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ORIGINAL RESEARCH

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Ultrasound-guided thoracic paravertebral nerve block in patients undergoing radical mastectomy

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Abstract

This research aims to investigate the effect of ultrasound-guided continuous thoracic paravertebral nerve block in patients undergoing radical mastectomy. Ninety-six patients who underwent radical mastectomy were equally divided into a study group (administered with a continuous thoracic paravertebral nerve block and general anesthesia) and a control group (given conventional general anesthesia) with a random number table. At T2–T4 (T2: immediate tracheal intubation; T3: at skin incision; T4: at extubation), mean artery pressure (MAP) and hear rate (HR) were significantly lower in the study group ($p < 0.05$); however, there was no significant difference in blood oxygen saturation (SpO_2) between the two groups at different time points. At T2–T4, cortisol (Cor) levels were significantly lower in the study group ($p < 0.05$). At T0–T2, there was no significant difference in the levels of adrenocorticotropic hormone (ACTH) between the two groups. At T3–T4, the levels of ACTH in the study group were significantly lower ($p < 0.05$). There were no significant differences in blood pressure between the two groups at any time point. At the moment of discharge from the resuscitation room and 2 hours after surgery, the numerical rating scale (NRS) score in the study group was significantly reduced ($p < 0.05$). The incidence of adverse reactions in the study group was 10.42%; this was lower than that in the control group (33.33%) ($p < 0.05$). Finally, the use of fentanyl and propofol, and the frequency of analgesic pump use, were significantly lower in the study group ($p < 0.05$). Ultrasound-guided thoracic paravertebral nerve block can effectively maintain hemodynamic stability, improve the stress response, reduce postoperative pain, reduce the use of anesthetic drugs, and effectively control the incidence of adverse reactions in patients undergoing radical mastectomy.

Keywords

Hemodynamics; Parathoracic nerve block; Radical cure of breast cancer; Stress response; Ultrasound guidance

1. Introduction

Breast cancer emerges as a common malignant tumor in clinical practice and poses a serious threat to women's health [1, 2]. Postoperative pain syndrome after breast cancer surgery is a chronic neuropathic pain that occurs in over 30% of patients undergoing breast cancer surgery. Following surgery, persistent pain can occur at multiple sites, including the chest, axillae and shoulders, and pain often lasts for many years [3, 4]. Furthermore, a range of complications, such as the postoperative stress response, can have a significant impact on the quality-of-life along with the physical and mental health of patients [5–7]. The implementation of effective pain relief and providing appropriate treatment, such as the reduction of the stress response by various anesthetic methods, can effectively avoid the incidence of complications such as pain syndrome [8, 9]. Radical mastectomy is a common form of surgery which features a range of anesthetic methods, including general anesthesia, regional blocks and general anesthesia combined with regional blocks. General anesthesia is more common in clinical practice, but is associated with certain limitations. For example, this form of anesthesia cannot completely block the conduction of peripheral stimulation to the central nervous system, but also cannot effectively inhibit the intraoperative stress response. Therefore, clinical experience is useful as this continues to optimize and improve the method of anesthesia deployed. The combination of general anesthesia and regional blocks can be applied for radical mastectomy. This method does not only reduce the dosage and side effects of intraoperative anesthetic drugs, but also effectively reduces the postoperative pain of patients and promotes recovery after anesthesia. Furthermore, compared with the traditional surface location and nerve stimulator guidance method, the ultrasound-guided visualization technique is highly effective, convenient

and associated with fewer complications. Ultrasound-guided nerve blocks can allow anesthesiologists to focus directly on the direction of the puncture needle, needle insertion, needle tip position, and the spread of local anesthetics, thus reducing the complications caused by puncture while improving the success rate of the procedure [10–13].

In this study, we investigated the effect of ultrasound-guided continuous thoracic paravertebral nerve block in patients undergoing radical mastectomy.

2. Patients and methods

2.1 General data

Ninety-six patients who underwent radical mastectomy between January 2020 and December 2022 in our hospital were screened as the main subjects for investigation. According to a random number table, the 96 patients were equally divided into a study group and a control group (48 cases per group). There were no significant differences between the two groups in terms of general data ($p > 0.05$) as shown in Table 1.

2.1.1 Inclusion criteria

Patients were included if they (1) met the diagnostic criteria for stage I–II breast cancer; (2) underwent unilateral surgery for the first time; (3) had indications for radical mastectomy, and (4) were informed of the study and agreed to participate.

2.1.2 Exclusion criteria

Patients were excluded if they (1) had a history of thoracotomy; (2) had severe arrhythmia, heart failure, respiratory failure or renal failure; (3) were pregnant or lactating, or (4) had abnormal coagulation function.

2.1.3 Flowchart

The flowchart is shown in Fig. 1.

2.2 Methodology

All subjects were prohibited from eating and drinking prior to surgery. After entering the operating room, peripheral venous access was established and clinical parameters were closely monitored, including electroencephalography (EEG), heart rate and electrocardiography.

The control group received conventional anesthesia induction involving an intravenous injection of cisatracurium, propofol, fentanyl and midazolam at doses of 0.15 mg/kg, 1.5 mg/kg, 3 μg/kg and 0.03 mg/kg, respectively. Mechanically controlled ventilation was performed by placing a laryngeal mask airway into the patients.

The study group received continuous thoracic paravertebral nerve block combined with general anesthesia and ultrasound to apply a nerve block to the T3 vertebra in the intercostal space on the operated side. The patient was placed in a supine posture so that the unaffected side was below. The T3 intervertebral space was marked as the site of puncture, and routine disinfection was performed. Under the guidance of ultrasound, the physiological structure of the patient was clearly evident. The probe was used to scan the T3 intercostal space. The transverse process, ligament, costotransverse process and pleura were observed and the thoracic paravertebral space was identified. The needle was inserted on the lateral side of the probe. The patient was given 2 mL of a 0.9% sodium chloride injection to identify the specific position of the needle tip in the patient's body. The needle was slowly inserted and pushed to the position of the costotransverse ligament. Following injection, the needle tube was withdrawn to ensure that there was no cerebrospinal fluid or blood. Patients were given ropivacaine at a concentration of 0.5% in a dose of 20 mL. Due to the bolus injection of the drug, the parietal pleura was evidently compressed, and the paravertebral space was therefore dilated, thus helping the medical staff to determine the ideal position of the needle tip. Following drug injection, the needle tube was withdrawn and a catheter was placed approximately 3 cm into the thoracic paravertebral space. The catheter was fixed appropriately. After 15 minutes of drug effect, the patients underwent the induction of general anesthesia; the induction method was equivalent to that used in the control group.

Patients in both groups were treated with intravenous propofol at a drug concentration of 1% and a dose of 2 to 3 μg/mL. During the procedure, the patients were given intermittent fentanyl injections and were closely monitored to ensure that BIS values remained between 45 and 60. If patients presented with an increased mean arterial pressure (MAP) and hear rate (HR), then the bolus dose of fentanyl was increased to maintain the stability of the MAP and HR. Patients in the control group were treated with patient-controlled intravenous analgesia, including dezocine, tropisetron and sufentanil at doses of 0.3 mg/kg, 30 mg and 2 μg/kg, respectively. The patient-controlled analgesia was given in a volume of 3 mL and background infusion at a dose of 5 mL/h. Analgesics were dissolved in 250 mL of normal saline. Patients in the study group were treated with patient controlled, thoracic, paravertebral analgesia (ropivacaine at a concentration of 0.2% and a volume of 250 mL). The lockout time, patient-controlled analgesia, and background dose were the same as that in the control group. Patients were monitored postoperatively for pain with the numerical rating scale (NRS). When the NRS score was >4 points, patients received a bolus of 5 mg dezocine to reduce pain.

2.3 Outcome measures

Hemodynamic indices, stress response indices, NRS scores, adverse reactions and analgesic drug use were recorded and compared between the groups.

(1) Hemodynamic indices included MAP, HR and blood oxygen saturation (SpO_2) at different time points (T0: before anesthesia; T1 before intubation; T2 immediately after endotracheal intubation; T3 skin incision; T4 extubation).

(2) Stress response indices contained cortisol (COR), adrenocorticotropic hormone (ACTH) and blood glucose at different time points (T0: before anesthesia; T1: before intubation; T2: immediately after tracheal intubation; T3: at skin incision; T4: at extubation).

(3) NRS: Scores on the NRS scale ranged from 0 to 10 points; the higher the score, the more severe the pain; 0: no pain; 1–3: mild pain (pain did not affect sleep); 4–6: moderate pain; 7–9: severe pain (unable to fall asleep or waking up

TABLE 1. Comparison of general clinical data between the two groups.

Indicator	Study group (n = 48)	Control group (n = 48)	Statistical value	*p* value
Mean age (yr)	54.35 ± 5.26	54.40 ± 5.18	0.0469	0.9627
BMI (kg/m^2)	24.05 ± 2.06	24.09 ± 1.97	0.0972	0.9228
Operative time (min)	126.35 ± 10.34	127.06 ± 9.98	0.3423	0.7329
ASA grade (n, %)				
Grade I	22, 45.83	23, 47.92	0.0418	0.8379
Grade II	26, 54.17	25, 52.08		
Census register (n, %)				
Nonlocal	1, 2.08	2, 4.17	0.3441	0.5575
Local	47, 97.92	46, 95.83		

Note: BMI: Body Mass Index; ASA: American society of Anesthesiologists.

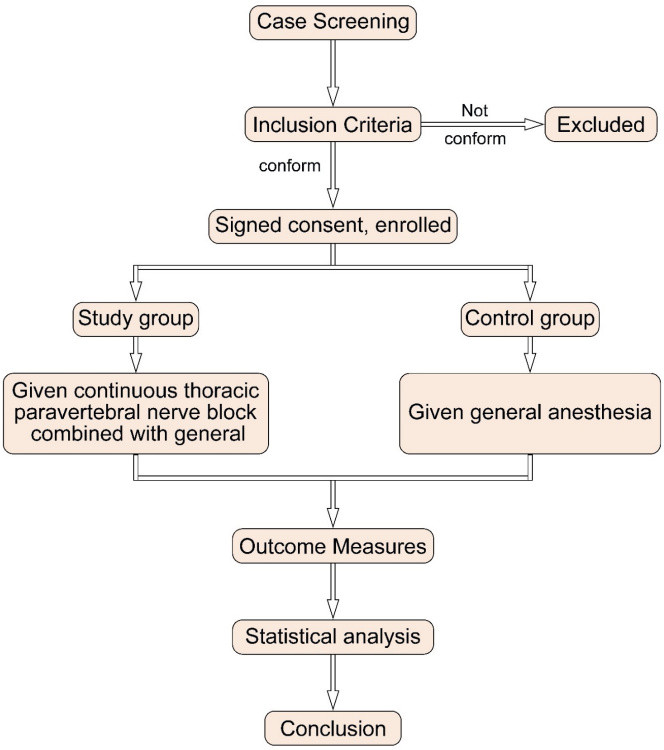

FIGURE 1. Flowchart.

during sleep), and 10: severe pain.

2.4 Sample size calculation

PASS version 15.0 software (NCSS LLC, Kaysville, UT, USA) was used to calculate the sample size. The α value (the test level) was set at 0.01 and the power 1-β value was set at 0.95. Total fentanyl consumption served as the main observation index. Referring to previous clinical experience, analysis demonstrated that at least 40 cases were required in each group. Considering patient dropout, the sample size was increased by 20%; thus, 48 patients needed to be included in each group, with a total of 96 patients required.

2.5 Statistical methods

Statistical analysis was performed with SPSS version 15.0 (IBM, Armonk, NY, USA). Numerical data (the incidence of adverse reactions) are presented as n and % and comparisons between groups were conducted with the Chi-squared test. Measurement data (hemodynamics, stress response indices, NRS scores, fentanyl, propofol and the frequency of analgesic pump use, are reported as means ± standard deviations. Data were compared by the *t*-test and $p < 0.05$ represented statistical significance.

3. Results

3.1 Clinical data

There was no significant difference between the two groups in terms of general clinical data ($p > 0.05$), as shown in Table 1.

3.2 Hemodynamic indices

At T0–T1, there was no significant difference between the two groups with regards to MAP, HR and SpO_2. At T2–T4, MAP, HR and SpO_2 in the study group were all significantly lower than that in the control group ($p < 0.05$). MAP and HR were significantly different when tested at different time points in the study group ($p < 0.05$). MAP and HR were not significantly different when tested at different time points in the control group (Table 2).

3.3 Stress response indicators

At T0–T1, there was no significant difference between the two groups in terms of COR; at T2–T4, COR was significantly lower in the study group when compared to the control group ($p < 0.05$). At T0–T2, there was no significant difference between the two groups in terms of ACTH. At T3–T4, ACTH was significantly lower in the study group than in the control group ($p < 0.05$). There was no significant difference between the two groups in terms of blood glucose at different time points (Table 3).

3.4 NRS scores

NRS scores in the study group were significantly lower than those in the control group at the time of discharge from the resuscitation room and two hours after surgery ($p < 0.05$) (Table 4).

3.5 Adverse reactions

The incidence of adverse reactions in the study group was 10.42%; this was significantly lower than the incidence of 33.33% in the control group ($p < 0.05$) (Table 5).

3.6 Use of analgesic drugs

The dosage of fentanyl and propofol, and the frequency of analgesic pump use, in the study group were significantly lower than the control group ($p < 0.05$) (Table 6).

4. Discussion

At present, there are two commonly used treatments for breast cancer in clinical practice: axillary lymph node dissection and radical mastectomy [14]. Although efficacy of these two treatments is good, there is significant surgical trauma with an extremely high probability of stress response in patients during surgery; this can result in severe damage to peripheral nerves in the breast tissue [15]. The postoperative pain associated with radical mastectomy is often more than moderate; this can be a miserable situation for the patient and cause adverse effects on their quality-of-life and postoperative recovery [16]. According to statistics, over 50% of breast cancer patients undergo surgery; the pain that these patients experience will gradually transform into chronic neuralgia due to the damage caused to the peripheral receptors; consequently, these patients will experience pain for the rest of their life [17].

Traditional modified radical mastectomy involves the induction of general anesthesia to relieve pain [18, 19]. Although general anesthesia plays a certain inhibitory role in the limbic system of the cerebral cortex, it cannot block the conduction of peripheral noxious stimuli to the central nervous system, thereby promoting stress responses in patients during surgery [7, 20, 21].

Patients can experience stress reactions during surgery which can lead to abnormal glucose tolerance, the increased secretion of hormones such as COR, an elevated metabolic rate, as well as hemodynamic fluctuations [22]. Previous studies [2, 23, 24] have suggested that patients who receive ultrasound-guided thoracic paravertebral nerve block combined with general anesthesia are hemodynamically stable, thus indicating that ultrasound-guided thoracic paravertebral nerve blocks can effectively inhibit the stress response of patients [25–27]. Once the stress response occurs, patients experience a number of symptoms, including insulin resistance (inducing gluconeogenesis and hepatic glycogenolysis) and the massive secretion of hormones such as COR, which leads to a rapid increase in blood glucose in patients [7, 28]. To avoid these phenomena, we selected ultrasound-guided thoracic paravertebral nerve block in the present study to inhibit the intraoperative stress response of patients, thus achieving excellent outcomes.

Our present findings revealed that the frequency of postoperative analgesic pump use in the study group was significantly reduced when compared to the control group; the pre-analgesic effect was clearly evident. The inflammatory response was eliminated, signal transduction was blocked, and the noxious stimulation of peripheral nerve receptors was minimized. Furthermore, various plastic changes were suppressed in neurons, pain level was reduced, and postoperative quality-of-life was improved [29, 30]. Our data showed that the probability of vomiting after surgery in the control group was higher than that in the study group; this was because the hemodynamic status of patients in the study group was relatively stable and the intake of opioid doses was reduced. Hence, the overall situation of patients tended to be good following surgery [31, 32].

This study has certain limitations which need to be considered. For example, the number of research samples involving ultrasound-guided thoracic paravertebral nerve block combined with general anesthesia was small. Furthermore, geographical and human factors could have influenced our findings. Consequently, our research conclusions have some limitations which need to be addressed by in-depth analysis.

5. Conclusions

In brief, ultrasound-guided thoracic paravertebral nerve blocks can efficiently maintain intraoperative hemodynamic stability, improve the inflammatory response, reduce postoperative pain experienced by patients undergoing radical mastectomy, and effectively control the incidence of adverse reactions. Further research should approach the concept of onco-plastic surgery

TABLE 2. Comparison of hemodynamic indices between the two groups ($\bar{x} \pm s$).

Index		Study group (n = 48)	Control group (n = 48)	*t* value	*p* value
MAP (mmHg)					
	T0	87.35 ± 8.16	87.40 ± 8.09	0.0301	0.9760
	T1	90.35 ± 9.35	90.41 ± 9.29	0.0315	0.9749
	T2	93.51 ± 9.22	104.06 ± 9.89	5.4058	<0.001
	T3	92.35 ± 9.16	98.95 ± 10.65	3.2551	0.0016
	T4	91.68 ± 8.61	101.98 ± 10.65	5.2107	<0.001
F value	—	1.012	16.848	—	—
p value	—	0.389	<0.001	—	—
HR (beats/min)					
	T0	67.95 ± 6.26	67.89 ± 6.19	0.0472	0.9624
	T1	71.36 ± 6.95	71.41 ± 7.01	0.0351	0.9721
	T2	70.14 ± 6.24	88.61 ± 8.19	12.4282	<0.001
	T3	69.04 ± 6.15	85.34 ± 7.95	11.2355	<0.001
	T4	67.56 ± 6.95	86.35 ± 6.24	13.9376	<0.001
F value	—	2.895	53.484	—	—
p value	—	0.057	<0.001	—	—
SpO_2 (%)					
	T0	98.35 ± 5.36	98.41 ± 5.41	0.0546	0.9566
	T1	98.03 ± 5.34	97.97 ± 4.98	0.0569	0.9547
	T2	98.40 ± 6.35	96.01 ± 5.26	2.0081	0.0475
	T3	98.46 ± 6.35	96.02 ± 5.39	2.0296	0.0452
	T4	98.38 ± 5.36	96.05 ± 5.16	2.1697	0.0326
F value	—	0.033	1.677	—	—
p value	—	0.992	0.173	—	—

MAP: mean artery pressure; HR: hear rate; SpO_2: oxygen saturation.

TABLE 3. Comparison of stress response indicators between the two groups (mean ± standard deviation).

Index	Study group (n = 48)	Control group (n = 48)	*t* value	*p* value
COR (nmol/L)				
T0	291.35 ± 22.35	290.35 ± 22.16	0.2201	0.8262
T1	304.25 ± 33.25	310.25 ± 32.65	0.8920	0.3747
T2	331.25 ± 31.05	377.35 ± 36.15	6.7022	<0.001
T3	357.25 ± 34.15	396.35 ± 36.54	5.4163	<0.001
T4	362.15 ± 35.09	411.25 ± 40.35	6.3615	<0.001
ACTH (ng/L)				
T0	14.21 ± 1.05	14.22 ± 1.09	0.0458	0.9636
T1	14.89 ± 1.15	14.91 ± 1.16	0.0848	0.9326
T2	17.65 ± 1.24	17.98 ± 1.31	1.2675	0.2081
T3	17.91 ± 1.65	20.34 ± 1.56	7.3227	<0.001
T4	19.06 ± 1.74	21.95 ± 2.06	7.4253	<0.001
Blood glucose (mmol/L)				
T0	5.41 ± 0.56	5.49 ± 0.52	0.7253	0.4701
T1	5.55 ± 0.57	5.56 ± 0.51	0.0906	0.9280
T2	5.91 ± 0.51	5.92 ± 0.52	0.0951	0.9244
T3	6.12 ± 0.59	6.13 ± 0.49	0.0903	0.9282
T4	6.11 ± 0.51	6.12 ± 0.48	0.0989	0.9214

COR: cortisol; ACTH: adrenocorticotropic hormone.

TABLE 4. Comparison of NRS scores between the two groups (mean ± standard deviation).

Index	Study group (n = 48)	Control group (n = 48)	*t* value	*p* value
NRS score (point)				
The moment of discharge from the resuscitation room	1.90 ± 0.52	3.92 ± 0.50	19.4001	<0.001
2 hours after surgery	2.00 ± 0.51	4.40 ± 0.49	23.5104	<0.001
12 hours after surgery	1.90 ± 0.47	1.94 ± 0.48	0.4125	0.6809

NRS: numerical rating scale.

TABLE 5. Comparison of adverse reactions between the two groups (n, %).

Group	Nausea and vomiting	Skin pruritus	Dizziness	Incidence
Study group (n = 48)	2, 4.17	1, 2.08	2, 4.17	5, 10.42
Control group (n = 48)	8, 16.67	2, 4.17	6, 12.50	16, 33.33
χ^2 value	——			7.3752
p value	——			0.0066

TABLE 6. Use of analgesic drugs in the two groups (mean ± standard deviation).

Group	Fentanyl (μg)	Propofol (mg)	Frequency of analgesic pump use (time)
Study group (n = 48)	241.25 ±16.31	586.35 ± 45.36	4.26 ± 0.53
Control group (n = 48)	336.25 ± 23.01	699.35 ± 50.25	12.65 ± 1.10
t value	23.3362	11.5649	47.6056
p value	<0.001	<0.001	<0.001

in combination with the individual conditions of patients when treating breast cancer.

AVAILABILITY OF DATA AND MATERIALS

The authors declare that all data supporting the findings of this study are available within the paper and any raw data can be obtained from the corresponding author upon request.

AUTHOR CONTRIBUTIONS

LS—designed the study and carried them out; LS, YSX and JYL—supervised the data collection, analyzed the data, interpreted the data, LS and WH—prepare the manuscript for publication and reviewed the draft of the manuscript. All authors have read and approved the manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Ethical approval was obtained from the Ethics Committee of The Affiliated Hospital of Beihua University (Approval no. 2019022). Written informed consent was obtained from a legally authorized representative(s) for anonymized patient information to be published in this article.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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