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Original Research

Effect of Ropivacaine Epidural Block Combined with General Anesthesia on the Expression of Oxidative Stress and Immune Indexes in Elderly Patients with Ovarian Cancer Cell Cytoreductive Surgery

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Abstract

Background: Perioperative oxidative stress (OS) and immunosuppression can increase the risk of tumor metastasis and diminish treatment efficacy in ovarian cancer (OC). To enhance the efficiency of cytoreductive surgery (CS) and reduce surgical risks, the combination of ropivacaine epidural block (REB) with general anesthesia (GA) has emerged as a novel regimen, particularly for elderly patients undergoing OC surgery. However, there is limited research on the effectiveness of this protocol, underscoring the need for comprehensive investigation. This study aims to evaluate the impact of REB combined with GA on oxidative stress and immune parameters in elderly patients undergoing cytoreductive surgery for OC. **Methods**: Out of 124 eligible patients undergone OC cytoreductive surgery at Lanzhou First People's Hospital (June 2022–December 2023), 79 patients received intravenous general anesthesia and 45 patients received ropivacaine epidural block combined with general anesthesia. Propensity score matching yielded 45 pairs. 45 patients given intravenous general anesthesia were included to the control group (CG), while 45 patients used ropivacaine epidural block combined with general anesthesia were included to the study group (SG). Perioperative recovery was assessed at multiple time points: 30 minutes preoperatively, during anesthesia induction, and at 5 and 30 minutes post-induction, as well as upon surgery completion. The parameters assessed included heart rate (HR), mean arterial pressure (MAP), C-reactive protein (CRP), OS indicators (cortisol, interleukin-6, and tumor necrosis factor-alpha [TNF-α]), and immune indicators (T lymphocyte subsets). Postoperative analgesic efficacy was measured using the visual analogue scale (VAS) and Bromage score. Additionally, adverse reactions within 48 hours post-surgery were monitored. **Results**: The SG exhibited significantly shorter times to respiratory recovery, awakening, and extubation, as well as a reduced need for remedial analgesia compared to the CG ($p < 0.05$). Furthermore, the SG demonstrated significant improvements in MAP, HR, OS markers, and immune parameters, alongside better VAS, and Bromage scores relative to the CG ($p < 0.05$). The incidence of adverse reactions was also lower in the SG ($p < 0.05$). **Conclusion**: The combination of REB with GA effectively shortens recovery times, reduces oxidative stress and immune suppression, enhances postoperative analgesia, and decreases the incidence of side effects. This regimen thereby ensures higher safety and improved outcomes in elderly patients undergoing surgery for ovarian cancer.

Keywords: ovarian cancer; cytoreductive surgery; ropivacaine; epidural block; general anesthesia

1. Introduction

Among the malignant tumors of female reproductive system, the incidence of ovarian malignant tumor ranks third, while the incidence of ovarian cancer (OC) in China ranks first in the world [1]. OC encompasses various pathological types, each presenting distinct clinical manifestations. Approximately 85% to 90% of malignant ovarian tumors originate from epithelial cells, classified as epithelial OC [2]. Due to the unique anatomical location of the ovaries, early clinical symptoms are often subtle or masked, leading to most diagnoses occurring at advanced stages. Consequently, epithelial OC is associated with a high rate of extensive metastasis and mortality. The five-year survival rate for patients diagnosed with advanced epithelial OC remains below 50% [3]. Cytoreductive surgery (CS) is a clinically recognized standard scheme for the treatment of OC, which can minimize tumor lesions [4]. However, elderly patients with OC often experience compromised organ function, weakened immune response, and a higher prevalence of chronic conditions like hypertension and diabetes. These factors increase the risks associated with anesthesia, potentially leading to perioperative complications and elevated mortality rates [5]. In addition, ovarian cytoreductive surgery has the advantages of large trauma, long time, obvious traction reflex, serious stress response after general anesthesia (GA) and acute traumatic pain af-

ter operation. Perioperative oxidative stress (OS) and immunosuppression increase the risk of tumor cell metastasis and compromise treatment efficacy [6]. To ensure the effectiveness of CS and minimize surgical risk, it is essential to implement practical and efficient measures at every stage of the operation.

Selecting an appropriate anesthesia modality based on surgical considerations can mitigate patients' OS responses while minimally affecting hemodynamics and preserving immune function. Advancements in anesthesia techniques have facilitated the widespread adoption of epidural block combined with GA, administered either intravenously or via inhalation, in abdominal surgeries, yielding favorable outcomes [7]. Ropivacaine, a commonly used agent in clinical epidural blocks, exhibits minimal adverse effects on the musculoskeletal, central nervous, and cardiovascular systems. Recent advancements in the management of ovarian cancer, particularly in recurrent cases, have focused on the role of secondary cytoreductive surgery and hyperthermic intraperitoneal chemotherapy, which have been associated with improved overall survival in selected patients [8]. However, there remains a paucity of literature on the application of combined anesthesia approaches in elderly patients undergoing OC cytoreductive surgery, and no standardized assessment exists regarding the impact of these approaches on OS and immune function. Therefore, further research is necessary to comprehensively elucidate the clinical utility of ropivacaine epidural block (REB) combined with GA in cytoreductive surgery for elderly patients with OC. Such studies would provide a theoretical foundation for the widespread adoption of this anesthesia regimen. To address this gap, our hospital conducted the present study with the aim of investigating the effects of REB combined with GA on OS and immune parameters in elderly patients undergoing cytoreductive surgery for OC.

2. Materials and Methods

2.1 Research Object

Out of 124 eligible patients undergone OC cytoreductive surgery at Lanzhou First People's Hospital (June 2022–December 2023), 79 patients received intravenous general anesthesia and 45 patients received ropivacaine epidural block combined with general anesthesia. Propensity score matching (PSM) was performed to minimize selection bias and ensure comparability between the study and control groups. Matching was based on variables including age, ASA classification, tumor size, and other relevant clinical characteristics. A 1:1 nearest neighbor matching algorithm with a caliper of 0.2 was applied without replacement. Post-matching, the balance between covariates was assessed using standardized mean differences (SMDs), and all covariates had SMDs less than 0.1, indicating adequate matching. Propensity score matching yielded 45 pairs. 45 patients given intravenous general anesthesia were included to the control group (CG), while 45 patients used ropivacaine epidural block combined with general anesthesia were included to the study group (SG). Inclusion criteria: (1) All selected cases must be pathologically classified as epithelial OC in accordance with precise diagnostic standards referenced from relevant literature [9]; (2) American Association of Anesthesiologists (ASA) [10] was classified as ASA physical status I–II; (3) Patients undergoing CS should present with large and irregular masses within the pelvic cavity of advanced OC, widespread implantation and metastasis in the pelvic peritoneum, and infiltration into abdominal cavity tissues and organs (including the greater omentum and peritoneum with implanted metastatic foci or significant organ infiltration). These conditions are typically confirmed through laparoscopic evaluation. All surgical procedures must be completed at our hospital; (4) Availability of complete clinical data and reliable follow-up information is required. Exclusion criteria: (1) Patients who have previously undergone cytoreductive surgery (CS); (2) Patients who have taken glucocorticoids, psychotropic drugs, or analgesics within the past three months; (3) Patients diagnosed with autoimmune diseases; (4) Patients with dysfunction of major organs; (5) Patients exhibiting abnormal blood coagulation profiles; (6) Patients with mental diseases and cognitive impairment; and (7) Patients who died from causes unrelated to the study.

2.2 Treatment Method

All subjects were evaluated by laparoscopic exploration before operation. According to the Fagootti score [11], cytoreductive surgery was performed with <4 points and neoadjuvant chemotherapy was performed with >4 points.

The TP chemotherapy (refers to a specific chemotherapy regimen involving Taxol (paclitaxel) and Platinum-based drugs (cisplatin)) regimen was administered, consisting of cisplatin at a dosage of 70 mg/m^2 on Day 1 and paclitaxel at a dosage ranging from 135 to 175 mg/m^2 on Day 1, with a 21-day interval per course. Chemotherapy was initiated following two courses of tumor cytoreductive surgery. The surgical procedure encompassed the resection of tumor lesions throughout the entire uterus, bilateral adnexa, and pelvic cavity, as well as metastases to the greater and lesser omentum. Additionally, pelvic and para-aortic lymph node dissection was performed as necessary. Optional surgical techniques were employed to remove gastrointestinal metastases, lesions in the hepatopancreas, and peritoneal involvement, with the objective of achieving maximal tumor debulking. The patients underwent varying degrees of ovarian cytoreductive surgery. Some patients required extensive procedures, including removal of adjacent tissues and organs, while others underwent less extensive surgeries. Specifically, 23 patients in the SG and 21 patients in the CG underwent extensive surgeries. During the operation, the patient assumed the supine position, and follow-

Table 1. General information of two groups [n (%)].

Project	Study group (n = 45)	Control group (n = 45)	t/χ^2	p
Age (years)	67.58 ± 3.77	67.36 ± 3.74	0.278	0.782
BMI (kg/m^2)	23.14 ± 2.66	23.19 ± 2.70	0.089	0.930
ASA Grading (I/II)	22 (48.89)/23 (51.11)	20 (44.44)/25 (55.56)	0.179	0.673
Tumor diameter (cm)	5.24 ± 0.83	5.19 ± 0.79	0.295	0.768
Operation time (hours)	2.38 ± 0.41	2.42 ± 0.43	0.452	0.653
Intraoperative bleeding volume (mL)	152.92 ± 12.94	153.11 ± 12.97	0.069	0.945
Pathological type			0.563	0.755
Mucus property	19 (42.22)	21 (46.67)		
Endometrioid	14 (31.11)	15 (33.33)		
Serous property	12 (26.67)	9 (20.00)		
TNM Staging			0.413	0.520
III Stage	25 (55.56)	28 (62.22)		
IV Stage	20 (44.45)	17 (37.78)		
Number of cases complicated with hypertension	10 (22.22)	9 (20.00)	0.067	0.796
Number of cases complicated with coronary heart disease	8 (17.78)	11 (24.44)	0.600	0.438
Number of cases complicated with diabetes mellitus	9 (20.00)	13 (28.89)	0.963	0.327
Number of years of education (years)	8.56 ± 2.10	8.60 ± 2.15	0.089	0.929

BMI, body mass index; ASA, American Association of Anesthesiologists; TNM, tumor-node-metastasis; t, t-test statistics; χ^2, Chi-squared test statistics.

Table 2. Postoperative recovery of the two groups.

Group	Respiratory recovery time (min)	Awakening time (min)	Extubating time (min)	Number of times of remedial analgesia
Study group (n = 45)	7.58 ± 1.87	20.67 ± 3.58	13.58 ± 2.54	4 (8.89%)
Control group (n = 45)	12.36 ± 1.94	28.64 ± 3.11	15.36 ± 2.96	12 (26.67%)
t/χ^2	11.900	11.274	3.061	4.865
p	<0.001	<0.001	0.003	0.027

ing anesthesia, an incision was made around the umbilical cord or on the left side of the lower abdomen. Subsequently, the abdominal cavity was explored after peritoneal incision, with ascites requiring aspiration and exfoliative cytology examination post-operation. For cases without ascites, rinsing with normal saline was performed, followed by preservation and cytological examination. Comprehensive exploration of the abdominal cavity, retroperitoneal lymph nodes, and upper abdominal lesions was conducted, including palpation of the fallopian tube, uterus, and ovaries. The procedure involved the elimination of the entire uterus, bilateral ovaries, fallopian tubes, greater omentum, and appendix, with visible metastatic lesions in the pelvis and abdominal cavity reduced to less than 1 cm. Finally, the pelvic and abdominal cavities were washed, and the abdomen was closed after suturing.

2.3 Anesthetic Method

All subjects were fasted for 6 hours and 8 hours before operation. After entering the room, deep subclavian vein catheterization and infusion were performed. Mean arterial pressure (MAP), blood oxygen saturation (SpO_2) and basic vital signs were monitored by radial artery puncture.

The CG received intravenous GA. Anesthesia induction was achieved by administering the following medications intravenously: midazolam (Yichang Renfu Pharmaceutical Co., Ltd., Yichang, Hubei, China) 0.05 mg/kg, etomidate (Jiangsu Enhua Pharmaceutical Co., Ltd., Xuzhou, Jiangsu, China) 2 mg/kg, sufentanil (Yichang Renfu Pharmaceutical Co., Ltd., Yichang, Hubei China) 0.3–0.5 µg/kg, cisatracurium (Jiangsu Hengrui Medicine Co., Ltd., Lianyungang, Jiangsu, China) 0.2 mg/kg were administered through intravenous, endotracheal intubation was observed for 4 minutes, and respiration was monitored by an anesthesia machine. Partial pressure of arterial carbon dioxide ($PaCO_2$) was 35–45 mmHg (1 mmHg = 0.133 Kpa). The respiratory rate was maintained at 10 to 12 times per minute, with a tidal volume ranging from 6 to 8 milligrams per kilogram. Continuous infusion included 5 mg/kg of propofol (Jiangsu Enhua Pharmaceutical Co., Ltd., Xuzhou, Jiangsu, China), 18 mg/kg of remifentanil (Jiangsu Enhua Pharmaceutical Co., Ltd., Xuzhou, Jiangsu, China), and 0.18 mg/kg of cisatracurium (Jiangsu Hengrui Medicine Co., Ltd., Lianyungang, Jiangsu, China) every hour. The Bispectral index (BIS) was targeted to remain within the range of 50 to 60, while the body temperature was maintained at 36.5 °C. The infusion of muscle relaxants was sus-

Table 3. Comparison of hemodynamic indexes at different time points involving the two groups ($\bar{x} \pm s$.)

Groups	MAP (mmHg)				
	T1	T2	T3	T4	T5
Study group (n = 45)	97.58 ± 5.69	97.64 ± 5.72	98.64 ± 6.04	101.87 ± 6.23*	97.25 ± 5.69
Control group (n = 45)	97.61 ± 5.72	98.45 ± 5.96	99.17 ± 6.12	105.59 ± 6.91*	98.36 ± 5.91
t	0.025	0.678	0.413	2.682	0.908
p	0.980	0.512	0.680	0.009	0.367
F_{time}/p			12.780/<0.001		
$F_{Intergroup}/p$			0.928/0.068		
$F_{Interaction}/p$			1.005/0.271		
Groups	HR (times/min)				
	T1	T2	T3	T4	T5
Study group (n = 45)	87.69 ± 4.61	88.11 ± 4.67	87.54 ± 4.58	82.29 ± 3.58*	86.12 ± 4.52
Control group (n = 45)	87.72 ± 4.59	88.36 ± 4.79	88.12 ± 4.76	79.36 ± 3.24*	84.36 ± 4.28
t	0.031	0.251	0.589	4.057	1.897
p	0.975	0.803	0.557	0.001	0.061
F_{time}/p			28.410/<0.001		
$F_{Intergroup}/p$			0.540/0.065		
$F_{Interaction}/p$			1.683/0.053		

Note: Compared with T1, T2, T3, T5, $^*p < 0.05$. F_{time}/p represents the F value and corresponding p-value for the effect of time. $F_{Intergroup}/p$ refers to the F-test statistic and corresponding p-value for the effect of the group factor (comparison between the study group and the control group) across all time points. $F_{Interaction}/p$ represents the interaction between group (study group *vs.* control group) and time (repeated measures at different time points). MAP, mean arterial pressure; T1, 30 min before surgery; T2, during anesthesia and sedation; T3, 5 min after anesthesia; T4, 30 min after anesthesia; T5, after surgery; HR, heart rate.

pended 25 min minutes prior to the procedure's completion, and propofol and remifentanil were suspended 10 min minutes ago.

The SG adopted REB combined with GA. Epidural puncture was performed at L2-3 before anesthesia induction, and an epidural catheter with a length of 2–5 cm was placed upward. After successful puncture, the epidural catheter was securely fixed, followed by the injection of 5 milliliters of 1% lidocaine (Shandong Hualu Pharmaceutical Co., Ltd., Liaocheng, Shandong, China). Subsequently, 10 mL of 0.15% ropivacaine (Jiangsu Hengrui Medicine Co., Ltd., Lianyungang, Jiangsu, China) (administered in 2 doses) were injected, with an additional 5 mL of 0.15% ropivacaine administered every hour once the operation commenced. Induction of GA was initiated using the same pharmacological agents as those administered to the CG. However, the infusion rates were adjusted based on individual patient conditions, and vasoactive medications were administered as necessary throughout the surgical procedure.

2.4 Observation Index

Record the recovery of perioperative period: Including respiratory recovery time, awakening time, extubating time and times of remedial analgesia. Respiratory recovery time: defined as the duration from the cessation of anesthetic administration (COAA) to the point at which the patient can breathe independently. Awakening time refers to the interval from the COAA to the patient's correct response to external verbal stimuli (such as raising hands, raising head). Extubating time refers to the time elapsed from the conclusion of surgery to the recovery of the cough and pharyngeal reflex. Remedial analgesia count: The number of additional analgesic administrations required due to inadequate anesthetic efficacy.

Hemodynamics: The changes of MAP and heart-rate (HR) levels were contrasted involving the two groupings 30 min before surgery (T1), during anesthesia and sedation (T2), 5 min after anesthesia (T3), 30 min after anesthesia (T4), and after surgery (T5).

OS and immune indexes: Venous blood samples (3 milliliters) were collected from the antecubital vein of fasting patients at three distinct time points: on the day of surgery, one day post-surgery, and three days post-surgery. Following collection, the blood samples were centrifuged at 3000 revolutions per minute (rpm) for 10 minutes to separate the plasma. The resulting supernatant was carefully harvested for subsequent analyses. Oxidative stress markers, including cortisol, C-reactive protein (CRP), tumor necrosis factor-alpha (TNF-α), and interleukin-6 (IL-6), were quantified using enzyme-linked immunosorbent assay (ELISA) kits (Nanjing Jiancheng Bioengineering Institute, Co., Ltd., Nanjing, Jiangsu, China) according to the manufacturers' protocols. Immune parameters were evalu-

ated using flow cytometry to identify T lymphocyte subsets, specifically $CD3^+$, $CD4^+$, and $CD8^+$ cells. The $CD4^+/CD8^+$ ratio was calculated to assess the patients' immune function.

Analgesic effect: pain visual analogue scale (VAS) [12] was used to evaluate the degree of pain at 2 hours, 8 hours and 24 hours after operation, and the scale of 0 to 10 cm was prepared. Pain intensity was evaluated using a numerical rating scale ranging from 0 to 10, where 0 indicated no pain and 10 represented the most severe pain experienced. Patients were instructed to select the number that best corresponded to their current level of discomfort.

Degree of lower extremity nerve block: The Bromage score [13] was used to assess the degree of lower extremity nerve block 2 h, 8 h and 24 h after surgery, respectively. 0 point: no nerve block was found; 1 point: both lower limbs cannot lift up; 2 points: unable to bend the knee joint of both lower limbs; 3 points: Unable to bend the ankle joints of both lower limbs.

Adverse reactions: the adverse reactions that may occur in the two groups within 48 hours after operation were recorded, including respiratory depression, hypotension, nausea and vomiting, dizziness and skin pruritus. The total incidence of adverse reactions = the total number of adverse reactions/the total number of cases $\times$ 100%.

Respiratory depression refers to the sudden interruption of the inspiratory phase due to severe chest pain, accompanied by a sudden suppression of respiratory movement. Patients typically exhibit signs of distress, such as a pained expression, and their breathing becomes shallower and more rapid than normal. Hypotension is defined as finger artery systolic blood pressure of less than 90 mmHg and diastolic blood pressure of less than 60 mmHg. Nausea refers to an intragastric discomfort that can cause vomiting impulses. Vomiting refers to stomach contents are forcefully excreted through the mouth. Dizziness refers to dizziness in the fingers, feeling heavy, or accompanied by a series of symptoms such as visual rotation, nausea, vomiting, *etc.*, which belong to common brain functional disorders. Skin itching refers to a symptom of itching caused by insect bite dermatitis, allergy, eczema, drugs and other factors.

2.5 Research Flow Chart

Fig. 1 shows the flow chart of this research.

2.6 Statistical Method

Software SPSS 23.0 (IBM Corp., Armonk, NY, USA) was used to analyze the data, while Prism 9.4.1 (GraphPad, Boston, MA, USA) was used to process the images. The general data were compared using the independent sample *t*-test, while the measurement data with uniform variance and a normal distribution were stated by ($\bar{x} \pm s$). Repeated measures analysis of variance (ANOVA) was utilized for analyzing repeated measurement data. Following ANOVA, pairwise comparisons were performed using the least significant difference (LSD) *t*-test. Categorical data were presented as frequencies and percentages (n [%]), and intergroup comparisons were conducted using the Chi-squared test (χ^2) test. A *p*-value of less than 0.05 was considered statistically significant.

3. Result

3.1 Two Groups of General Information

No significant differences were observed between the two groups concerning operation time, ASA classification, body mass index (BMI), age, intraoperative blood loss, pathological type, tumor-node-metastasis (TNM) staging, prevalence of hypertension, diabetes, coronary heart disease, and years of education (all $p > 0.05$), as shown by Table 1.

3.2 Postoperative Recovery of the Two Groupings

The respiratory recovery time, extubating time and awakening time in the SG were shorter, and the times of rescue analgesia in the SG were less ($p < 0.05$), as seen in Table 2.

3.3 Comparison of Hemodynamic Indexes at Different Time Points Involving the Two Groupings

MAP and HR were significantly different in time involving the two groupings ($p < 0.05$, Table 3). There wasn't a discernible distinction involving MAR and HR groupings ($p > 0.05$, Table 3). Compared with T5, T3, T2 and T1, MAP increased, and HR decreased at T4 in both groupings ($p < 0.05$, Table 3).

3.4 Comparison of Oxidative Stress Indicators Involving the Two Groupings

There were considerable differences in time, intergroup and interaction involving the two groupings in cortisol (Cor), TNF-α, IL-6 and CRP ($p < 0.05$). Pairwise comparison: In contrast to the day after operation, the levels of 1-day Cor, TNF-α, IL-6 and CRP in the two groupings increased on the 1st day after operation, and decreased on the 3rd day after operation ($p < 0.05$). On the first and third postoperative days, the SG exhibited significantly lower levels of Cor, IL-6, TNF-α, and CRP compared to the CG ($p < 0.05$, Table 4).

3.5 Comparison of T Lymphocytes Involving the Two Groupings

Significant differences were observed in the levels of $CD3^+$, $CD4^+$, $CD8^+$ T lymphocyte subsets, and the $CD4^+/CD8^+$ ratio between the two groups across all time points. Additionally, significant interactions between group and time were identified, indicating that the temporal changes in these immune parameters differed between the study groups ($p < 0.05$).

On the first and third days after the operation, compared to the baseline (the day after the operation), the lev-

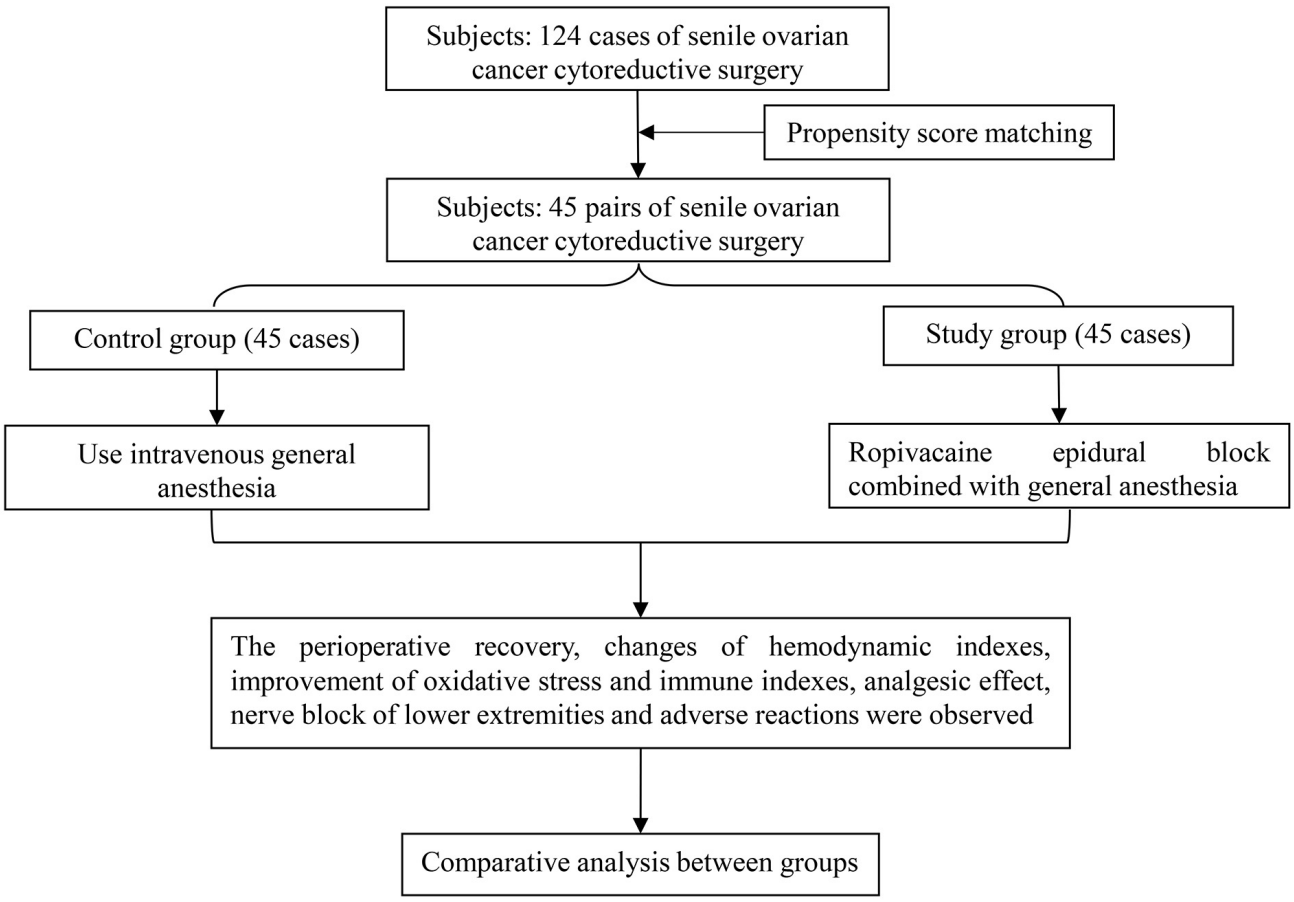

Fig. 1. Research flow chart.

els of $CD3^+$, $CD4^+$, and the $CD4^+/CD8^+$ ratio decreased, while the level of $CD8^+$ increased. However, by the third day, $CD3^+$, $CD4^+$, and the $CD4^+/CD8^+$ ratio showed an increase, and the $CD8^+$ level decreased. Table 5 illustrates that on the first and third postoperative days, the levels of $CD3^+$, $CD4^+$, and $CD4^+/CD8^+$ in the SG were significantly greater than those of the CG, whereas the level of $CD8^+$ was considerably reduced ($p < 0.05$).

3.6 Comparison of Analgesic Effect and Nerve Block of Lower Extremities Involving the Two Groupings

Analysis of variance of repeated measurement: there were considerable differences in time, inter-group and interaction involving the two groupings in VAS score and Bromage score ($p < 0.05$). Compared to the scores recorded 2 hours after surgery, both groups experienced an increase in VAS scores at 8 hours and a decrease at 24 hours ($p < 0.05$). The Bromage score decreased at 8 hours compared to 2 hours post-surgery in both groups ($p < 0.05$). Additionally, there was a decrease in VAS and Bromage scores at 24 hours compared to 8 hours post-surgery in both groupings ($p < 0.05$). The VAS and Bromage scores of the SG were considerably lower at both 8- and 24-hours post-surgery ($p < 0.05$), as depicted in Table 6 and Fig. 2.

3.7 Comparison of Adverse Reactions Involving the Two Groupings

Table 7 illustrates that the overall incidence of adverse events in the SG was considerably lower ($p < 0.05$).

4. Discussion

CS stands as an effective treatment option for OC [14, 15]. However, given the complications often observed in elderly patients, along with a noticeable decline in physical function and reduced ability to cope with the stress induced by surgery, selecting the most suitable anesthetic regimen is paramount for facilitating patient recovery [16,17].

At present, single GA is commonly used in laparoscopic surgery, but GA cannot block the nociceptive stimulation caused by the operation to stimulate the nerve center through the cerebral cortex, which makes the basic circulatory function fluctuate [18]. In this result, the respiratory recovery time, awakening time and extubating time in the SG were shorter, and the times of remedial analgesia in the SG were less. It is suggested that REB combined with GA can shorten respiratory recovery time, awakening time, extubating time and reduce the times of rescue analgesia. Ropivacaine, a long-acting amide local anesthetic, offers prolonged efficacy with minimal impact on vital

Table 4. Comparison of oxidative stress indicators involving the two groups ($\bar{x} \pm s$).

Groups	Cor (ng/mL)			TNF-α (pg/mL)		
	The day of the operation	After operation 1 d	After operation 3 d	The day of the operation	After operation 1 d	After operation 3 d
Study group (n = 45)	78.81 ± 7.38	121.91 ± 12.39*	92.18 ± 9.46*#	3.28 ± 0.31	4.79 ± 0.45*	3.92 ± 0.42*#
Control group (n = 45)	78.18 ± 7.42	149.82 ± 15.81*	113.17 ± 11.84*#	3.42 ± 0.38	5.11 ± 0.54*	4.61 ± 0.37*#
t	0.404	10.162	9.291	1.915	3.054	8.269
p	0.687	<0.001	<0.001	0.059	0.003	<0.001
F_{time}/p		6.281/<0.001			66.070/<0.001	
$F_{Intergroup}/p$		37.091/<0.001			5.650/<0.001	
$F_{Interaction}/p$		49.224/<0.001			2.016/<0.001	
Groups	IL-6 (ng/mL)			CRP (μg/mL)		
	The day of the operation	After operation 1 d	After operation 3 d	The day of the operation	After operation 1 d	After operation 3 d
Study group (n = 45)	31.52 ± 3.48	42.81 ± 4.13*	33.32 ± 3.67*#	7.38 ± 1.82	15.92 ± 2.38*	9.41 ± 2.02*#
Control group (n = 45)	30.94 ± 3.31	47.54 ± 4.87*	38.18 ± 3.79*#	7.41 ± 1.85	19.45 ± 3.95*	12.51 ± 2.84*#
t	0.810	4.969	6.189	0.077	5.280	5.967
p	0.420	<0.001	<0.001	0.938	<0.001	<0.001
F_{time}/p		64.221/<0.001			68.471/<0.001	
$F_{Intergroup}/p$		4.291/<0.001			4.635/<0.001	
$F_{Interaction}/p$		3.056/<0.001			2.284/<0.001	

Note: $^{*}p < 0.05$ in contrast to the day of operation, and $^{\#}p < 0.05$ in contrast to the day after operation. F_{time}/p represents the F value and corresponding p-value for the effect of time. $F_{Intergroup}/p$ refers to the F-test statistic and corresponding p-value for the effect of intra-group comparison across all time points. $F_{Interaction}/p$ represents the interaction between group (study group *vs.* control group) and time (repeated measures at different time points). Cor, cortisol; TNF-α, tumor necrosis factor-alpha; IL-6, interleukin-6; CRP, C-reactive protein.

Table 5. Comparison of T lymphocytes involving the two groups ($\bar{x} \pm s$).

Groups	$CD3^+$ (%)			$CD4^+$ (%)		
	The day of the operation	After operation 1 d	After operation 3 d	The day of the operation	After operation 1 d	After operation 3 d
Study group ($n = 45$)	66.18 ± 6.30	52.39 ± 5.28*	57.21 ± 5.72*#	35.19 ± 4.21	29.38 ± 3.47*	31.21 ± 3.63*
Control group ($n = 45$)	66.31 ± 6.35	49.13 ± 5.02*	53.27 ± 5.69*#	35.14 ± 4.19	24.18 ± 3.12*	25.25 ± 3.37*
t	0.097	3.002	3.276	0.056	7.475	8.072
p	0.923	0.003	0.002	0.955	<0.001	<0.001
F_{time}/p		55.110/<0.001			41.972/<0.001	
$F_{Intergroup}/p$		1.808/0.001			10.945/<0.001	
$F_{Interaction}/p$		1.031/0.040			5.401/<0.001	
Groups	$CD8^+$ (%)			$CD4^+/CD8^+$		
	The day of the operation	After operation 1 d	After operation 3 d	The day of the operation	After operation 1 d	After operation 3 d
Study group ($n = 45$)	22.91 ± 3.02	26.82 ± 3.12*	23.17 ± 3.25*#	1.52 ± 0.38	1.09 ± 0.27*	1.35 ± 0.29*#
Control group ($n = 45$)	22.84 ± 3.11	29.31 ± 3.82*	27.14 ± 3.65*#	1.53 ± 0.40	0.82 ± 0.21*	0.93 ± 0.25*#
T	0.108	3.387	5.449	0.120	5.295	7.358
p	0.914	0.001	<0.001	0.905	<0.001	<0.001
F_{time}/p		26.142/<0.001			33.221/<0.001	
$F_{Intergroup}/p$		6.571/<0.001			7.568/<0.001	
$F_{Interaction}/p$		4.034/<0.001			4.678/<0.001	

Note: $^*p < 0.05$ in contrast to the day of operation, and $^\#p < 0.05$ in contrast to the day after operation. F_{time}/p represents the F value and corresponding p-value for the effect of time. $F_{Intergroup}/p$ refers to the F-test statistic and corresponding p-value for the effect of intra-group comparison across all time points. $F_{Interaction}/p$ represents the interaction between group (study group *vs.* control group) and time (repeated measures at different time points).

Table 6. Comparison of analgesic effect and lower limb nerve block involving the two groups ($\bar{x} \pm s$, points).

Groups	VAS score			Bromage score		
	After operation 2 h	After operation 8 h	After operation 24 h	After operation 2 h	After operation 8 h	After operation 24 h
Study group ($n = 45$)	3.28 ± 0.85	3.76 ± 0.92*	2.74 ± 0.52*#	2.25 ± 0.43	1.28 ± 0.24*	0.42 ± 0.18*#
Control group ($n = 45$)	3.11 ± 0.81	4.81 ± 1.11*	3.48 ± 0.87*#	2.24 ± 0.47	1.82 ± 0.36*	0.84 ± 0.22*#
t	0.971	4.886	4.897	0.105	8.372	9.912
p	0.334	<0.001	<0.001	0.916	<0.001	<0.001
F_{time}/p		24.741/<0.001			74.624/<0.001	
$F_{Intergroup}/p$		5.793/<0.001			4.276/<0.001	
$F_{Interaction}/p$		6.301/<0.001			2.377/<0.001	

Note: $^*p < 0.05$ in contrast to 2 hours after operation, and $^\#p < 0.05$ in contrast to 8 hours after operation. F_{time}/p represents the F value and corresponding p-value for the effect of time. $F_{Intergroup}/p$ refers to the F-test statistic and corresponding p-value for the effect of the group factor (comparison between the study group and the control group) across all time points. $F_{Interaction}/p$ represents the interaction between group (study group *vs.* control group) and time (repeated measures at different time points). VAS, visual analogue scale.

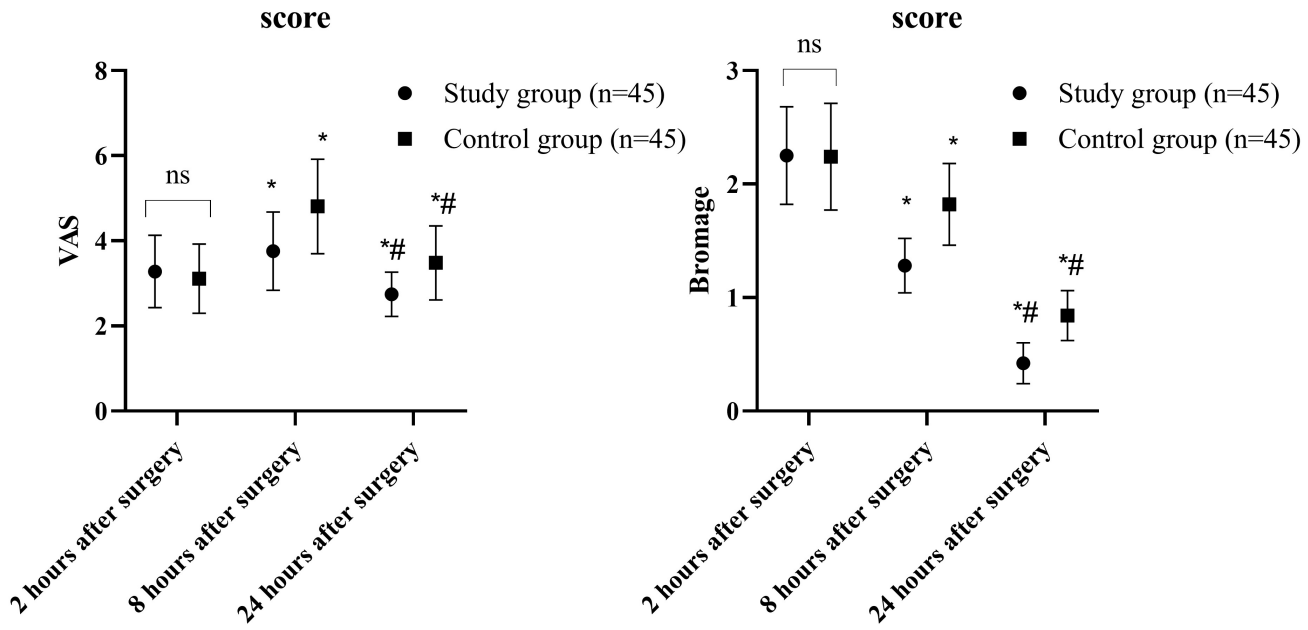

Fig. 2. Comparison of analgesic effect and nerve block degree of lower limbs involving the two groupings. Note: $^{*}p < 0.05$ in contrast to 2 hours after operation, $^{\#}p < 0.05$ in contrast to 8 hours after operation, $^{ns}p > 0.05$.

organs and the central nervous system. This pharmacological profile facilitates respiratory recovery and reduces the time required for awakening and extubation. Numerous studies have demonstrated that epidural block anesthesia effectively attenuates the conduction of thoracic and abdominal sympathetic nerves in response to nociceptive stimuli, thereby preserving the functions of the cardiovascular, respiratory, and gastrointestinal systems. Consequently, the combination of REB with GA proves to be more efficacious in enhancing surgical outcomes and improving patient safety [19,20]. In the results of this study, MAP and HR fluctuated within the allowable range, only at T4, the fluctuation was obvious, and the rest time points were meaningless. At T4, 30 minutes post-anesthesia induction, tracheal intubation and surgical incision were completed. The continuous increase in intra-abdominal pressure and diaphragmatic elevation resulted in an increased cardiac load, affecting venous return, and heightening sympathetic excitability through reflex mechanisms. Consequently, MAP and HR exhibited fluctuations. However, the increase in MAP and the decrease in HR observed in the SG were less pronounced compared to those in the CG at T4. This outcome may be attributed to the effects of ropivacaine epidural anesthesia, which attenuates stimulation of the cardiac sympathetic nerves, reduces myocardial oxygen consumption, and maintains hemodynamic stability. Clinical studies with analogous designs demonstrate that ropivacaine combined with epidural block is more adept at sustaining hemodynamic stability [21,22].

Operations such as incision trauma, ovarian exploration and traction during OC cytoreductive surgery in the elderly stimulate the hyperfunction of the pituitary-adrenocortical axis and accelerate the excessive secretion of OS hormones in the body. lead to abnormal secretion of adrenocortical hormone after operation [23]. The swift elevation of Cor indicates stress [24]. Proinflammatory M1 macrophages secrete inflammatory cytokines including TNF-α, IL-6, which trigger an inflammatory cascade [25]. CRP is an acute-phase reactant, particularly under the influence of surgical trauma [26]. The findings indicated that on the first and third postoperative days, there was a decrease in the levels of 3d Cor, IL-6, TNF-α, and CRP in the SG, suggesting that ropivacaine combined with GA can alleviate the OS reaction after CS in elderly OC. Ropivacaine can act on sodium channels on neuron membrane and block nerve impulse conduction, and epidural block can effectively block spinal nerve and block the introduction of stimulating signals. Compound GA can inhibit the stimulation conduction of surgical operation, thus relieving OS [27,28]. The trauma, anesthetic drugs, anesthetic methods, and OS during CS for OC will have adverse effects on the immune function of patients [29].

T lymphocyte subsets play a crucial role in the body's anti-tumor immune defense system [30]. Specifically, $CD3^{+}$ cells serve as markers of overall immune competence, $CD4^{+}$ cells facilitate the immune response, and $CD8^{+}$ cells are involved in the release of immune effector factors [31]. The findings of this study revealed that the SG exhibited higher concentrations of $CD3^{+}$ and $CD4^{+}$ cells, as well as an increased $CD4^{+}/CD8^{+}$ ratio, while displaying lower levels of $CD8^{+}$ cells compared to the CG. These results suggest that the combination of REB with GA can mitigate immunosuppression in elderly patients undergoing OC surgery. It is hypothesized that epidural ropiva-

Table 7. Comparison of adverse reactions involving the two groups [*n* (%)].

Groups	Respiratory inhibition	Hypotension	Nausea and vomiting	Dizzy	Pruritus	Total incidence of adverse reactions
Study group ($n = 45$)	1 (2.22)	1 (2.22)	1 (2.22)	0 (0.00)	1 (2.22)	4 (8.89)
Control group ($n = 45$)	2 (4.44)	3 (6.67)	4 (8.89)	2 (4.44)	2 (4.44)	13 (28.89)
χ^2			/			5.874
p			/			0.015

caine reduces nociceptive stimulation induced by surgical trauma, thereby minimizing its impact on immune function. Additionally, the use of combined GA may decrease the necessity for intraoperative opioid administration, which is known to have adverse effects on cellular immune responses. Consequently, the integrated use of REB and GA not only preserves immune integrity but also enhances the overall immunological profile of patients during the perioperative period.

Studies have shown that REB has been widely used for labor analgesia, and the analgesic effect is strong [32,33]. Therefore, it was also found that the VAS score and Bromage score in the SG were lower at 8 hours and 24 hours after operation, which indicated that ropivacaine combined with GA could achieve ideal analgesic effect and had little effect on lower limb block. The mechanism of action may be that REB anesthesia plays a preemptive analgesic role, obviously inhibit neuronal channels, and make the corresponding area controlled by ropivacaine temporarily achieve paralysis effect, and at the same time take effect quickly and maintain a long time, so it can better relieve pain [34]. The combination of ropivacaine with GA enables rapid and selective inhibition of nociceptive nerve fibers, effectively distinguishing motor block from sensory block. This selective blockade alleviates compression on the inferior vena cava, contributing to enhanced hemodynamic stability. Consequently, the Bromage score, which assesses the degree of motor block, was significantly lower in the postoperative SG compared to the CG. Additionally, the overall incidence of adverse reactions was reduced in the SG. These outcomes may be attributed to the complementary mechanisms of ropivacaine and GA, which act synergistically to enhance anesthetic efficacy. By combining these agents, it is possible to reduce the total dosage of GA drugs required, thereby mitigating the adverse effects typically associated with higher doses of anesthetics. This synergistic interaction not only improves patient safety but also facilitates a smoother and quicker postoperative recovery. A potential limitation of this study is the heterogeneity in the extent of surgeries performed. While all patients underwent cytoreductive surgery, the extent of the procedure varied significantly, with some patients requiring extensive surgery. This variation could influence hemodynamic stability and immune response outcomes. Future studies should aim to stratify patients based on the extent of surgery to minimize this variability.

However, this study has certain limitations. Firstly, the participants were recruited from a single center, potentially introducing bias into the research data. Secondly, the assessment of pain sensation and lower limb nerve block relied on subjective self-reports from patients postoperatively, which may impact accuracy. Hence, addressing these limitations in future research endeavors is warranted.

5. Conclusion

REB combined with GA demonstrates several benefits, including shortened respiratory recovery time, reduced need for remedial analgesia, maintenance of hemodynamic stability, and mitigation of OS and immune function suppression. Moreover, postoperative analgesia is improved, and lower limb nerve block is mild with fewer side effects, contributing to enhanced safety.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

XX and JY designed the research study. JY and HL performed the research. XX, YY and LG provided help and advice on the experiments. JY, HL and LG analyzed the data. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

All subjects gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the First People's Hospital of Lanzhou City (approval number: LZ20220511693).

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Conflict of Interest

The authors declare no conflict of interest.

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