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Efficacy of Single-port Thoracoscopic Resection of Benign Lung Tumors and Its Impacts on Respiratory Function and Inflammatory Factors: A Randomized Controlled Study

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ABSTRACT

Peripheral benign lung tumors are often asymptomatic and incidentally detected on chest radiographs. Surgical intervention is recommended when feasible. Single-port thoracoscopic resection has emerged as a promising technique for treating various chest diseases, including lung tumors. This study aimed to assess the clinical efficacy of single-port thoracoscopic resection for benign lung tumors and its impact on respiratory function and inflammatory factors.

A total of 128 eligible patients diagnosed with benign lung tumors were randomly assigned to either the observation group (undergoing single-port thoracoscopic resection) or the control group (undergoing conventional thoracic surgery). Surgical outcomes, complications, pulmonary and respiratory function, and inflammatory factors were compared between the two groups.

The observation group showed significantly lower intraoperative bleeding, shorter hospitalization time, and lower complication rates compared to the control group. Patients in the observation group exhibited higher vital capacity (VC), forced vital capacity (FVC), and total lung capacity (TLC) levels at 1/2 week and 1 month after surgery. Additionally, forced expiratory volume in one second (FEV1) and maximum ventilation volume per minute (MVV) levels were higher in the observation group post-surgery, with a lower Borg score. Levels of C-reactive protein (CRP), precalcitonin (PCT), and tumor necrosis factor (TNF-α) were lower in the observation group post-surgery.

Single-port thoracoscopic resection demonstrates favorable clinical efficacy for treating benign lung tumors, reducing bleeding, and shortening hospital stays. Furthermore, it improves lung and respiratory function while reducing inflammatory factors. This technique is safe, effective, and holds promise for wider application in managing benign lung tumors.

Keywords: Benign lung tumor; Clinical efficacy; Inflammatory factors; Respiratory function; Single-port thoracoscopic resection

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INTRODUCTION

As a relatively uncommon respiratory disease in clinical practice, benign lung tumors encompass a group of epithelial and mesenchymal tumors of various types, including pulmonary bullae tumors and pulmonary malformations.[1] These tumors are typically small in size (less than 3 cm) and often do not cause noticeable symptoms or discomfort in most patients. They are often detected incidentally during routine X-ray examinations. Depending on their location of origin (endobronchial or lung parenchyma), patients may experience symptoms related to endobronchial involvement, such as cough, sputum, hoarseness, obstructive pneumonia, hemoptysis, or they may be asymptomatic with a solitary pulmonary nodule.[2]

Surgical resection is commonly employed as the primary treatment modality for benign lung tumors in clinical practice. The treatment principle aims to preserve the patient's normal lung tissue to the greatest extent possible. It is also aims to reduce postoperative complications, and maintain normal respiratory function. However, conventional thoracotomy has traditionally been the main surgical approach to tumor removal, based on the lesion's location and type. Nevertheless, previous studies have indicated that invasive surgery can induce inflammatory stress, leading to immunosuppression and increasing complications risk. Moreover, it may predispose patients to tumor recurrence and metastasis, impacting their quality of life and overall safety. Conventional thoracotomy requires a large chest incision, resulting in increased traumatic injury and potential postoperative complications. Therefore, there is a need to explore effective treatment methods to enhance the benign lung tumor treatment outcome.

Thoracoscopic surgery, specifically Video-Assisted Thoracoscopic Surgery (VATS), has rapidly evolved as a minimally invasive technique in thoracic surgery and is widely utilized in the diagnosis and treatment of various thoracic surgical conditions.[3] Single-port thoracoscopic resection, a potentially advanced technique within VATS, allows for direct visualization of the target structure through a single port. It is associated with potentially lower intercostal pain and comparable surgical outcomes to those achieved by experienced operators.[4] The focus of this approach is to eliminate the need for secondary operating ports, performing all surgical procedures using a single primary operating port to minimize intraoperative injuries.[5,6.]

In recent years, single-port thoracoscopic resection of benign lung tumors has garnered significant attention among thoracic surgeons in Asia. This study aims to investigate the clinical efficacy of single-port thoracoscopic resection for benign lung tumors, as well as its impact on respiratory function and inflammatory factors.

MATERIALS AND METHODS

Study Objects

All patients with benign lung tumors diagnosed and proposed for surgical resection treatment were recruited in this study. A total of 128 of them who met the complete inclusion criteria were included as subjects in this study. Among the patients included, there was no gender restriction, the age limit was under 75 years and all were adults. All patients were divided into two groups, observation group and control group by random assignment. Patients in the control group were treated by conventional thoracic surgery and patients in the observation group were treated by single-port thoracoscopic resection, and 64 patients were included in each group. A consent letter was voluntarily signed by all patients and their families, and the experiment was approved by Renmin Hospital, Hubei University of Medicine Ethics Committee.

Inclusion and Exclusion Criteria

Inclusion Criteria:

1) diagnosed as a benign lung tumor by X-ray, eligible for surgery and intended to undergo surgery in our hospital; 2) tumor diameter below 5 cm; 3) no previous lung surgery; 4) no recent treatment with hormones or anticoagulant drugs.

Exclusion Criteria

1) the presence of serious organ pathology such as the heart and kidney; 2) the presence of contraindications to anesthesia or surgery-related treatment; 3) the presence of pleural adhesions or other malignant tumors, etc.; and 4) the presence of intraoperative intermediate thoracotomy due to uncontrollable bleeding or failure to complete the study for other reasons.

Control Group

In the control group, patients received conventional open thoracotomy as follows: Before the treatment, patients were thoroughly informed about the surgical plan, including its purpose, significance, and necessary precautions. Additionally, relevant preoperative examinations were conducted, and patients followed routine preoperative fasting. To meet surgical requirements, patients were assisted in adopting a contralateral or oblique lying position. Tracheal intubation was performed, and general anesthesia was administered to ensure patient comfort and safety throughout the procedure.

The patient's chest posterior lateral position was carefully determined. An incision approximately 20-25 cm long was made, allowing access to the underlying structures. The surgeon carefully incised the skin and subcutaneous tissues, ensuring precision and minimizing trauma. The latissimus dorsi and anterior serratus muscles were then freed, further exposing the operative field. To fully expose the thoracic cavity and lung lobes, the surgeon gently retracted the veins, ensuring a clear view of the surgical site. This step was crucial for accurate tumor localization and excision. With the assistance of an ultrasonic knife, the surgeon excised the tumor site based on the patient's condition. The ultrasonic knife allowed precise and controlled tissue dissection. After tumor removal, routine hemostatic sutures were applied to ensure proper hemostasis and prevent postoperative bleeding. To maintain cleanliness within the thoracic cavity, the surgeon repeatedly flushed the area with saline solution. This step ensured the removal of any debris or residual tumor cells, reducing infection risk and promoting optimal healing. Subsequently, a drainage tube was carefully placed to facilitate the postoperative drainage of any fluids or air. Finally, the surgical incision was closed layer by layer using sutures. This meticulous closure technique ensured proper wound healing and minimized complications risk.

Observation Group

In the observation group, single-port thoracoscopic resection was performed[7,8] with the following detailed steps: Firstly, routine preoperative preparations were completed, including patient identification, consent, and administration of preoperative medications. The surgical plan was thoroughly explained to the patients, ensuring their understanding and cooperation. Next, the patients were positioned on the healthy side or in an oblique position, allowing optimal access to the surgical site. One-lung ventilation was initiated under compound intravenous anesthesia to ensure a clear field of vision and patient comfort. The precise location for the incision was carefully determined between the seventh and eighth ribs, along the mid-axillary line. A small incision was made, and a protective sleeve was inserted to maintain the integrity of the incision and prevent tissue damage. To visualize the thoracic cavity, a 30° thoracoscope was gently inserted through the incision and carefully maneuvered to explore the patient's thoracic cavity. The thoracoscope provided a magnified view, enabling the surgeon to observe the target area with precision. During the procedure, various techniques such as "picking, pulling, disconnecting, and breaking" were employed to facilitate tumor removal. Specialized cutting and suturing devices were used to dissect and remove the tumor while minimizing trauma to the surrounding tissues.

Throughout the operation, careful attention was paid to any bleeding from the incision. The surgeon promptly identified and controlled bleeding using electrocautery or sutures. Once bleeding was under control, the incision stump was meticulously sutured to ensure proper closure. Finally, the surgical incision was closed using appropriate suturing techniques, ensuring optimal wound healing and cosmetic outcomes. Postoperatively, patients were provided with detailed instructions regarding postoperative care, including dietary guidelines, exercise recommendations, and self-care measures. Regular communication and follow-up were maintained to monitor the patient's recovery and address any concerns or complications.

Observation Indicators

Surgical Conditions and Complications

Surgery-related conditions (intraoperative bleeding, length of hospital stay) and postoperative complications (incisional infection, postoperative bleeding, poor lung recruitment) were recorded for all patients and compared between groups.

Lung Function Indexes

Measurements of lung function-related indexes, including vital capacity (VC), force vital capacity (FVC), and total lung capacity (TLC), were recorded for all patients at different times (preoperative, 1 week postoperative, 2 weeks postoperative, and 1 month postoperative).

Respiratory Function

The preoperative and postoperative forced expiratory volume in one second (FEV1) and maximum ventilation volume per minute (MVV) of all patients were measured and recorded; the preoperative and postoperative respiratory function of patients was evaluated by the Borg

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Dyspnea Scale, and the score of the scale was inversely proportional to the respiratory function, i.e. the higher the score, the worse the respiratory function and the more difficult the breathing.

Inflammatory Factors

3 mL of elbow venous blood was drawn from all patients for centrifugation at 3000 r/min for 15 min in the early mornings of the preoperative and postoperative days, respectively, and C-reactive protein (CRP), precalcitonin (PCT), and tumor necrosis factor (TNF-α) were measured by enzyme-linked immunosorbent assay (R&D Systems, Inc., Abingdon, UK).

Statistical Analysis

GraphPad Prism Version 8.4.2 (Dotmatics, Boston, Massachusetts, United States) was used for image processing; SPSS software (version 26.0; SPSS Inc., Chicago, IL, USA) was used for data collation and statistical analysis; measurement data were expressed as mean and standard deviation.

Kolmogorov-Smirnov test was employed to assess the data distribution. Normally distributed variables are presented as mean (standard deviation) and compared between groups using two-tailed, unpaired t-tests. Non-normally distributed variables are presented as median (interquartile range) and compared between groups using the Mann-Whitney U test. The count data were presented as percentages (%), and statistical analysis involved the use of the chi-square test (χ^2) to assess whether there were any significant differences between groups. A significance level of $p<0.05$ was considered statistically significant, indicating that there were notable differences in the comparison.

RESULTS

General Information

The two groups were well-balanced in terms of baseline characteristics ($p>0.05$). Details are shown in Table 1.

Surgical Conditions and Complications

The intraoperative bleeding, hospital stay and complication rate of patients in the observation group were significantly lower than those in the control group, $p<0.05$. Details are shown in Table 2.

Lung Function

The difference in lung function between the two groups before surgery was not statistically significant ($P>0.05$), and the VC, FVC, and TLC levels of patients in the observation group were higher than those in the control group at 1/2 week and 1 month postoperatively, $P<0.05$. Details are shown in Figure 1.

Table 1. General Information of Patients in Control and Observation Groups ($\bar{x}\pm s$)

		Control Group	Observation Group	*t*	*p*
Number of Cases		64	64	-	-
Gender	Male	33	30	-	-
	Female	31	34	-	-
Age (year)	-	40-70	40-70	-	-
	Average	52.41±7.23	52.20±7.45	0.162	0.872
Body Mass Index（kg/m^2）		23.84±0.88	23.61±0.96	1.413	0.160
Pathology Type	Pulmonary alveolar tumor	35	32	-	-
	Pulmonary hamartoma	29	32	-	-
Education	High school	19	15	-	-
	Junior college	36	35	-	-
	Undergraduate	9	14	-	-
Payment Method	Self-pay	11	10	-	-
	Medical insurance	53	54	-	-
Household Registration	Our city	52	50	-	-
	Outside	12	14	-	-

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Table 2. Surgical Conditions and Complications in control and observation Groups ($\bar{x}$±s, %)

		Control Group	Observation Group	t/x^2	*p*
Number of Cases		64	64	-	-
Surgical Conditions	Intraoperative bleeding (mL)	225.12±50.54	112.26±34.84	14.708	<0.001
	Hospital stay (d)	16.12±4.25	9.21±2.08	11.683	<0.001
Complications	Incision infection	4	0	-	-
	Postoperative bleeding	3	0	-	-
	Poor lung recruitment	6	1	-	-
	Total incidence	13（20.31）	1（1.56）		<0.001

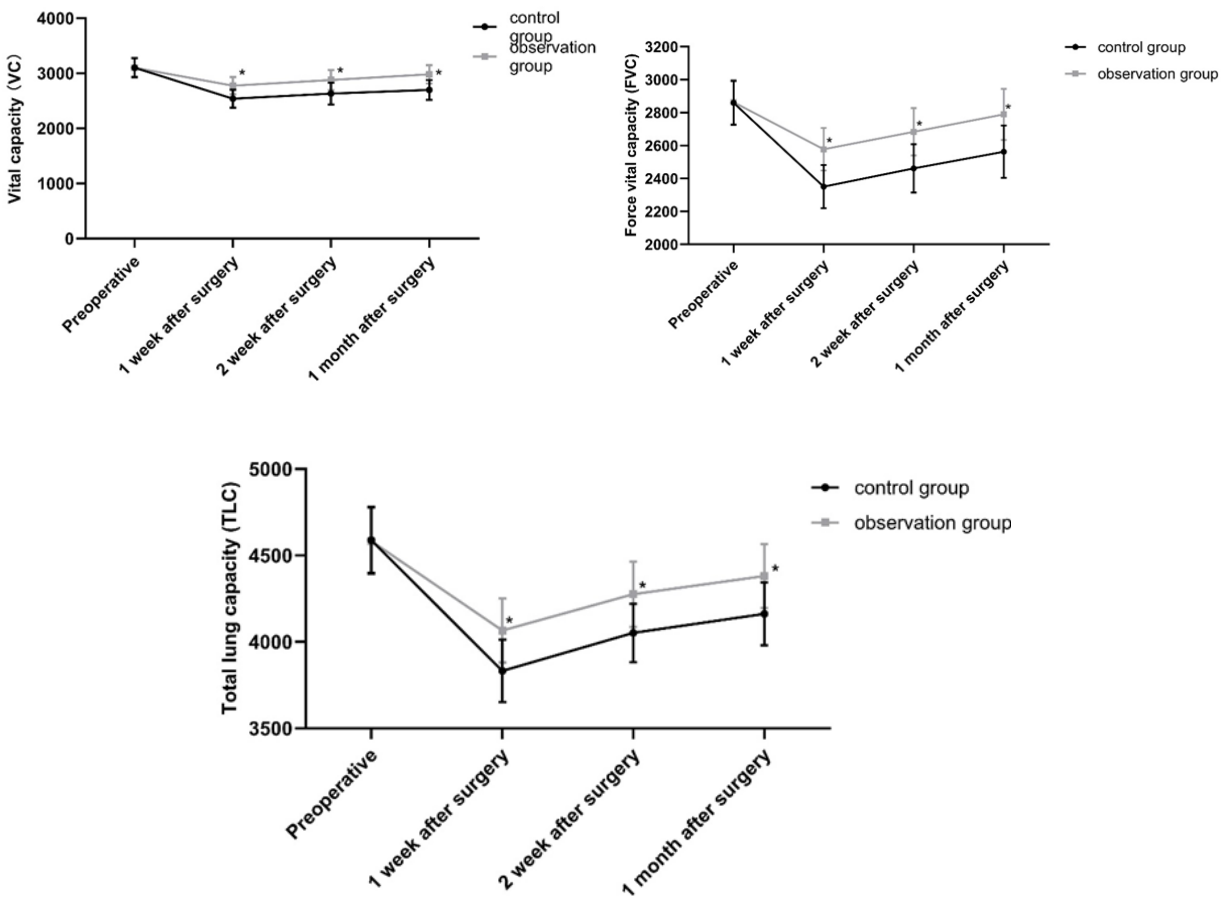

Figure 1. Pulmonary Function Indexes (VC, FVC, and TLC) of Two Groups of Patients at Different Times indicates a significant difference between the two groups (*p*<0.05), VC is vital capacity, FVC is forced vital capacity, and TLC is total lung capacity.

Respiratory Function

There was no statistically significant contrast difference in respiratory function between the two groups before surgery (*p>0.05*); postoperatively, the FEV1 and MVV levels of patients in the observation group were higher than those in the control group, and the Borg score was lower than that in the control group, *p<0. 05*. Details are shown in Table 3.

Inflammatory Factors

The contrast difference in respiratory function between the two groups before surgery was not statistically significant (*p>0.05*), and the CRP, PCT, and TNF-α levels of patients in the observation group were lower than those in the control group after surgery, *p>0. 05*. See Table 4 for details as follows:

Table 3. Respiratory function-related Indexes in Control and Observation Groups ($\bar{x}$ ±s)

		Control Group	Observation Group	t/x^2	*p*
Number of Cases		64	64	-	-
Preoperative	Forced expiratory volume in one second (FEV1)（l）	1.95±0.21	1.94±0.22	0.263	0.793
	Maximum ventilation volume per minute (MVV)（l/min）	73.01±6.12	73.12±6.11	0.102	0.919
	Borg score	0.44±0.05	0.45±0.04	1.249	0.214
Postoperative	Forced expiratory volume in one second (FEV1)（l）	1.30±0.15	1.81±0.12	26.120	<0.001
	Maximum ventilation volume per minute (MVV)（l/min）	59.81±5.65	67.94±6.08	7.836	<0.001
	Borg score	2.35±0.45	1.41±0.21	15.143	<0.001

MVV is maximum ventilation volume per minute, FEV1 is forced expiratory volume in one second, and Borg is the Borg Dyspnea Scale score.

Table 4. Levels of Inflammatory Factors in Control and Observation Groups ($\bar{x}$ ±s)

		Control Group	Observation Group	t/x^2	*p*
Number of Cases		64	64	-	-
Preoperative	C-reactive protein (CRP)（mg/L）	4.74±0.85	4.75±0.83	0.067	0.947
	Precalcitonin (PCT)（ng/mL）	0.08±0.01	0.08±0.02	0.000	1.000
	Tumor necrosis factor (TNF-α)（ng/L）	23.08±2.12	23.02±2.23	0.156	0.876
Postoperative	CRP（mg/L）	8.74±1.25	5.98±1.01	13.739	<0.001
	PCT（ng/mL）	0.20±0.05	0.12±0.03	10.976	<0.001
	TNF-α（ng/L）	31.25±3.21	25.14±2.25	12.469	<0.001

CRP is C-reactive protein, PCT is procalcitonin, and TNF-α is tumor necrosis factor α.

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DISCUSSION

The findings of this study provide valuable insights into the clinical efficacy of single-port thoracoscopic resection for benign lung tumors and its impact on respiratory function and inflammatory factors. The results demonstrated several advantages of this surgical approach, including reduced intraoperative bleeding, shorter hospital stays, improved lung function, enhanced respiratory function, and decreased levels of inflammatory factors.

The significant reduction in intraoperative bleeding observed in the observation group compared to the control group highlights the potential benefits of single-port thoracoscopic resection. This finding suggests that the minimally invasive nature of this technique may contribute to better hemostatic control during surgery, leading to reduced blood loss. The shorter hospital stays in the observation group further support the notion that single-port thoracoscopic resection offers advantages in postoperative recovery and resource utilization. These findings suggest that this technique preserves lung function better than conventional thoracic surgery, potentially leading to improved postoperative respiratory outcomes and overall patient well-being.

Furthermore, the higher levels of FEV1 and MVV in the observation group, along with a lower Borg score, suggest that patients who underwent single-port thoracoscopic resection experienced improved respiratory performance and perceived exertion compared to those who underwent conventional surgery. This finding highlights the potential advantages of this technique in facilitating better postoperative respiratory recovery and physical functioning.[9]

Moreover, the lower levels of inflammatory factors, including CRP, PCT, and TNF-α, in the observation group compared to the control group indicate that single-port thoracoscopic resection may suppress the inflammatory response. This finding suggests that the minimally invasive nature of this technique may lead to reduced tissue trauma and subsequent inflammatory reactions. potentially contributing to better postoperative recovery and lower complications risk.[10]

The advantages of single-port thoracoscopic resection, including reduced intraoperative bleeding, shorter hospital stays, improved lung function, enhanced respiratory performance, and suppression of the inflammatory response, can be attributed to several factors. The minimally invasive nature of single-port thoracoscopic resection plays a crucial role in reducing intraoperative bleeding.[11-13] The precise dissection and better control of blood vessels enabled by the single-port approach contribute to decreased blood loss. Additionally, the smaller incisions and reduced tissue trauma associated with this technique lead to faster postoperative recovery, reduced pain, and decreased risk of complications, resulting in shorter hospital stays.[14,15] The preservation of lung function observed in single-port thoracoscopic resection can be attributed to the avoidance of rib spreading and minimized surgical trauma to the surrounding lung tissue.[16] By minimizing tissue damage, this approach helps preserve respiratory mechanics and lung capacity. The improved respiratory performance, as indicated by higher FEV1 and MVV values and a lower Borg score, may be explained by reduced postoperative pain, decreased respiratory muscle impairment, and improved overall lung function.[17-19] Single-port thoracoscopic resection causes less disruption to the intercostal muscles and rib cage, leading to better postoperative respiratory muscle function.[20,21] The suppression of the inflammatory response observed in the observation group can be linked to the minimally invasive nature of single-port thoracoscopic resection. The smaller incision and decreased tissue trauma result in a milder inflammatory reaction and reduced release of inflammatory mediators, such as CRP, PCT, and TNF-α.[22]

While this study provides preliminary insights into the clinical efficacy of single-port thoracoscopic resection for benign lung tumors, its strengths lie in its clinical relevance, comparative analysis, and comprehensive assessment. However, limitations should be acknowledged. 1) Limited sample size: The study recruited a relatively small sample size from a single hospital, which may limit the generalizability of the findings. A larger and more diverse sample would strengthen the study's conclusions. 2) Non-randomized design: The study utilized non-random assignment of patients to observation and control groups, and lacked blinding. This introduces the potential for selection bias and may affect the reliability and accuracy of the study results. 3) Operator variability: The study did not account for potential differences in surgical techniques and expertise among operators performing single-port thoracoscopic resection. This variability may influence surgery outcomes and efficacy assessment. 4) Limited

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outcome measures: While the study assessed surgical outcomes, pulmonary function, and inflammatory factors, other factors relevant to the treatment of lung tumors, such as pain levels, quality of life, and postoperative complications, were not included in the study. 5) Short-term follow-up: The study had a limited observation period of 1 month after surgery, without long-term follow-up data. Therefore, the assessment of long-term effects and patient prognosis remains uncertain.

Further studies should incorporate long-term follow-up to assess the durability of clinical outcomes and the impact of single-port thoracoscopic resection on the recurrence rate of benign lung tumors. This would provide more comprehensive evidence regarding the long-term efficacy and safety of this surgical approach. Moreover, comparative studies comparing single-port thoracoscopic resection with other minimally invasive techniques, such as multi-port VATS or robotic-assisted thoracic surgery, would help determine the optimal surgical approach for benign lung tumors. These studies could assess not only clinical outcomes but also factors such as postoperative pain, quality of life, and cost-effectiveness. Additionally, investigating the cost-effectiveness of single-port thoracoscopic resection compared to conventional thoracic surgery would provide valuable information for healthcare decision-makers and help determine the economic implications of adopting this technique.

In conclusion, the current study demonstrates that single-port thoracoscopic resection of benign lung tumors is associated with high clinical efficacy. It effectively reduces intraoperative bleeding, shortens hospital stays, improves lung function, enhances respiratory function, and decreases inflammatory factors. These findings suggest that single-port thoracoscopic resection is a safe and effective approach with potential wide applications. However, the study's limitations, including the small sample size and non-randomized design, should be considered when interpreting the results. Further research with larger sample sizes, randomized designs, longer follow-up periods, and comprehensive outcome measures is warranted to validate and expand upon these findings and optimize the management of benign lung tumors.

STATEMENT OF ETHICS

This study was conducted in accordance with the principles outlined in the Helsinki Declaration. The research protocol was reviewed and approved by the Ethics Committee. Informed consent was obtained from all participants, and their privacy and confidentiality were protected throughout the study. The study followed ethical guidelines to ensure the welfare and rights of the participants were upheld.

FUNDING

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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Not applicable

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