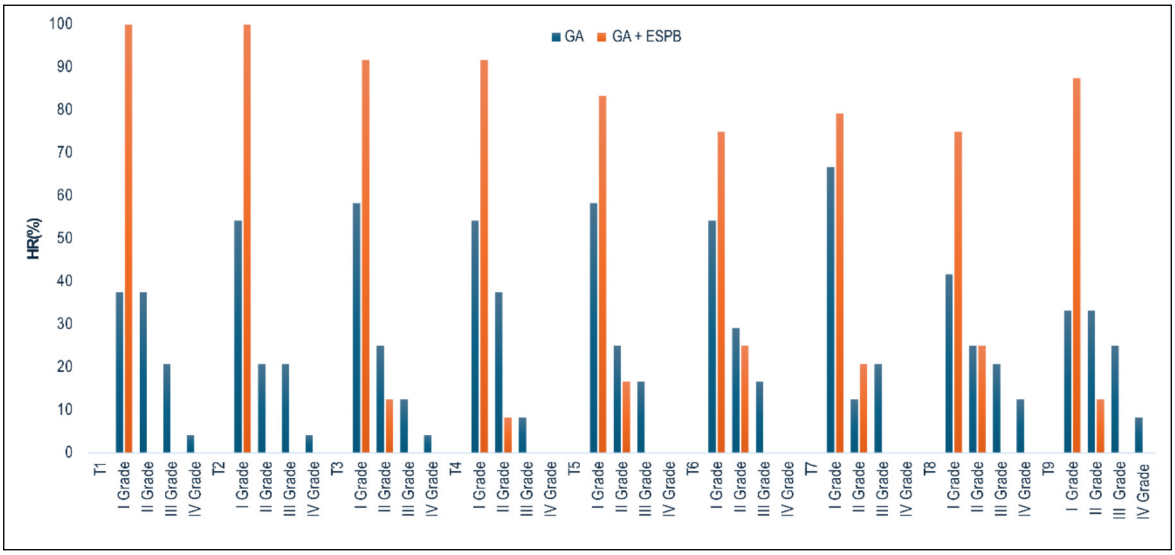

Figure 1. Patient distribution by cardiovascular instability grades considering heart rate. GA: general anesthesia, GA+ESPB: general anesthesia + erector spinae plane block, HR: heart rate, T1 –before induction of anesthesia, T2 – after induction of anesthesia, T3 – before surgical incision, T4 – 5 minutes after incision, T5 – 15 minutes after incision, T6 – 25 minutes after incision, T7 – 35 minutes after incision, T8 – before the conclusion of the operation, T9 – after awakening from anesthesia, Grade I – 0-10% deviation from baseline values (T0), Grade II – 11-20% deviation from baseline values (T0), Grade III – 21-30% deviation from baseline values (T0), Grade IV – more than 30% deviation from baseline values (T0).

Table I. Demographic and operational characteristics of patients.

Variable		GA group (n = 24)		GA+ESPB group (n = 24)		p^1
Age (yrs)	Mean ± SD	60.96 ± 5.51		58.50 ± 6.68		0.171
BMI (kg/m^2)	Mean ± SD	24.54 ± 1.93		24.17 ± 1.49		0.456
ASA status						
I	n - %	12	50.0%	13	54.2%	1.000[2]
II	n - %	12	50.0%	11	45.8%	
Cardiovascular comorbidity (arterial hypertension)	n - %	8	53.3%	7	58.3%	1.000[2]
Duration of anesthesia (min)	Mean ± SD	90.83 ± 24.08		90.28 ± 14.81		0.926
Duration of surgical intervention (min)	Mean ± SD	76.46 ± 23.93		76.00 ± 13.57		0.935
Intraoperative blood loss (ml)	Mean ± SD	57.08 ± 49.89		39.58 ± 40.32		0.209[3]
Total intraoperative Remifentanil consumption (mcg)	Mean ± SD	505.38 ± 247.18		390.71 ± 91.49		0.248[3]
Total intraoperative Propofol consumption (mg)	Mean ± SD	475.83 ± 152.88		372.13 ± 94.15		0.012[3]

Values are presented as mean ± SD and median or number (%). GA: general anesthesia, GA+ESPB: general anesthesia + erector spinae plane block, BMI: body mass index, ASA: American Society of Anesthesiologist, min: minutes, mcg: microgram, mg: milligram, ml: milliliters, [1]*t*-test, [2] χ^2 test, [3]Mann-Whitney test.

0.003, $p = 0.005$, $p = 0.012$, $p = 0.001$, $p = 0.004$), except the last one T9 (Table III, Figure 4). In the GA group, the frequency of levels of cardiovascular instability in systolic, diastolic, and MAP significantly changed ($p < 0.001$, $p = 0.015$, $p < 0.001$), while in the GA+ESPB group, there was no statistically significant change in the frequency of different levels of instability in systolic and diastolic blood pressure ($p = 0.698$, $p = 0.780$, $p = 0.377$) (Table III, Figure 2, Figure 3, Figure 4).

The values of the VAS score showed a statistically significant interaction time*group ($p <$

Table II. Patients distribution by cardiovascular instability grades considering heart rate.

Time interval and grade of cardiovascular instability	GA		GA+ESPB		p^1
	n	%	n	%	
T1					
I Grade	9	37.5	24	100.0	< 0.001
II Grade	9	37.5	0	0.0	
III Grade	5	20.8	0	0.0	
IV Grade	1	4.2	0	0.0	
T2					
I Grade	13	54.2	24	100.0	< 0.001
II Grade	5	20.8	0	0.0	
III Grade	5	20.8	0	0.0	
IV Grade	1	4.2	0	0.0	
T3					
I Grade	14	58.3	22	91.7	0.015
II Grade	6	25.0	3	12.5	
III Grade	3	12.5	0	0.0	
IV Grade	1	4.2	0	0.0	
T4					
I Grade	13	54.2	22	91.7	0.007
II Grade	9	37.5	2	8.3	
III Grade	2	8.3	0	0.0	
IV Grade	0	0.0	0	0.0	
T5					
I Grade	14	58.3	20	83.3	0.030
II Grade	6	25.0	4	16.7	
III Grade	4	16.7	0	0.0	
IV Grade	0	0.0	0	0.0	
T6					
I Grade	13	54.2	18	75.0	0.040
II Grade	7	29.2	6	25.0	
III Grade	4	16.7	0	0.0	
IV Grade	0	0.0	0	0.0	
T7					
I Grade	16	66.7	19	79.2	0.021
II Grade	3	12.5	5	20.8	
III Grade	5	20.8	0	0.0	
IV Grade	0	0.0	0	0.0	
T8					
I Grade	10	41.7	18	75.0	0.004
II Grade	6	25.0	6	25.0	
III Grade	5	20.8	0	0.0	
IV Grade	3	12.5	0	0.0	
T9					
I Grade	8	33.3	21	87.5	< 0.001
II Grade	8	33.3	3	12.5	
III Grade	6	25.0	0	0.0	
IV Grade	2	8.3	0	0.0	

GA: general anesthesia, GA+ESPB: general anesthesia + erector spinae plane block, $^1\chi^2$ test, T1 – before induction of anesthesia, T2 – after induction of anesthesia, T3 – before surgical incision, T4 – 5 minutes after incision, T5 – 15 minutes after incision, T6 – 25 minutes after incision, T7 – 35 minutes after incision, T8 – before the conclusion of the operation, T9 – after awakening from anesthesia, Grade I – 0-10% deviation from baseline values (T0), Grade II – 11-20% deviation from baseline values (T0), Grade III – 21-30% deviation from baseline values (T0), Grade IV – more than 30% deviation from baseline values (T0).

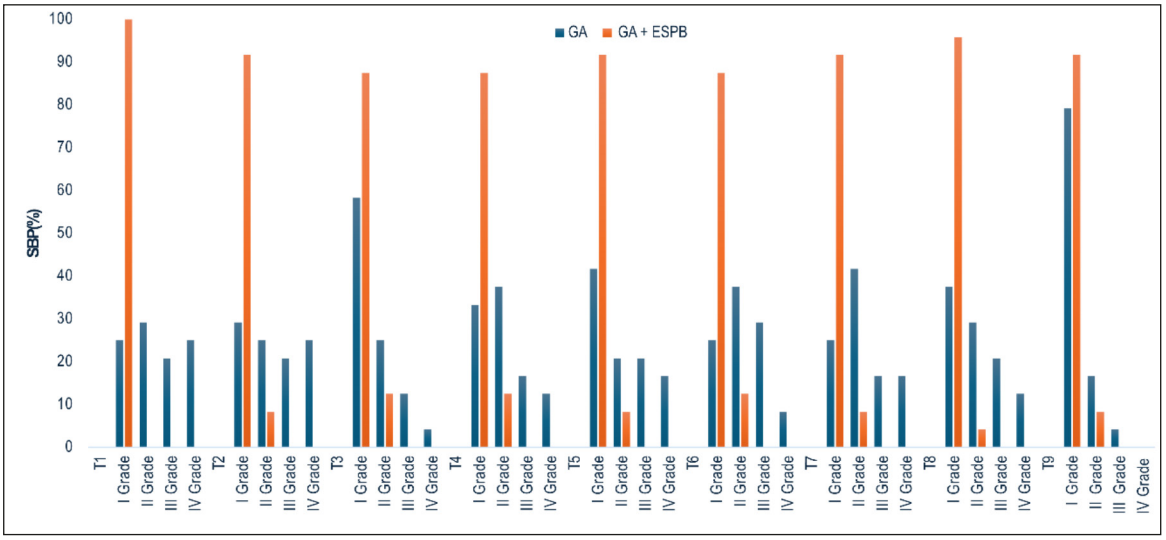

Figure 2. Patient distribution by cardiovascular instability grades considering systolic arterial pressure. GA: general anesthesia, GA+ESPB: general anesthesia + erector spinae plane block, SBP: Systolic blood pressure; T1 - before induction of anesthesia, T2 – after induction of anesthesia, T3 – before surgical incision, T4 – 5 minutes after incision, T5 – 15 minutes after incision, T6 – 25 minutes after incision, T7 – 35 minutes after incision, T8 – before the conclusion of the operation, T9 – after awakening from anesthesia, Grade I – 0-10% deviation from baseline values (T0), Grade II – 11-20% deviation from baseline values (T0), Grade III - 21-30% deviation from baseline values (T0), Grade IV – more than 30% deviation from baseline values (T0).

0.001). Simple effects analysis revealed that the values of this score statistically differ between groups at all time points ($p \leq 0.001$) (Figure 5). The VAS score values significantly decreased from 6 hours after the surgery compared to the values after 30 minutes ($p < 0.05$) in the GA group. In the GA+ESPB group, the values significantly increase after 2 hours ($p = 0.001$) and 6 hours ($p = 0.010$) compared to the values after 30 minutes post-surgery, then begin to significantly decrease, and the values after 24 hours are significantly lower compared to those after 6 hours ($p =$

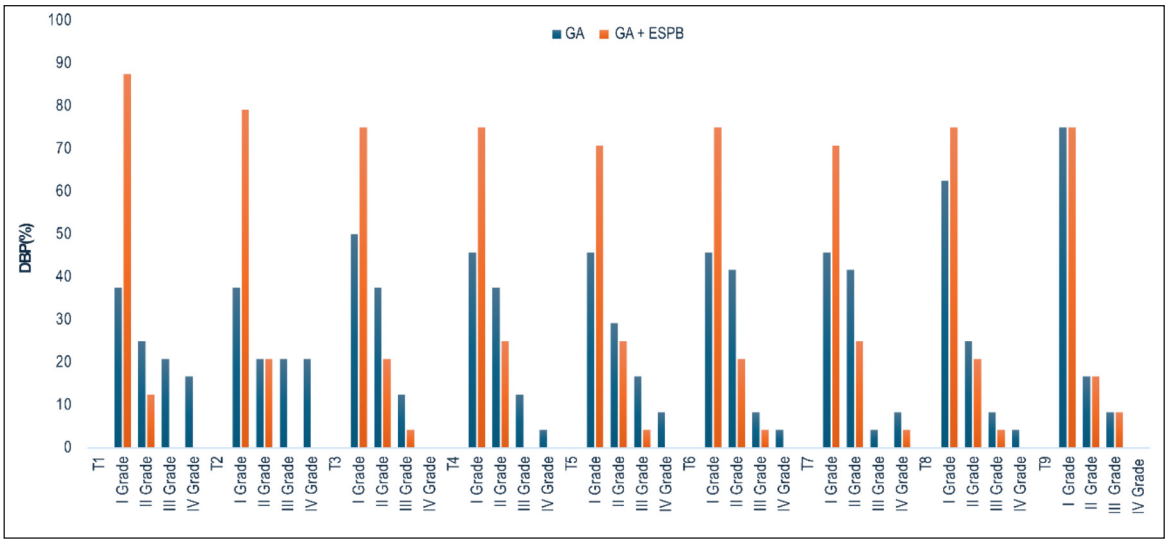

Figure 3. Patient distribution by cardiovascular instability grades considering diastolic arterial pressure. GA: general anesthesia, GA+ESPB: general anesthesia + erector spinae plane block, DBP: Diastolic blood pressure, T1 – before induction of anesthesia, T2 – after induction of anesthesia, T3 – before surgical incision, T4 – 5 minutes after incision, T5 – 15 minutes after incision, T6 – 25 minutes after incision, T7 – 35 minutes after incision, T8 – before the conclusion of the operation, T9 – after awakening from anesthesia, Grade I – 0-10% deviation from baseline values (T0), Grade II – 11-20% deviation from baseline values (T0), Grade III - 21-30% deviation from baseline values (T0), Grade IV – more than 30% deviation from baseline values (T0).

Table III. Patients distribution by cardiovascular instability grades considering systolic, diastolic, and mean arterial pressure.

Time interval and grade of cardiovascular instability	SBP					DBP					MAP				
	GA		GA+ESPB		p[1]	GA		GA+ESPB		p[1]	GA		GA+ESPB		p[1]
	n	%	n	%		n	%	n	%		n	%	N	%	
T1															
I Grade	6	25.0	24	100.0	< 0.001	9	37.5	21	87.5	< 0.001	8	33.3	23	95.8	< 0.001
II Grade	7	29.2	0	0.0		6	25.0	3	12.5		9	37.5	1	4.2	
III Grade	5	20.8	0	0.0		5	20.8	0	0.0		2	8.3	0	0.0	
IV Grade	6	25.0	0	0.0		4	16.7	0	0.0		5	20.8	0	0.0	
T2															
I Grade	7	29.2	22	91.7	< 0.001	9	37.5	19	79.2	0.001	6	25.0	21	87.5	< 0.001
II Grade	6	25.0	2	8.3		5	20.8	5	20.8		9	37.5	3	12.5	
III Grade	5	20.8	0	0.0		5	20.8	0	0.0		3	12.5	0	0.0	
IV Grade	6	25.0	0	0.0		5	20.8	0	0.0		6	25.0	0	0.0	
T3															
I Grade	14	58.3	21	87.5	< 0.047	12	50.0	18	75.0	0.181	13	54.2	22	91.7	0.006
II Grade	6	25.0	3	12.5		9	37.5	5	20.8		8	33.3	2	8.3	
III Grade	3	12.5	0	0.0		3	12.5	1	4.2		3	12.5	0.0	0.0	
IV Grade	1	4.2	0	0.0		0	0.0	0	0.0		0	0.0	0	0.0	
T4															
I Grade	8	33.3	21	87.5	< 0.001	11	45.8	18	75.0	0.049	10	41.7	20	83.3	0.003
II Grade	9	37.5	3	12.5		9	37.5	6	25.0		7	29.2	4	16.7	
III Grade	4	16.7	0	0.0		3	12.5	0	0.0		6	25.0	0	0.0	
IV Grade	3	12.5	0	0.0		1	4.2	0	0.0		1	4.2	0	0.0	
T5															
I Grade	10	41.7	22	91.7	< 0.001	11	45.8	17	70.8	0.108	11	45.8	20	83.3	0.005
II Grade	5	20.8	2	8.3		7	29.2	6	25.0		6	25.0	4	16.7	
III Grade	5	20.8	0	0.0		4	16.7	1	4.2		6	25.0	0	0.0	
IV Grade	4	16.7	0	0.0		2	8.3	0	0.0		1	4.2	0	0.0	
T6															
I Grade	6	25.0	21	87.5	< 0.001	11	45.8	18	75.0	0.162	10	41.7	18	75.0	0.012
II Grade	9	37.5	3	12.5		10	41.7	5	20.8		8	33.3	6	25.0	
III Grade	7	29.2	0	0.0		2	8.3	1	4.2		4	16.7	0	0.0	
IV Grade	2	8.3	0	0.0		1	4.2	0	0.0		2	8.3	0	0.0	
T7															
I Grade	6	25.0	22	91.7	< 0.001	11	45.8	17	70.8	0.258	9	37.5	22	91.7	0.001
II Grade	10	41.7	2	8.3		10	41.7	6	25.0		12	50.0	2	8.3	
III Grade	4	16.7	0	0.0		1	4.2	0	0.0		1	4.2	0	0.0	
IV Grade	4	16.7	0	0.0		2	8.3	1	4.2		2	8.3	0	0.0	
T8															
I Grade	9	37.5	23	95.8	< 0.001	15	62.5	18	75.0	0.554	12	50.0	22	91.7	0.004
II Grade	7	29.2	1	4.2		6	25.0	5	20.8		6	25.0	2	8.3	
III Grade	5	20.8	0	0.0		2	8.3	1	4.2		4	16.7	0	0.0	
IV Grade	3	12.5	0	0.0		1	4.2	0	0.0		2	8.3	0	0.0	
T9															
I Grade	19	79.2	22	91.7	0.319	18	75.0	18	75.0	1.000	21	87.5	22	91.7	0.834
II Grade	4	16.7	2	8.3		4	16.7	4	16.7		2	8.3	1	4.2	
III Grade	1	4.2	0	0.0		2	8.3	2	8.3		1	4.2	1	4.2	
IV Grade	0	0.0	0	0.0		0	0.0	0	0.0		0	0.0	0	0.0	

GA: general anesthesia, GA+ESPB: general anesthesia + erector spinae plane block, SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure, [1] χ^2 test, T1 – before induction of anesthesia, T2 – after induction of anesthesia, T3 – before surgical incision, T4 – 5 minutes after incision, T5 – 15 minutes after incision, T6 – 25 minutes after incision, T7 – 35 minutes after incision, T8 – before the conclusion of the operation, T9 – after awakening from anesthesia, Grade I – 0-10% deviation from baseline values (T0), Grade II – 11-20% deviation from baseline values (T0), Grade III – 21-30% deviation from baseline values (T0), Grade IV – more than 30% deviation from baseline values (T0).

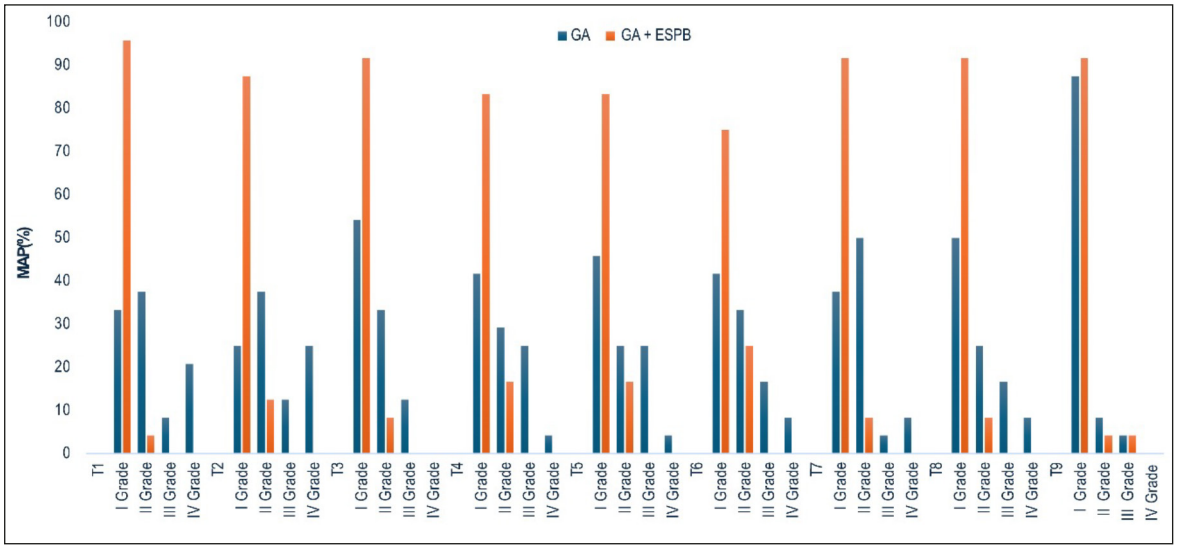

Figure 4. Patient distribution by cardiovascular instability grades considering mean arterial pressure. GA: general anesthesia, GA+ESPB: general anesthesia + erector spinae plane block, MAP: mean arterial pressure, T1 – before induction of anesthesia, T2 – after induction of anesthesia, T3 – before surgical incision, T4 – 5 minutes after incision, T5 – 15 minutes after incision, T6 – 25 minutes after incision, T7 – 35 minutes after incision, T8 – before the conclusion of the operation, T9 – after awakening from anesthesia, Grade I – 0-10% deviation from baseline values (T0), Grade II – 11-20% deviation from baseline values (T0), Grade III – 21-30% deviation from baseline values (T0), Grade IV – more than 30% deviation from baseline values (T0).

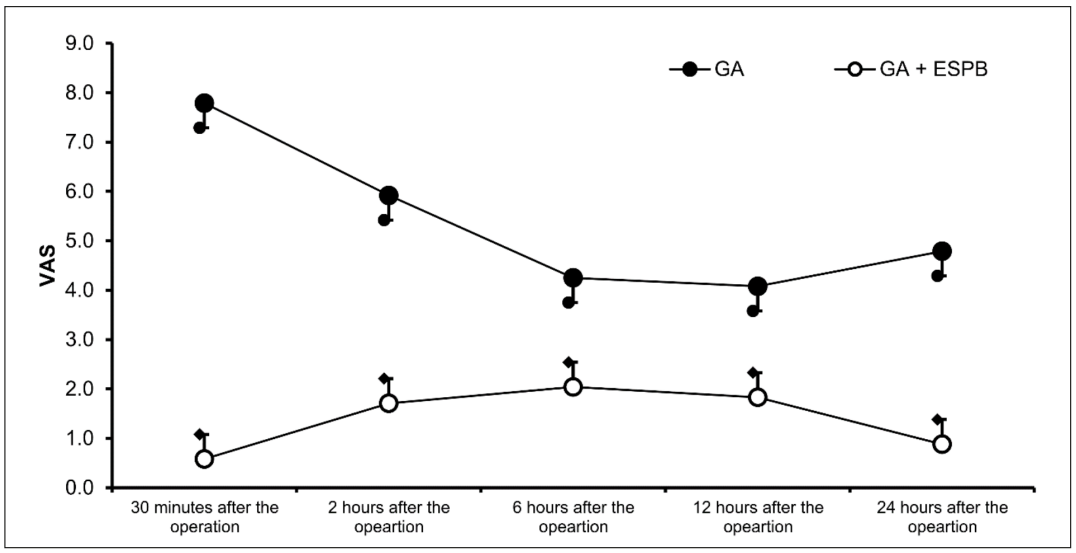

Figure 5. VAS score in the follow-up period in relation to the examined groups. VAS: Visual analogue score, GA: general anesthesia, GA+ESPB: general anesthesia + erector spinae plane block.

0.014) and return to the values observed after 30 minutes post-surgery ($p = 1.000$).

Discussion

The erector spinae plane block (ESPB) is performed at the T4-T5 level for any type of breast surgery[24-28]. The operative area is innervated by a complex network of nerves, but the details are not yet fully elucidated. Kimachi et al[29] achieved sufficient surgical anesthesia for breast cancer surgery by applying preoperative ESPB along with propofol sedation, despite other studies in literature believing that ESPB may not provide adequate analgesia for radical breast surgery.

In addition to the ESPB block for postoperative pain control, ultrasound-guided interfascial

PECS I and PECS II blocks are utilized, both independently and in combination with general anesthesia[17]. A systematic review[30] and meta-analysis indicate the advantage of PECS blocks over ESPB concerning postoperative opioid consumption and pain control; however, further research is necessary. Regarding the technique itself, performing PECS I[31] and PECS II[32] blocks requires two needle punctures, while only one puncture is needed for the ESPB block[12]. Furthermore, during the ESPB block procedure, the needle is directed towards the transverse process, reducing the risk of bone misplacement compared to performing PECS blocks, where needle guidance towards the rib is necessary. Although the possibilities of complications during the execution of these interfascial blocks are minimal, these differences in approach can be crucial when deciding on the optimal blocking technique. Anesthesiologists can carefully assess the advantages and disadvantages of each method to provide patients with the most effective and safest analgesia during breast surgeries. The mechanism through which ESPB provides analgesia for somatic and visceral regions is still not fully understood. Research suggests that local anesthetics are spread into the paravertebral space (PVS)[33,34] and epidural space[35]. These findings contribute to understanding the effects of the ESPB technique on pain reduction, particularly by providing insight into the pathways of local anesthetic distribution in anatomical spaces around the spine. Since intense intraoperative pain can affect hemodynamic stability, ESPB as multimodal analgesia in the intraoperative period leads to a lower degree of pain caused by surgical intervention and, therefore, greater hemodynamic stability. In our study, we focused on the application of ultrasound-guided erector spinae plane block (ESPB) in breast cancer surgery to analyze the impact of this technique on hemodynamic stability and postoperative pain. Our results show statistically significant differences in pulse cardiovascular instability levels between the studied groups throughout the entire intraoperative period T1-T9 ($p < 0.001$, $p < 0.001$, $p = 0.015$, $p = 0.007$, $p = 0.030$, $p = 0.040$, $p = 0.021$, $p = 0.004$, $p < 0.001$) (Table II, Figure 1). These results indicate that the application of the erector spinae plane block (ESPB) significantly contributed to maintaining pulse stability in patients undergoing modified radical breast cancer surgery. The analysis of the distribution of patients according to the degree of cardiovascular instability, considering the pulse in both groups during different time intervals, further confirms the utility of ESPB in maintaining cardiovascular stability (Table II, Figure 1). It is noted that the frequency of levels of cardiovascular instability statistically changed significantly in both groups ($p = 0.024$ and $p = 0.007$), further confirming the effectiveness of ESPB in reducing pulse fluctuations during the intraoperative period. In our study, we concluded that there are statistically significant differences in the variation of levels of cardiovascular instability, especially regarding systolic blood pressure (SBP), diastolic blood pressure (DBP), and mean arterial pressure (MAP) during the intraoperative period in patients undergoing general anesthesia (GA) and GA with the addition of the erector spinae plane block (GA+ESPB).

Our results clearly indicate statistically significant differences in systolic blood pressure instability levels between the studied groups at all time points, except the last one (Table III, Figure 2). These findings imply that the addition of ESPB to general anesthesia significantly contributes to maintaining systolic blood pressure stability during the intraoperative period.

Furthermore, the analysis of diastolic blood pressure in our study revealed statistically significant differences between groups at specific time intervals (T1 – before induction of anesthesia, T2 – after induction of anesthesia, T4 – 5 minutes after incision), suggesting that ESPB also influences maintaining diastolic blood pressure stability during certain phases of the operation (Table III, Figure 3). It is also essential to note that the levels of MAP instability statistically vary between groups at all time points, except the last one. These results confirm that ESPB positively influences maintaining MAP stability during the intraoperative period, which may be crucial for reducing intraoperative complications and improving overall surgical treatment outcomes.

Research investigating the impact of hemodynamic stability monitoring during major general surgical procedures has provided valuable insights into reducing the incidence of intraoperative hypotension and improving patient outcomes. The group of patients subjected to detailed monitoring for early detection of hypotension experienced significantly fewer hypotensive episodes and shorter durations of hypotension compared to those receiving standard care. These findings point to the potential benefits of implementing sophisticated monitoring of hemodynamic parameters during surgical procedures. Early detection of hemodynamic instability allows for

prompt intervention to maintain optimal blood circulation and prevent prolonged organ exposure to hypotension. This is particularly significant as studies have also demonstrated an association between intraoperative hypotension and adverse postoperative outcomes. The implementation of such monitoring systems can provide surgeons and anesthesiologists with real-time information on hemodynamic changes, enabling them to take preventive measures to maintain patient stability throughout the entire surgical procedure. This is not only crucial for reducing the risk of complications but also for safeguarding vital organs from potential damage due to inadequate perfusion[18,19].

Our results align with the study by Ali et al[36], who investigated the efficacy of ultrasound-guided erector spinae plane block on hemodynamic stability in patients undergoing abdominal surgery. Their research showed that patients who received the erector spinae plane block along with general anesthesia exhibited improved intraoperative and postoperative hemodynamic stability, including pulse, systolic, diastolic, and mean arterial pressure, compared to the group of patients under general anesthesia without the block.

In addition to standard blood pressure monitoring, research underscores the importance of appropriate fluid therapy during surgical procedures to enhance postoperative outcomes. Some studies[20,21] have focused on various methods for assessing fluid responsiveness in critically ill patients, analyzing both static and dynamic indices. Static indices, such as central venous pressure and pulmonary artery occlusion pressure, have shown limited accuracy in predicting fluid responsiveness. In contrast, dynamic indices, including stroke volume variation, pulse pressure variation, and respiratory changes in the diameter of the inferior vena cava, have proven promising, particularly in mechanically ventilated patients[20,21].

On the other hand, Singh et al[37] used the ESPB in modified radical mastectomy for postoperative pain control and did not show a significant difference in intraoperative hemodynamic stability between the group that received ESPB with general anesthesia and the group of patients under general anesthesia alone. In comparison to their approach, our study used a larger volume of local anesthetic during ESPB, achieving better distribution and potentially more intense block and analgesia. These findings may further emphasize the potential benefits of adjusting the anesthetic dose in ESPB to achieve adequate analgesia and optimal hemodynamic stability, adding a new layer of complexity to the study of this technique. There is still no consensus on the recommended concentration of local anesthetic to use. Commonly used local anesthetics include lidocaine at concentrations of 1-2%, bupivacaine, levobupivacaine, and ropivacaine at concentrations ranging from 0.125% to 0.25%, 0.375%, and 0.5%. The study by De Cassai and Tonetti[38], conducted on cadavers, showed that an effective erector spinae plane block (ESPB) requires a specific volume of solution per dermatome, estimated to be around 3.4 ml. These findings align with clinical experiences where 20 ml of local anesthetic is often used to cover 4-6 dermatomes or 30 ml to extend the block to 8 dermatomes.

It is important to note that individual patient characteristics, such as constitution and BMI, may influence variations in the required amount of local anesthetic. In certain situations, when it is necessary to expand the field of analgesia, considering performing the block at multiple levels may be beneficial[39]. These conclusions from the literature complement the insights gained from our study, providing an additional perspective on tailoring the approach to ESPB in accordance with the specificities of each patient. Our analysis of VAS scores measured in the postoperative period indicates a significant impact of ultrasound-guided erector spinae plane block (ESPB) on postoperative pain in patients undergoing modified radical surgery for breast cancer. The group receiving only general anesthesia (GA) also showed a statistically significant reduction in the visual analog scale (VAS) from 6 hours post-operation compared to values recorded 30 minutes after the surgery ($p < 0.05$). However, this reduction did not reach the levels observed in patients who also received ESPB. On the other hand, patients under general anesthesia with the addition of ESPB exhibited an initial increase in VAS scores after 2 and 6 hours compared to values recorded 30 minutes post-operation ($p = 0.001$ and $p = 0.010$, respectively). However, after this period, a significant decrease in VAS scores occurred, reaching levels significantly lower than those recorded after 6 hours ($p = 0.014$) and returning to the values recorded 30 minutes post-operation ($p = 1.000$) after 24 hours (Figure 5).

These results support the assumption that the application of ESPB contributes significantly to reducing postoperative pain in patients undergoing radical breast cancer surgery. Additionally, it was observed that the effect of ESPB is most pronounced in the later stages of the postopera-

tive period, after 6 hours of surgery, when values become statistically significantly lower compared to the group without the additional block. In line with our results, a meta-analysis[40], including eight studies with a total of 456 participants investigating the safety and efficacy of ESPB in the postoperative course, indicated that ESPB has a significant analgesic effect in the postoperative period in patients undergoing chest surgery. This meta-analysis also provided data suggesting that patients who received ESPB had fewer postoperative complications[40]. Another study[41] that investigated the efficacy of ESPB in postoperative analgesia after laparoscopic hysterectomy demonstrated better pain control in patients who received preoperative ESPB, which is also consistent with our findings.

In addition to ESPB's impact on hemodynamic stability and postoperative pain, we also analyzed the overall intraoperative consumption of anesthetics and opioids. Our results show a statistically significant higher total intraoperative administration of anesthetics in the GA group compared to the GA+ESPB group ($p = 0.012$) (Table I). These results suggest a potential benefit of additional ESPB application in terms of reducing the overall consumption of anesthetics during surgery. Reducing anesthetic consumption can significantly impact a patient's postoperative stability and faster recovery. Possible mechanisms supporting these findings may involve the selective reduction of the need for intravenous anesthetics during surgery due to the effectiveness of ESPB in reducing intraoperative surgical stress on the body. Our results are similar to those of a study investigating the impact of ESPB on perioperative analgesia, including 180 patients undergoing chest surgery, which indicated that preoperatively administered ESPB leads to reduced intraoperative opioid and anesthetic consumption[42].

Our results regarding the analysis of total opioid administration show a numerical difference between the GA group (505.38 ± 247.18) and the GA+ESPB group (390.71 ± 91.49) with a $p = 0.2483$, indicating a lack of statistically significant difference in total opioid administration between these two groups (Table I). Although the analysis of total opioid administration did not show a statistically significant difference between the control and experimental groups, it is crucial to emphasize the clinical context of these results. The numerical difference in total opioid administration between the groups may indicate a potential clinical benefit of ESPB as an additional form of intraoperative analgesia. In some clinical situations, even small reductions in intraoperative opioid use can have a significant impact on patients, reducing the risk of adverse effects and improving rapid recovery. Therefore, although we did not achieve statistical significance, the results indicate the need for further research and perhaps protocol adjustments to achieve optimal clinical outcomes. Our results are consistent with those of a study[43] involving 100 patients undergoing abdominal hysterectomy, investigating the impact of preoperatively administered ESPB on intraoperative opioid consumption. The number of studies in the literature specifically analyzing the impact of ESPB on intraoperative opioid and anesthetic consumption is limited. Unlike our study, which analyzed intraoperative opioid consumption, most research in this area has focused on postoperative opioid consumption, and data on intraoperative requirements for analgesics and anesthetics are still insufficient. A meta-analysis[44] including 52 studies investigating the impact of ESPB on postoperative opioid consumption indicates that preoperatively administered ESPB leads to a reduction in postoperative opioid consumption and better control of postoperative pain. Also, in a recent retrospective observational study by Hong et al[45] investigating the effects of multiple intermittent doses of the erector spinae plane block through a catheter after total mastectomy, a significant reduction in fentanyl consumption and postoperative pain was observed. These results indicate the potential benefit of using ESPB in the postoperative period after total mastectomy, providing data on reducing the need for opioids and improving pain control compared to standard procedures.

Limitations

Our study, while providing valuable insights, faces several limitations that need to be considered when interpreting the results. The first limitation pertains to the sample size, which was restricted to 48 patients. While we carefully analyzed the available data, a larger sample would enable a broader generalization of results to the overall population, enhancing the overall relevance of our findings. Second, a limitation worth noting is that the study was conducted at a single center. Additionally, we opted for non-invasive blood pressure monitoring instead of invasive, even though the latter might have provided more detailed information on hemodynamics. It is important to emphasize that we consciously recognized this decision as part of the

study's methodology, highlighting our choice for a non-invasive approach to avoid procedures like arterial cannulation and facilitate patient participation. An additional limitation arises from patients' awareness of the applied pain reduction method. Awareness of the treatment can significantly impact patient behavior and subjective pain perception, representing a potential source of bias and increasing the risk of subjective assessments that are not entirely objective. Considering the implementation of a blinded study design or similar methods could be crucial in future research to mitigate the influence of subjective factors and enhance result reliability.

Conclusions

Based on the results of our study, we conclude that ultrasound-guided erector spinae plane block is effective in maintaining hemodynamic stability and controlling postoperative pain in patients undergoing modified radical surgery for breast cancer. This technique shows promising results in reducing the risk of hemodynamic variations and postoperative pain, which could contribute to the reduction of intra and postoperative complications. With these findings in mind, this technique may be crucial for a comprehensive and improved approach to the surgical treatment of breast cancer. Further research is essential to confirm the results of this study and develop guidelines for the optimal use of ESPB in breast cancer surgery. Such research can further expand our understanding of the benefits of this technique and enhance anesthesia and surgical intervention procedures, contributing to the quality of healthcare for patients undergoing such procedures.

Conflict of Interest
The authors declare that they have no conflict of interest.

Ethics Approval
The request to conduct the study was approved by the Ethics Committee of the University Clinical Center Niš under reference number 35797/4 and registered with ISRTN reference number ISRCTN16469348.

Informed Consent
Written informed consent was obtained from all patients at least 24 hours prior to participation.

Funding
The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Authors' Contributions
All authors contributed to the conception and design of the study. Aleksandar Nikolić conducted the preparation of materials, data collection, and analysis, and drafted the initial manuscript. All others, Marija Stošić, Jelena Živadinović, Marko Gmijović, participated in data collection and assisted the lead researcher, Aleksandar Nikolić. Biljana Stosic, Radmilo Jankovic, Miodrag Đorđević, and Aleksandar Karanikolić reviewed the manuscript, provided assistance in its editing, conducted revisions, and gave final approval for the submitted version. All authors have read and approved the final manuscript.

Availability of Data and Materials
The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

ORCID ID
Aleksandar Nikolić: 0009-0007-7662-6412
Marija Stošić: 0000-0001-9921-8488
Jelena Živadinović: 0000-0003-0230-6735
Marko Gmijović: 0000-0003-0748-7520
Miodrag Đorđević: 0000-0002-2985-6748
Radmilo Janković: 0000-0003-0742-8686
Aleksandar Karanikolić: 0000-0002-9491-7228
Biljana Stošić: 0000-0001-5114-0917

References

1) Gu X, Zheng R, Xia C, Zeng H, Zhang S, Zou X, Yang Z, Li H, Chen W. Interactions between life expectancy and the incidence and mortality rates of cancer in China: a population-based cluster analysis. Cancer Commun (Lond) 2018; 38: 44.
2) Siegel RL, Miller KD, Jemal A. Cancer statistics, 2020. CA Cancer J Clin 2020; 70: 7-30.
3) Fecho K, Miller NR, Merritt SA, Klauber-DeMore N, Hultman CS, Blau WS. Acute and Persistent Postoperative Pain after Breast Surgery. Pain Med 2009; 10: 708-715.
4) Hickey OT, Burke SM, Hafeez P, Mudrakouski AL, Hayes ID, Shorten GD. Severity of Acute Pain After Breast Surgery Is Associated With the Likelihood of Subsequently Developing Persistent Pain. Clin J Pain 2010; 26: 556-560.
5) Andersen KG, Kehlet H. Persistent Pain After Breast Cancer Treatment: A Critical Review of Risk Factors and Strategies for Prevention. J Pain 2011; 12: 725-746.

6) Gan TJ, Habib AS, Miller TE, White W, Apfelbaum JL. Incidence, patient satisfaction, and perceptions of post-surgical pain: results from a US national survey. Curr Med Res Opin 2014; 30: 149-160.
7) Garg R. Regional anaesthesia in breast cancer: Benefits beyond pain. Indian J Anaesth 2017; 61: 369-372.
8) Andreae MH, Andreae DA. Regional anaesthesia to prevent chronic pain after surgery: a Cochrane systematic review and meta-analysis. Br J Anaesth 2013; 111: 711-720.
9) Jüttner T, Werdehausen R, Hermanns H, Monaca E, Danzeisen O, Pannen BH, Janni W, Winterhalter M. The paravertebral lamina technique: a new regional anesthesia approach for breast surgery. J Clin Anesth 2011; 23: 443-450.
10) Huan S, Deng Y, Wang J, Ji Y, Yin G. Efficacy and safety of paravertebral block versus intercostal nerve block in thoracic surgery and breast surgery: A systematic review and meta-analysis. PLoS One 2020; 15: e0237363.
11) Guerra-Londono CE, Privorotskiy A, Cozowicz C, Hicklen RS, Memtsoudis SG, Mariano ER, Cata JP. Assessment of Intercostal Nerve Block Analgesia for Thoracic Surgery. JAMA Netw Open 2021; 4: e2133394.
12) Forero M, Adhikary SD, Lopez H, Tsui C, Chin KJ. The Erector Spinae Plane Block. Reg Anesth Pain Med 2016; 41: 621-627.
13) Haskins SC, Boublik J, Wu CL. Point-of-Care Ultrasound for the Regional Anesthesiologist and Pain Specialist. Reg Anesth Pain Med 2017; 42: 281-282.
14) El-Boghdadly K, Pawa A. The erector spinae plane block: plane and simple. Anaesthesia 2017; 72: 434-438.
15) Kendall MC, Alves L, Traill LL, De Oliveira GS. The effect of ultrasound-guided erector spinae plane block on postsurgical pain: a meta-analysis of randomized controlled trials. BMC Anesthesiol 2020; 20: 99.
16) Tsui BCH, Fonseca A, Munshey F, McFadyen G, Caruso TJ. The erector spinae plane (ESP) block: A pooled review of 242 cases. J Clin Anesth 2019; 53: 29-34.
17) Garreffa E, Cantagalli F, Mastrantuono A, Cammarota E, Torresini G, Sozio A, Minora S, Brucchi M. Pectoral nerves blocks (PECS) and sedation: A way to avoid general anesthesia in breast surgery – A single institution early experience. Breast J 2020; 26: 303-305.
18) Gregory A, Stapelfeldt WH, Khanna AK, Smischney NJ, Boero IJ, Chen Q, Stevens M, Shaw AD. Intraoperative Hypotension Is Associated With Adverse Clinical Outcomes After Noncardiac Surgery. Anesth Analg 2021; 132: 1654-1665.
19) Murabito P, Astuto M, Sanfilippo F, La Via L, Vasile F, Basile F, Cappellani A, Longhitano L, Distefano A, Li Volti G. Proactive Management of Intraoperative Hypotension Reduces Biomarkers of Organ Injury and Oxidative Stress during Elective Non-Cardiac Surgery: A Pilot Randomized Controlled Trial. J Clin Med 2022; 11: 392.
20) La Via L, Vasile F, Perna F, Zawadka M. Prediction of fluid responsiveness in critical care: Current evidence and future perspective. Trends Anaesth Crit Care 2024; 54: 101316.
21) Monnet X, Shi R, Teboul JL. Prediction of fluid responsiveness. What's new? Ann Intensive Care 2022; 12: 46.
22) Benes J, Chytra I, Altmann P, Hluchy M, Kasal E, Svitak R, Pradl R, Stepan M. Intraoperative fluid optimization using stroke volume variation in high risk surgical patients: results of prospective randomized study. Crit Care 2010; 14: R118.
23) Su P, Kong M, Yang E. Effect of combined erector-spinae plane blocks on the immediate postoperative neuronal and stress biomarkers after thoracoscopic radical resection for lung cancers. Asian J Surg 2023; 46: 405-411.
24) Gürkan Y, Aksu C, Kuş A, Yörükoğlu UH, Kılıç CT. Ultrasound guided erector spinae plane block reduces postoperative opioid consumption following breast surgery: A randomized controlled study. J Clin Anesth 2018; 50: 65-68.
25) Altıparmak B, Korkmaz Toker M, Uysal Aİ, Turan M, Gümüş Demirbilek S. Comparison of the effects of modified pectoral nerve block and erector spinae plane block on postoperative opioid consumption and pain scores of patients after radical mastectomy surgery: A prospective, randomized, controlled trial. J Clin Anesth 2019; 54: 61-65.
26) De Cassai A, Bonvicini D, Correale C, Sandei L, Tulgar S, Tonetti T. Erector spinae plane block: a systematic qualitative review. Minerva Anestesiol 2019; 85: 308-319.
27) Tulgar S, Selvi O, Senturk O, Serifsoy TE, Thomas DT. Ultrasound-guided Erector Spinae Plane Block: Indications, Complications, and Effects on Acute and Chronic Pain Based on a Single-center Experience. Cureus 2019; 11: e3815.
28) De Cassai A, Marchet A, Ori C. The combination of erector spinae plane block and pectoralis blocks could avoid general anesthesia for radical mastectomy in high risk patients. Minerva Anestesiol 2018; 84: 1420-1421.
29) Kimachi PP, Martins E, Gouveia MA. Erector spinae plane block for radical mastectomy: A new indication? Rev Bras Anestesiol 2019; 69: 421-424.
30) Elshanbary AA, Zaazouee MS, Darwish YB, Omran MJ, Elkilany AY, Abdo MS, Saadeldin AM, Elkady S, Nourelden AZ, Ragab KM. Efficacy and Safety of Pectoral Nerve Block (PECS) Compared With Control, Paravertebral Block, Erector Spinae Plane Block, and Local Anesthesia in Patients Undergoing Breast Cancer Surgeries. Clin J Pain 2021; 37: 925-939.
31) Blanco R. The 'pecs block': a novel technique for providing analgesia after breast surgery. Anaesthesia 2011; 66: 847-848.
32) Blanco R, Fajardo M, Parras Maldonado T. Ultrasound description of Pecs II (modified Pecs

I): A novel approach to breast surgery. Rev Esp Anestesiol Reanim 2012; 59: 470-475.

33) Vidal E, Giménez H, Forero M, Fajardo M. Bloqueo del plano del músculo erector espinal: estudio anatómico-cadavérico para determinar su mecanismo de acción. Rev Esp Anestesiol Reanim 2018; 65: 514-519.

34) Schwartzmann A, Peng P, Maciel MA, Forero M. Mechanism of the erector spinae plane block: insights from a magnetic resonance imaging study. Can J Anesth 2018; 65: 1165-1166.

35) Adhikary SD, Bernard S, Lopez H, Chin KJ. Erector Spinae Plane Block Versus Retrolaminar Block: A Magnetic Resonance Imaging and Anatomical Study. Reg Anesth Pain Med 2018; 43: 756-762.

36) Ali N, Elshorbagy H, Hassanien A. Efficacy of ultrasound guided erector spinae plane block on hemodynamic in patient undergoing abdominal surgery. Minia Journal of Medical Research 2022; 31: 107-111.

37) Singh S, Kumar G, Akhileshwar. Ultrasound-guided erector spinae plane block for postoperative analgesia in modified radical mastectomy: A randomised control study. Indian J Anaesth 2019; 63: 200-204.

38) De Cassai A, Tonetti T. Local anesthetic spread during erector spinae plane block. J Clin Anesth 2018; 48: 60-61.

39) Tulgar S, Selvi O, Senturk O, Ermis MN, Cubuk R, Ozer Z. Clinical experiences of ultrasound-guided lumbar erector spinae plane block for hip joint and proximal femur surgeries. J Clin Anesth 2018; 47: 5-6.

40) Liu J, Fang S, Wang Y, Wang L, Gao L, Xin T, Liu Y. The safety and efficacy of ultrasound-guided erector spinae plane block in postoperative analgesic of PCNL: A systematic review and meta-analysis. PLoS One 2023; 18: e0288781.

41) O. Baran. Quadratus lumborum and erector spinae plane blocks are effective for analgesia in laparoscopic hysterectomy: a randomized controlled trial. Eur Rev Med Pharmacol Sci 2023; 27: 11323-11333.

42) Zhu X, Ye W, Chen J, Xiao J, Zhao W. Comparative retrospective review of perioperative analgesia using ultrasound-guided programmed intermittent erector spinae plane block for video-assisted thoracoscopic lobectomy. BMC Anesthesiol 2023; 23: 370.

43) Hamed MA, Boules ML, Mahmoud MAEM, Abdelghaffar RA. The effect of erector spinae plane block on fentanyl consumption during open abdominal hysterectomy: a randomised controlled study. BMC Anesthesiol 2023; 23: 194.

44) Cui Y, Wang Y, Yang J, Ran L, Zhang Q, Huang Q, Gong T, Cao R, Yang X. The Effect of Single-Shot Erector Spinae Plane Block (ESPB) on Opioid Consumption for Various Surgeries: A Meta-Analysis of Randomized Controlled Trials. J Pain Res 2022; 15: 683-699.

45) Hong B, Bang S, Chung W, Yoo S, Chung J, Kim S. Multimodal analgesia with multiple intermittent doses of erector spinae plane block through a catheter after total mastectomy: a retrospective observational study. Korean J Pain 2019; 32: 206-214.