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Original Article

Respiratory training reduces postoperative pulmonary complications in elderly gynecological patients undergoing general anesthesia

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Abstract: Objective: To evaluate the effects of respiratory training in reducing postoperative pulmonary complications (PPCs) in elderly gynecological patients undergoing general anesthesia. Methods: A total of 240 elderly gynecological patients who underwent surgery under general anesthesia were included. Among them, 120 patients received standard postoperative care (control group), while the other 120 received additional respiratory training (research group). The incidence of PPCs, length of hospital stay, treatment costs, pulmonary function parameters, arterial blood gas indices, mean arterial pressure (MAP), and respiratory rate (RR) were compared between the two groups. Risk factors associated with PPCs were also identified through univariate and binary logistic regression analyses. Results: The research group had a significantly lower overall incidence of PPCs, shorter hospital stays, and reduced treatment costs compared to the control group (all $P < 0.05$). Postoperative pulmonary function was better preserved, and arterial blood gas parameters improved more markedly in the research group (both $P < 0.05$). Although MAP showed no significant change, RR was significantly lower (both $P < 0.05$). Regression analyses identified body mass index, and treatment modality as independent risk factors for PPCs. Conclusions: Respiratory training significantly reduces the risk of postoperative pulmonary complications in elderly gynecological patients undergoing general anesthesia and contributes to better recovery outcomes.

Keywords: Elderly gynecological patients, general anesthesia, respiratory training, postoperative pulmonary complications

Introduction

Postoperative pulmonary complications (PPCs) are clinically significant disturbances in pulmonary function that occur after surgery, encompassing conditions such as respiratory insufficiency, atelectasis, pleural effusion, pulmonary infection, pneumothorax, bronchospasm, aspiration pneumonia, acute respiratory failure, and acute respiratory distress syndrome [1, 2]. These complications profoundly impact postoperative recovery and overall outcomes in surgical patients.

In contemporary gynecological surgery, laparoscopic procedures are increasingly common, offering benefits such as reduced tissue trauma, diminished postoperative pain, and shorter hospital stays [3]. However, the CO_2 pneumoperitoneum required for laparoscopy, combined with the Trendelenburg position, leads to cephalad displacement of abdominal organs, increased intrathoracic pressure, diaphragmatic elevation, restricted alveolar expansion, and elevated airway pressure. These physiological changes predispose patients to atelectasis, ventilator-associated lung injury, and a heightened risk of aspiration [4, 5].

A notable feature of gynecological patients is their older age. At our institution, patients over 50 years accounted for 26% of all gynecological cases undergoing general anesthesia in the past year, with many presenting with preexisting cardiopulmonary dysfunction or chronic pulmonary disease [6, 7]. Even in the absence of comorbidities, middle-aged and elderly individuals are more prone to expiratory dyspnea due to age-related anatomical and physiological changes. These include early airway closure, reduced lung compliance, and an increased susceptibility to respiratory infections [8, 9]. Additionally, age-related declines in metabolic and secretory function impair pulmonary recovery following mechanical ventilation, increasing vulnerability to PPCs and underscoring the need for enhanced postoperative airway management [10].

Despite the clinical relevance of PPCs-similar in prevalence and consequence to deep vein thrombosis (DVT) - they remain under-recognized in elderly gynecological patients. PPCs prolong hospitalization, elevate mortality risk, and escalate medical costs [11]. However, unlike DVT prevention, standardized PPC prevention protocols for this population are lacking, and preventive strategies have yet to be fully integrated into routine care [12]. Most studies have focused on surgical, anesthetic, or ventilatory techniques, often overlooking the critical role of postoperative respiratory management.

Current clinical practice tends to be reactive, initiating intervention only after respiratory symptoms arise, which may lead to delayed recovery and extended hospital stays [13-15]. Given the need for cost-effective, non-pharmacological, and easily implementable interventions, guided respiratory exercises supervised by healthcare professionals represent an ideal strategy [16]. This proactive approach not only fills the gap in postoperative respiratory care but also streamlines clinical workflows, improves patient outcomes, and enhances quality of life. Integrating such respiratory training into standard postoperative protocols may help establish a new model of patient-centered care, especially for high-risk elderly gynecological patients.

Materials and methods

Case selection

This retrospective study enrolled 240 elderly patients who underwent gynecological surgery under general anesthesia at Hangzhou Women's Hospital between May 2023 and December 2024. Patients were assigned to either a control group (n=120), which received standard postoperative care, or a research group (n=120), which received additional respiratory training.

The study protocol was approved by the Ethics Committee of Hangzhou Women's Hospital. All participants met predefined inclusion and exclusion criteria.

Inclusion criteria: (1) Age > 50 years. (2) American Society of Anesthesiologists (ASA) physical status classification I-III [17], indicating no severe cardiac disease, preserved renal function, and no significant electrolyte imbalances or electrocardiographic abnormalities prior to surgery.

Exclusion criteria: (1) Presence of cognitive impairment, psychiatric illness, stroke, unstable angina or arrhythmias, unstable fractures, deep vein thrombosis or pulmonary embolism, acute asthma, active infectious respiratory disease, progressive neuromuscular disorders, severe anemia, cachexia, significant frailty (e.g., from chemotherapy), or severe visual or hearing impairment. (2) Surgeries involving non-gynecological systems. (3) Hospital stays of less than 24 hours.

Intervention methods

All patients underwent general anesthesia. Induction was performed with intravenous propofol, cisatracurium besylate, and remifentanil. Anesthesia was maintained with continuous infusion of propofol and remifentanil, targeting a Bispectral Index range of 40-50 while ensuring hemodynamic stability.

Mechanical ventilation was delivered in volume-controlled mode, with a tidal volume of 10 mL/kg based on ideal body weight, a respiratory rate (RR) of 10 breaths/min, and an inspired oxygen concentration of 40%. RR was adjusted to maintain end-tidal CO_2 ($PETCO_2$) between 35-45 mmHg. A stable CO_2 pneumoperitoneum was maintained at a pressure of 12 mmHg with a high flow rate of 40 L/min, and the Trendelenburg position was adjusted as needed. Intraoperative hypothermia prevention strategies were implemented.

Postoperative analgesia was managed using patient-controlled intravenous analgesia, consisting of butorphanol 12 mg, tropisetron 5 mg, and normal saline, diluted to 150 mL. The background infusion rate was set at 2-3 mL/h, with a bolus dose of 2 mL and a 15-minute lockout interval. Nonsteroidal anti-inflammatory drugs (NSAIDs) were used as adjuncts when necessary.

Standard treatment (control group)

Standard care included: (1) Routine electrocardiogram monitoring and continuous assessment of vital signs. Wound, drain, urinary catheter, and skin condition were closely observed. (2) Postoperative oxygen therapy for 6 hours, multimodal analgesia, and blood glucose control maintained at or below 10.0-11.1 mmol/L. (3) Bed-based ankle exercises, guided repositioning, and fall-prevention protocols for early mobilization (e.g., sitting upright for 1 minute, leg dangling for 1 minute, standing for 1 minute). (4) Initiation of oral fluid intake at 6 hours postoperatively in the absence of contraindications. (5) Urinary catheter removal 6-12 hours after surgery (if feasible), followed by assisted ambulation using handrails. The goal was to walk 1,000 meters on postoperative day one. (6) Administration of laxatives as needed to promote gastrointestinal motility. (7) For patients with chronic respiratory conditions, a combination of bronchodilators and corticosteroids (terbutaline 5 mg + ipratropium bromide 0.5 mg + budesonide 1 mg) was delivered via nebulization three times daily from 2-3 days before to 2-3 days after surgery. Ambroxol oral solution (10 mL) was also administered three times daily.

Respiratory training (research group)

In addition to standard treatment, the research group received guided respiratory training consisting of: (1) Patient Education: Patients received education about PPCs and watched instructional videos on respiratory training via bedside smart terminals. (2) Reinforcement and Personalized Guidance: Within 6 hours postoperatively, physicians reviewed the training content with patients and provided in-person coaching. (3) Structured Respiratory Exercise Regimen: ① Active Cycle of Breathing Techniques (ACBT): Breathing Control: Diaphragmatic breathing with abdominal palpation, slow inhalation, and pursed-lip exhalation, repeated 3-5 times. Thoracic Expansion: Chest-focused breathing with lower rib palpation, 3-second breath hold, and pursed-lip exhalation, repeated 3-5 times. Forced Expiratory Technique: Deep inhalation to mid-lung volume, followed by open-mouth, open-glottis huffing. ② Autogenic Drainage (AD): Mobilization Phase: Low-lung-volume breathing with 2-3 second breath holds at inspiration and full expiration to expiratory reserve volume, repeated 3-4 times or until mucus vibrations were felt. Collection Phase: Mid-lung-volume breathing with 3-second breath holds and forceful expiration, repeated 3-4 times or until secretion movement was perceived. Evacuation Phase: High-lung-volume breathing to mobilize secretions into the trachea, followed by strong huffing to clear mucus.

Data collection

The occurrence of PPCs, including pulmonary infection, pleural effusion, and atelectasis, was recorded and analyzed.

Duration of hospitalization and associated medical expenses were documented for all patients.

Pulmonary function was assessed preoperatively and on postoperative day 3 using a bedside portable spirometer. Key parameters included maximum voluntary ventilation (MVV), forced expiratory volume in 1 second (FEV_1), residual volume (RV), and total lung capacity (TLC). Ratios of MVV/FEV_1 and RV/TLC were subsequently calculated.

Arterial blood samples were obtained via puncture and analyzed to determine arterial oxygen partial pressure (PaO_2) and carbon dioxide partial pressure ($PaCO_2$). The inspired oxygen concentration (FiO_2) was recorded from the ventilator or oxygen delivery device, and the oxygenation index (PaO_2/FiO_2) was calculated. Peripheral oxygen saturation (SaO_2) was measured non-invasively via pulse oximetry.

Mean arterial pressure (MAP) and respiratory rate (RR) were continuously monitored using a multifunctional digital monitoring system.

Among these, incidence of PPCs, pulmonary function indices, and blood gas parameters were defined as primary outcome measures,

Table 1. Comparison of baseline characteristics

General data	Control group (n=120)	Research group (n=120)	χ^2/t	P
Age (years)	70.15±5.42	70.99±5.81	1.158	0.248
BMI (kg/m^2)	23.33±2.11	23.36±2.37	0.104	0.918
ASA classification			0.937	0.333
Grade I	78 (65.00)	85 (70.83)		
Grade II	42 (35.00)	35 (29.17)		
History of pregnancy			0.703	0.402
0-1	40 (33.33)	34 (28.33)		
≥2	80 (66.67)	86 (71.67)		
Underlying chronic diseases				
Hypertension	26 (21.67)	32 (26.67)	0.819	0.366
Diabetes	20 (16.67)	27 (22.50)	1.296	0.255

Notes: BMI, body mass index; ASA, American Society of Anesthesiologists. History of pregnancy: number of births occurring after 28 weeks.

Table 2. Comparison of incidence of PPCs

PPCs	Control group (n=120)	Research group (n=120)	χ^2	P
Pulmonary infection	38 (31.67)	16 (13.33)	11.565	< 0.001
Pleural effusion	3 (2.50)	6 (5.00)	1.039	0.308
Atelectasis	12 (10.00)	0 (0.00)	12.632	< 0.001
Total	53 (44.17)	22 (18.33)	18.638	< 0.001

Notes: PPCs, postoperative pulmonary complications.

while hospital stay, treatment costs, MAP, and RR were considered secondary outcomes.

Statistical analysis

Statistical analyses were performed using SPSS version 24.0. Continuous variables were expressed as mean ± standard error of the mean (SEM). Intergroup comparisons of continuous data were conducted using independent samples t-tests, while pre- and post-treatment comparisons within groups were assessed using paired t-tests. Categorical variables were presented as frequencies (percentages) and analyzed using the chi-square (χ^2) test. A *P* value < 0.05 was considered statistically significant.

Results

Comparison of general characteristics

No significant differences were found between the control and research groups regarding baseline characteristics, including age, BMI, ASA classification, history of pregnancy, and preexisting chronic diseases (hypertension, diabetes) (all P > 0.05). See **Table 1**.

Comparison of PPC incidence

The control group experienced 38 cases of pulmonary infection, 3 cases of pleural effusion, and 12 cases of atelectasis. In contrast, the research group reported 16 cases of pulmonary infection, 6 cases of pleural effusion, and no cases of atelectasis. The research group had significantly lower rates of pulmonary infection, atelectasis, and overall PPCs compared to the control group (all P < 0.001). See **Table 2**.

Comparison of hospital stay and treatment costs

The research group had a significantly shorter hospital stay and lower treatment costs compared to the control group (both P < 0.05). See **Table 3**.

Comparison of pulmonary function indices

Before treatment, no significant differences in MVV/FEV_1 and RV/TLC were observed between the two groups (both P > 0.05). Postoperatively, both groups showed a significant reduction in MVV/FEV_1 (both P < 0.05); however, the research group maintained higher MVV/FEV_1 values than the control group (P < 0.05). RV/

Table 3. Comparison of Hospital stay and treatment costs

Indicators	Control group (n=120)	Research group (n=120)	t	P
Hospital stay (days)	27.69±5.20	26.13±4.51	2.483	0.014
Treatment cost (RMB)	8539.63±1782.32	8072.39±1686.94	2.086	0.038

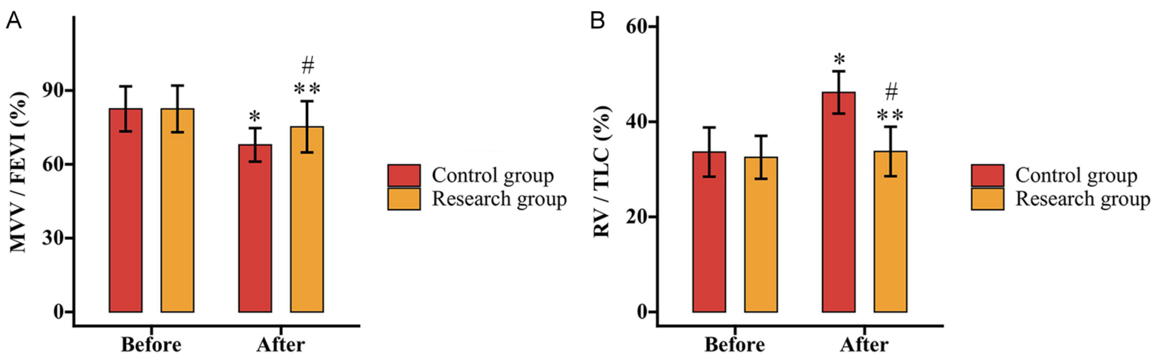

Figure 1. Comparison of Pulmonary function indices. A. Pre- and post-treatment MVV/FEVI in two groups. B. Pre- and post-treatment RV/TLC in two groups. Note: $^{*}P < 0.05$ and $^{**}P < 0.01$ *vs.* the pre-treatment levels; $^{\#}P < 0.05$ *vs.* the control group. MVV/FEV_1, maximum voluntary ventilation/forced expiratory volume in one second; RV/TLC, residual volume/total lung capacity.

TLC increased significantly in the control group after treatment (P < 0.05), while it remained unchanged in the research group (P > 0.05) and was significantly lower than that in the control group (P < 0.05). See **Figure 1**.

Comparison of blood gas parameters

Pre-treatment PaO_2, $PaCO_2$, PaO_2/FiO_2, and SaO_2 levels did not differ significantly between groups (all P > 0.05). Following treatment, all parameters improved significantly in both groups, with the research group showing significantly greater improvements than the control group (all P < 0.05). See **Figure 2**.

Comparison of MAP and RR

At baseline, MAP and RR did not differ significantly between the two groups (both P > 0.05). Postoperatively, MAP increased significantly in the control group and was significantly higher than that in the research group (P < 0.05). RR decreased significantly in both groups, with a more pronounced reduction observed in the research group (P < 0.05). See **Figure 3**.

Analysis of risk factors for PPCs in elderly gynecological patients undergoing general anesthesia

Univariate analysis showed no significant association of PPC incidence rates with age, ASA classification, history of pregnancy, or underlying chronic diseases in elderly gynecological patients undergoing general anesthesia (all P > 0.05). In contrast, BMI and treatment modality were significantly associated with PPC occurrence (all P < 0.05; **Table 4**).

These significant variables were entered into a binary logistic regression model with the occurrence of PPCs as the dependent variable. The results indicated that BMI and treatment modality were independent risk factors for PPCs in this patient population (all P < 0.05; **Tables 4**, **5**).

Discussion

This study found that the research group had significantly lower rates of pulmonary infections, atelectasis, and overall PPCs, indicating that respiratory training is effective in preventing PPCs among elderly gynecological patients under general anesthesia.

The respiratory training protocol integrated patient education, face-to-face instruction, and supervised exercises, with an emphasis on helping patients master and practice both ACBT and AD. ACBT is a patient-directed, adaptable method designed to improve airway clearance and respiratory function. It comprises three core components: breathing control, thoracic expansion exercises, and forced expirato-

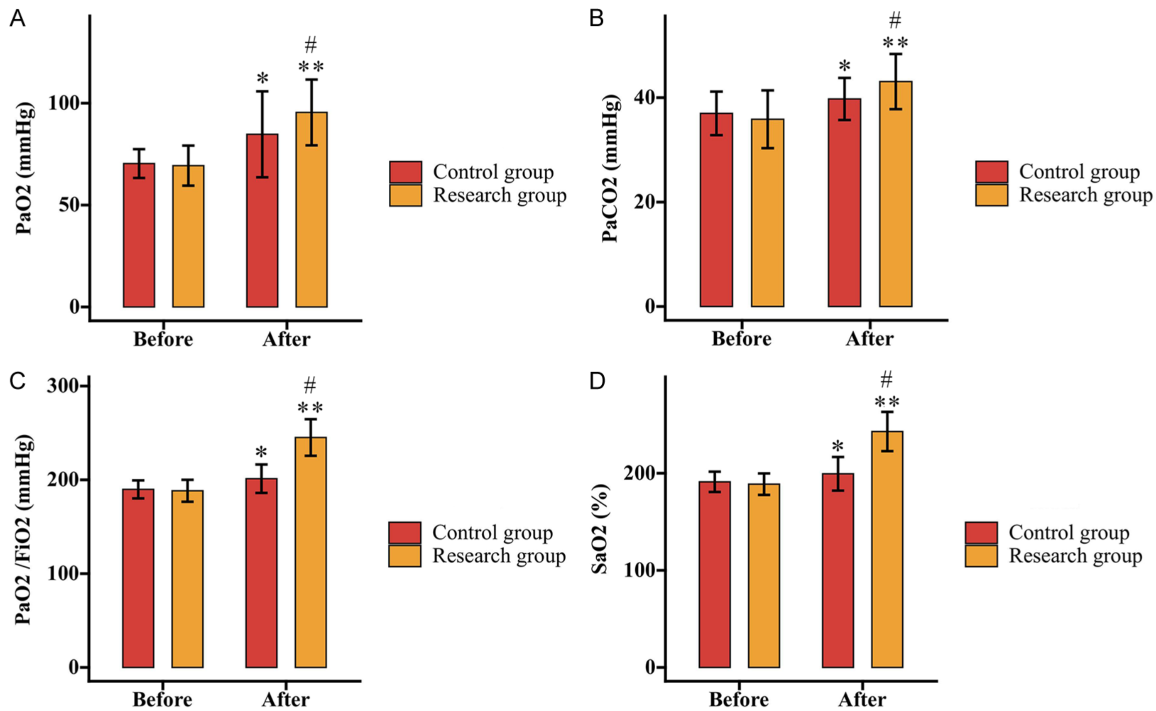

Figure 2. Comparison of blood gas analysis indexes. A. Pre- and post-treatment PaO_2 in two groups. B. Pre- and post-treatment $PaCO_2$ in two groups. C. Pre- and post-treatment PaO_2/FiO_2 in two groups. D. Pre- and post-treatment SaO_2 in two groups. Note: $^{*}P < 0.05$ and $^{**}P < 0.01$ *vs.* the pre-treatment levels; $^{\#}P < 0.05$ *vs.* the control group. PaO_2, arterial oxygen partial pressure; $PaCO_2$, arterial carbon dioxide partial pressure; PaO_2/FiO_2, oxygenation index; SaO_2, oxygen saturation.

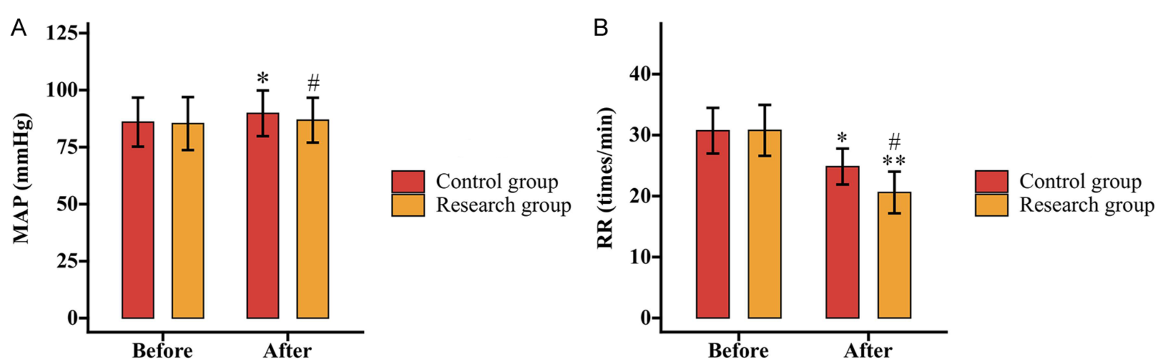

Figure 3. Comparison of MAP and RR. A. Pre- and post-treatment MAP in two groups. B. Pre- and post-treatment RR in two groups. Note: $^{*}P < 0.05$ and $^{**}P < 0.01$ *vs.* the pre-treatment level; $^{\#}P < 0.05$ *vs.* the control group. MAP, mean arterial pressure; RR, respiratory rate.

ry techniques, which collectively facilitate secretion clearance and enhance pulmonary capacity [18].

AD is another airway clearance technique involving controlled breathing at varying lung volumes. It utilizes shear forces generated by airflow to mobilize and expel pulmonary secretions [19]. When incorporated into postoperative care, these methods offer a comprehensive respiratory management strategy.

While respiratory training is commonly used in respiratory medicine and intensive care, it is not yet widely adopted in gynecology and obstetrics. To address this gap, our study capitalized on the respiratory expertise of ICU professionals. For high-risk patients admitted to

Table 4. Univariate analysis of factors influencing PPCs in elderly gynecological patients undergoing general anesthesia

Variable	PPCs (n=75)	Non-PPCs (n=165)	χ^2	P
Age (years)			3.117	0.078
< 70	25 (33.33)	75 (45.45)		
≥ 70	50 (66.67)	90 (54.55)		
BMI (kg/m^2)			8.758	0.003
< 24	31 (41.33)	102 (61.82)		
≥ 24	44 (58.67)	63 (38.18)		
ASA classification			0.100	0.751
Grade I	52 (69.33)	111 (67.27)		
Grade II	23 (30.67)	54 (32.73)		
History of pregnancy			3.139	0.076
0-1	29 (38.67)	45 (27.27)		
≥2	46 (61.33)	120 (72.73)		
Underlying chronic diseases				
Hypertension	22 (29.33)	36 (21.82)	1.589	0.208
Diabetes	18 (24.00)	29 (17.58)	1.351	0.245
Treatment modality			18.638	< 0.001
Conventional therapy	53 (70.67)	67 (40.61)		
Conventional therapy + respiratory training	22 (29.33)	98 (59.39)		

Notes: PPCs, postoperative pulmonary complications; BMI, body mass index; ASA, American Society of Anesthesiologists.

Table 5. Multivariate analysis of factors influencing postoperative pulmonary complications in elderly gynecological patients undergoing general anesthesia

Variable	β	SE	Wald	P	OR	95% CI
Body mass index (kg/m^2)	0.871	0.297	8.603	0.003	2.390	1.335-4.278
Treatment modality	-1.287	0.306	17.739	< 0.001	0.276	0.152-0.503

the ICU postoperatively, respiratory training was initiated early under the supervision of ICU staff. For patients transferred directly to the gynecology ward, respiratory instruction was provided by ward-based gynecological staff. At our institution, elderly and high-risk patients typically undergo multidisciplinary preoperative assessment. ICU physicians deliver preoperative bedside respiratory training and remain available for consultation or ICU transfer if PPCs occur, ensuring continuity of care and comprehensive support.

Through this coordinated approach, respiratory training effectively prevented PPCs in this vulnerable population. In addition, respiratory training significantly reduced both hospital stay and treatment costs. This may be attributed to the reduced incidence of PPCs, which lowers the need for additional diagnostic and therapeutic interventions.

Our findings also suggest that respiratory training attenuates the adverse effects of surgery and intubation on postoperative pulmonary function. This aligns with the results reported by Chen et al. [20], who showed that ACBT combined with external diaphragmatic pacing improved lung function and exercise tolerance in perioperative lung cancer patients.

Arterial blood gas analysis in our study revealed significantly higher post-treatment PaO_2, $PaCO_2$, PaO_2/FiO_2, and SaO_2 levels in the research group compared to the control group. These improvements suggest that respiratory training promotes the release of endogenous pulmonary surfactant, enhances ventilation-perfusion matching, and improves oxygenation in elderly gynecological patients receiving general anesthesia. These physiological benefits likely contribute to the observed reduction in PPCs.

Similarly, Brocki et al. [21] demonstrated that inspiratory muscle training combined with breathing exercises and early mobilization improved oxygenation in elderly high-risk patients undergoing pneumonectomy, compared to standard physiotherapy alone. This supports the findings of our study.

Moreover, our findings indicated that while respiratory training did not significantly affect MAP, it was associated with a significant reduction in RR. Physiological decline due to aging, compounded by the effects of anesthesia, can lead to fluctuations in MAP in elderly patients [22]. Additionally, age-related weakening of respiratory muscles and decreased thoracic excursion often result in elevated RR compared to younger individuals [23]. The implementation of respiratory training may help stabilize MAP and reduce RR by improving respiratory mechanics, enhancing oxygenation, and decreasing the physiological stress associated with surgery and anesthesia.

Furthermore, we analyzed risk factors for the development of PPCs in elderly gynecological patients undergoing general anesthesia. Univariate analysis revealed significant associations between PPCs and BMI and treatment modality. Binary logistic regression analysis confirmed high BMI and receiving conventional treatment alone as independent risk factors.

High BMI may predispose individuals to PPCs primarily due to increased abdominal adiposity, which elevates intra-abdominal pressure, displaces the diaphragm, restricts diaphragmatic motion, and consequently reduces lung volume and compliance. These alterations decrease pulmonary reserve and increase susceptibility to respiratory complications [24]. In contrast, respiratory training emerged as a protective factor, likely due to its ability to enhance lung function, reduce the incidence of pulmonary infections, and facilitate recovery.

This study has several limitations. First, the relatively short follow-up period limited our ability to assess the long-term impact of respiratory training. Future studies should include extended follow-up periods of 1-3 years to evaluate sustained effects on pulmonary function, hospital readmission rates, and quality of life. Second, we did not assess patient-centered outcomes such as quality of life or long-term complication rates. Incorporating these endpoints in future research could provide a more comprehensive understanding of the clinical benefits of respiratory training. Finally, the underlying physiological mechanisms remain incompletely understood. Further investigations into the effects of respiratory training on inflammatory markers, diaphragmatic function, and other potential protective mechanisms are warranted. Addressing these gaps will help strengthen the rationale for broader clinical adoption of respiratory training protocols.

In conclusion, the implementation of respiratory training in elderly gynecological patients undergoing general anesthesia demonstrated substantial clinical benefits. These include a significant reduction in PPC incidence, shorter hospital stays, lower treatment costs, mitigation of postoperative pulmonary impairment, improved oxygenation, stabilization of MAP, and reduced RR. Additionally, high BMI and reliance on standard care alone were identified as independent risk factors for PPCs. For patients exhibiting these risk factors, enhanced monitoring and targeted preventive measures are essential.

Our findings support incorporating respiratory training as a routine component of postoperative care for elderly gynecological patients. This approach improves pulmonary outcomes, shortens recovery time, and enhances overall perioperative care quality.

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Disclosure of conflict of interest

None.

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