Original Article

Impact of Lobar Resection Site on Postoperative Pulmonary Function in Non-Malignant Lung Disease

R Karmakar[1], AA Akond[2], MA Noor[3], SH Supti[4], I Jahan[5], SK Biswas[6]

Abstract:

Background: *Pulmonary lobectomy often leads to significant postoperative declines in lung function, influenced by lobar location and anatomical changes. Since most research focuses on malignancies, this study aims to bridge the gap by exploring how lobar site affects functional outcomes in non-malignant cases.*

Materials & Methods: *This cross-sectional analytical study, conducted over 18 months at NIDCH, included 54 patients who underwent lobectomy for non-tubercular diseases and met specific inclusion criteria. Eligible participants were adults capable of performing spirometry and diagnosed with various benign pulmonary conditions, while those with severe systemic illnesses, pulmonary malignancy, or active tuberculosis were excluded. Two months after surgery, face-to-face interviews and pulmonary function tests were performed to assess postoperative outcomes.*

Results: *The demographic and clinical characteristics across lobectomy groups were largely comparable, with no significant differences in age, sex, BMI, smoking history, or comorbidities, ensuring a balanced baseline. Bronchiectasis was the most common diagnosis, especially in bilobectomy and LUL cases, while aspergilloma and other conditions appeared less frequently and varied by lobar site. Preoperative pulmonary function tests showed consistent values across all groups, affirming uniform baseline respiratory status. Postoperatively, there was a universal decline in FEV1, FVC, and FEV1/FVC across all lobectomy types, with the most marked reductions seen in bilobectomy and lower lobe resections, highlighting the significant impact of lobar location on pulmonary function.*

Conclusions: *This study highlights the critical role of lobar location in determining postoperative pulmonary function after lobectomy for non-malignant lung diseases. Despite limitations, the findings emphasize the need for site-specific surgical planning.*

Keywords: Pulmonary lobectomy, Postoperative pulmonary function, Non-malignant lung disease, Lobar resection site, Lobar location–specific outcomes.

Introduction:

Pulmonary lobectomy, the anatomical resection of a lung lobe, is a cornerstone of thoracic surgery, performed for both malignant and non-malignant conditions.[1-3] While it remains the gold standard for early-stage NSCLC,[4] it is also indicated in tuberculosis, bronchiectasis, lung abscess, benign tumors, fungal infections, congenital anomalies, and traumatic injuries causing extensive lobar damage or life-threatening ventilation–perfusion mismatch.[2,5,6] Postoperatively, significant declines in FEV1 and FVC are common,

1. Rajeebshankar Karmakar, MBBS, MS (Thoracic Surgery), Resident Surgeon, Faridpur Medical College and Hospital, Faridpur. Email: rajeebfmc16@gmail.com
2. Atik Ahmed Akond, MBBS, MS (Thoracic Surgery), Resident Surgeon, Dhaka Medical College Hospital, Dhaka. Email: atikahmedakond@gmail.com
3. Masnoon Ahmed Noor, MBBS, MS (Thoracic Surgery), Consultant, Dhaka Central International Medical College, Dhaka, Email: noor.rmc@gmail.com
4. Sutopa Halder Supti, MBBS, Medical officer, Dept of Pediatric Gastroenterology BMU, Email: sutopashankarss39@gmail.com
5. Israt Jahan, MBBS, MPH (Epidemiology), Clinical Research Associate, Department of Orthopedic Surgery, Ibn Sina Medical College and Hospital, Kallyanpur, Dhaka. Email: dr.isratjahan 28@gmail.com
6. Sushit Kumar Biswas, MBBS, FCPS (Surgery), Resident Surgeon (General Surgery), Faridpur medical college hospital, Faridpur. Email: sumontrosb @gmail. com

Address of correspondence:

Rajeebshankar Karmakar, MBBS, MS (Thoracic Surgery), Resident Surgeon, Faridpur Medical College and Hospital, Faridpur. Email: rajeebfmc16@gmail.com, Contact No.: +881911030354

particularly in the early phase, with partial recovery over 6-12 months but rarely returning to preoperative levels.[7-9] Structural airway changes, increased resistance, and altered pulmonary blood flow lead to adaptive capillary recruitment and remodeling.[9-11] Thoracotomy-associated chest wall compliance loss further compromises ventilation due to intercostal nerve and rib trauma.[9,12] Compensation involves not just alveolar expansion but also structural regeneration and angiogenesis, with lower lobectomies showing better functional preservation likely due to diaphragmatic mechanics and basal perfusion, while upper lobectomies often suffer from bronchial kinking and spatial constraints.[8-14] The right middle lobe may behave uniquely, exhibiting post-upper lobectomy shrinkage due to anatomical limitations.[11] Most studies focus on malignancies, leaving a gap in understanding lobectomy's impact on non-malignant diseases, which is essential for refining surgical strategies and improving patient-centered outcomes in benign thoracic pathology.

Materials and Methods:

This cross-sectional analytical study was conducted among patients who underwent lobectomy for non-tubercular diseases at the Department of Thoracic Surgery, National Institute of Diseases of the Chest and Hospital (NIDCH), over an 18-month period from January 2022 to June 2023. Ethical clearance was obtained from the Academic and Institutional Review Board of NIDCH, Mohakhali, Dhaka, and the study was conducted in accordance with the Helsinki Declaration of 2011; all participants were fully informed about the study objectives and procedures, provided written informed consent, were assured of their right to withdraw at any time without consequence, and were interviewed voluntarily with strict maintenance of confidentiality throughout the research process. A total of 54 participants were selected using a convenient sampling technique. Inclusion criteria encompassed patients aged over 18 years who were capable of performing spirometry and had been diagnosed with conditions such as post-tuberculous bronchiectasis, post-tubercular cavitary lesions, aspergilloma, post-tuberculous fibrosis, lung abscess, post-pneumonic bronchiectasis, bronchiectasis due to impacted foreign body, pulmonary hydatid cyst, infected cyst, or multiple or giant bullae confined to a single lobe. Patients with severe systemic illnesses, including uncontrolled diabetes mellitus, acute myocardial infarction, hepatic, renal, or heart failure, those undergoing lobectomy for pulmonary malignancy, or patients with smear-positive tuberculosis, were excluded from the study. Data were collected using a semi-structured questionnaire that was initially developed in English and, after rigorous correction and pretesting in comparable non-NIDCH populations, translated into Bangla. Following further refinements based on the pilot testing, the final version was used. Two months post-lobectomy, participants were interviewed face-to-face, after which pulmonary function tests were conducted. The collected data were then processed and analyzed using SPSS version 29.

Results:

As shown in Table 1, the demographic characteristics across different lobectomy groups were largely comparable, with no statistically significant differences in age, sex, BMI, smoking history, or comorbid conditions such as COPD, IHD, or diabetes, suggesting a well-balanced baseline among study participants. While patients in the right lower lobectomy group appeared slightly older and those in the bilobectomy group somewhat younger, these variations were not clinically meaningful. Male predominance was observed in most groups, especially in the RUL and bilobectomy cohorts, whereas female patients were more common in the LLL group. Smoking history was more frequently reported in RUL and LUL resections, though the difference was not significant. Although occupational distribution showed a statistically significant difference, its clinical relevance remained limited within the study context.

Table 1: Distribution of respondents according to patient characteristics (N=54).

Characteristics	RUL (n=15)	RML (n=6)	RLL (n=6)	LUL (n=14)	LLL (n=8)	Bi (n=5)	p-Value
Age	38.7±15.9	30±8.7	48.0±15.7	41.5±11.4	33.9±14.9	27.2±14.4	0.14
Sex							
Male	13 (86.7%)	4 (66.7%)	3 (50%)	11 (78.6%)	3 (37.5%)	4 (80%)	0.15
Female	2 (13.3%)	2 (33.3%)	3 (50%)	3 (21.4%)	5 (62.5%)	1 (20%)	
BMI	23.6±12.9	19.3±3.4	21.5±2.7	20.4±3.5	19.6±2.5	18.8±3.5	0.16
Occupation							
Businessman	9 (60%)	2 (33.3%)	1 (16.7%)	7 (50%)	0 (0%)	3 (60%)	<0.05
Housewife	3 (20%)	2 (33.3%)	3 (50%)	2 (14.3%)	6 (75%)	0 (0%)	
Teacher	0 (0%)	1 (16.7%)	0 (0%)	0 (0%)	1 (12.5%)	0 (0%)	
Day Laborer	0 (0%)	0 (0%)	2 (33.3%)	1 (7.1%)	0 (0%)	1 (20%)	
Student	2 (13.3%)	1 (16.7%)	0 (0%)	0 (0%)	0 (0%)	1 (20%)	
Shopkeeper	1 (6.7%)	0 (0%)	0 (0%)	4 (28.6%)	1 (12.5%)	0 (0%)	
History of Smoking	8 (53.3%)	2 (33.3%)	1 (16.7%)	7 (50%)	1 (12.5%)	0 (0%)	0.12
Comorbidity							
COPD	1 (6.7%)	0 (0%)	1 (16.7%)	3 (21.4%)	1 (12.5%)	0 (0%)	0.75
IHD	0 (0%)	0 (0%)	0 (0%)	1 (7.1%)	0 (0%)	0 (0%)	0.72
DM	0 (0%)	0 (0%)	1 (16.7%)	0 (0%)	1 (12.5%)	0 (0%)	0.20

p-value was calculated by using chi-square test for categorical and ANOVA for quantitative variables. Fisher's exact test was done if any of cell had expected value less than 5

In Table 2, bronchiectasis emerged as the most prevalent diagnosis across all groups, particularly in the bilobectomy and LUL groups, while aspergilloma was more common in RUL, RML, and LUL resections. Less frequent conditions such as bullous disease, lung abscess, and hydatid cyst appeared infrequently and were distributed variably depending on the lobar site.

Table 2: Distribution of respondents according to diagnosis (N=54).

Diagnosis	RUL (n=15)	RML (n=6)	RLL (n=6)	LUL (n=14)	LLL (n=8)	Bi (n=5)	p-Value
Bronchiectasis	7 (46.7%)	1 (16.7%)	3 (50%)	8 (57.1%)	3 (37.5%)	4 (80%)	0.12
Lung Abscess	0 (0%)	1 (16.7%)	0 (0%)	1 (7.1%)	0 (0%)	1 (20%)	
Bullous Disease	2 (13.3%)	0 (0%)	2 (33.3%)	0 (0%)	1 (12.5%)	0 (0%)	
Hydatid Cyst	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (12.5%)	0 (0%)	
Broncho pulmonary Fistula	0 (0%)	0 (0%)	1 (16.7%)	0 (0%)	0 (0%)	0 (0%)	
Hamartoma	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (12.5%)	0 (0%)	
Aspergilloma	5 (33.3%)	4 (66.7%)	0 (0%)	4 (28.6%)	1 (12.5%)	0 (0%)	
Fibrosis	1 (6.7%)	0 (0%)	0 (0%)	1 (7.1%)	1 (12.5%)	0 (0%)	

p-value was calculated by using chi-square test for categorical and ANOVA for quantitative variables. Fisher's exact test was done if any of cell had expected value less than 5

As detailed in Table 3, preoperative pulmonary function measured by FEV1, FVC, and the FEV1/FVC ratio demonstrated consistent values across all groups, with slightly higher lung volumes noted in the bilobectomy group, though without statistical significance, affirming a uniform baseline respiratory function among participants irrespective of the lobe targeted for resection.

Table 3: Distribution of respondents according to preoperative pulmonary function tests (N=54).

Characteristics	RUL (n=15)	RML (n=6)	RLL (n=6)	LUL (n=14)	LLL (n=8)	Bi (n=5)	p-Value
FEV1	1.9±0.6	1.6±0.6	1.8±0.3	1.8±0.5	1.7±0.4	2.2±0.6	0.06
FVC	2.3±0.6	2.3±0.6	2.3±0.2	2.4±0.5	2.1±0.4	2.6±0.8	0.14
FEV1/FVC	76.3±10	76.2±18.3	76.5±13.9	75.0±13.0	81.2±9.7	79.6±0.8	0.41

p-value was calculated by using chi-square test for categorical and ANOVA for quantitative variables. Fisher's exact test was done if any of cell had expected value less than 5.

As demonstrated in Table 4, postoperative FEV1 declined across all lobectomy groups, indicating a universal reduction in lung function following surgery, irrespective of statistical significance. The most substantial decreases were observed in the right upper lobe, left upper lobe, left lower lobe, and bilobectomy groups, suggesting a notable impact on expiratory airflow, while the right middle lobe group showed minimal change.

Table 4: Distribution of respondents according to pre and postoperative FEV1 (N=54).

Characteristics	Pre FEV1	Post FEV1	Mean Difference	Mean % of Difference	p-Value
RUL (n=15)	1.9±0.6	1.5±0.6	-0.3	-17.1%	<0.05
RML (n=6)	1.6±0.6	1.6±0.6	-0.01	2.1%	0.63
RLL (n=6)	1.8±0.3	1.6±0.5	-0.2	-12.8%	0.02
LUL (n=14)	1.8±0.5	1.6±0.6	-0.3	-17.1%	<0.05
LLL (n=8)	1.7±0.4	1.4±0.4	-0.3	-16%	<0.05
Bilobectomy (n=5)	2.2±0.6	1.9±0.8	-0.3	-13.1%	0.04

p-value was calculated by using chi-square test for categorical and ANOVA for quantitative variables. Fisher's exact test was done if any of cell had expected value less than 5.

Complementing this, Table 05 reveals a consistent postoperative decline in FVC across all groups, reflecting a reduction in lung volume after lobectomy. The extent of decline varied by lobar location, with the most pronounced losses seen in the bilobectomy, right lower, and left lower lobectomy groups. Importantly, even where the differences were not statistically significant, the uniform downward trend underscored the overall effect of surgical resection on pulmonary capacity.

Table 5: Distribution of respondents according to pre and postoperative FVC (N=54).

Characteristics	Pre FVC	Post FVC	Difference	% of Difference	p-Value
RUL (n=15)	2.3±0.6	1.9±0.7	-0.4	-13.5%	<0.05
RML (n=6)	2.3±0.6	2.1±0.3	-0.3	-9.6%	0.06
RLL (n=6)	2.3±0.2	2.1±0.4	-0.2	-8.8%	0.08
LUL (n=14)	2.4±0.5	2.1±0.5	-0.3	-10.7%	<0.05
LLL (n=8)	2.1±0.4	1.8±0.5	-0.3	-13.2%	<0.05
Bilobectomy (n=5)	2.6±0.8	2.0±0.6	-0.5	-19.4%	0.01

p-value was calculated by using chi-square test for categorical and ANOVA for quantitative variables. Fisher's exact test was done if any of cell had expected value less than 5.

Table 6 highlights a consistent postoperative decrease in the FEV1/FVC ratio across all lobectomy types, suggesting reduced airflow efficiency relative to lung volume. The most marked reductions occurred in the left lower lobectomy and bilobectomy groups, although even smaller declines across other lobes point to a general trend of diminished pulmonary mechanics following surgery. Collectively, these findings emphasize that lobar resection, regardless of anatomical location or statistical threshold, results in measurable and clinically relevant impairments in postoperative respiratory function.

Table 6: Distribution of respondents according to pre and postoperative FEV1/FVC (N=54).

Characteristics	Pre FEV1/FVC	Post FEV1/FVC	Difference	% of Difference	p-Value
RUL (n=15)	76.3±10.0	73.2±10.5	-3.1	-4%	0.14
RML (n=6)	76.2±18.3	74.5±18.9	-1.7	-2.3%	0.60
RLL (n=6)	76.5±13.9	75.5±16.8	-1.0	-1.6%	0/71
LUL (n=14)	75.0±13.0	72.5±14.9	-2.5	-3.6%	0.20
LLL (n=8)	81.2±9.7	76.5±11.8	-4.7	-6%	0.13
Bilobectomy (n=5)	79.6±8.0	75.6±9.2	-4.0	-5.2%	0.31

p-value was calculated by using chi-square test for categorical and ANOVA for quantitative variables. Fisher's exact test was done if any of cell had expected value less than 5.

Discussion:

Compared to findings from previous studies, the baseline characteristics of our patients reveal both notable differences and striking similarities. Our study population was considerably younger, with a mean age ranging from the late 20s to mid-40s across lobectomy groups, while other studies reported mean ages in the 60s, likely due to their focus on malignant lung conditions that predominantly affect older individuals.[2,8] In contrast, our cohort involved non-malignant etiologies, which tend to present earlier in life. The male predominance observed in our sample was more pronounced than in other reports, possibly reflecting regional variations in healthcare access, disease patterns, or cultural factors influencing health-seeking behavior.[7,8] Regarding BMI, our findings were broadly consistent with previous literature, though with slightly more variability, potentially due to outliers in a diverse patient population.[8] The occupational diversity in our cohort, ranging from businessmen and housewives to students and day laborers, was not highlighted in earlier studies and may reflect the wider socioeconomic spectrum of patients with non-malignant conditions treated in a public healthcare setting. Smoking history and comorbidity rates such as COPD and diabetes were generally lower in our study, which may again be attributed to the younger, non-cancer profile of our participants.[2] While differences exist, particularly in age and comorbidities, they underscore the unique demographic and clinical characteristics of patients undergoing lobectomy for non-malignant lung diseases. Bronchiectasis emerged as the most common indication for lobectomy in our study, especially in bilobectomy and left upper lobe resections, reflecting the chronic infectious nature of the population, whereas other studies reported higher rates of hydatid cysts and aspergilloma, likely due to regional epidemiological patterns and differences in public health measures.[7]

In our study, preoperative pulmonary function values, including FEV1, FVC, and FEV1/FVC ratios, were relatively consistent across different lobectomy groups, indicating a uniform baseline respiratory status among patients with non-malignant lung diseases. When compared to previous studies, our FEV1 and FVC values were somewhat lower, which is an expected variation given the differing patient profiles.[2,8] This difference likely arises from the nature of our cohort, composed predominantly of individuals with chronic infectious or structural lung conditions such as bronchiectasis and aspergilloma, which inherently cause progressive pulmonary impairment. Variations in sample size, demographic characteristics, and regional disease burden may also contribute to these differences. Interestingly, the relatively preserved FEV1/FVC ratios observed across all groups suggest that, despite their underlying pathology, most patients maintained a balanced ventilatory pattern and acceptable baseline function prior to surgery.

Our study revealed a consistent postoperative decline in FEV1 across all lobectomy groups, with percentage reductions ranging from 12.8% to 17.1%, closely aligning with findings in other studies[2], where decreases between 11.9% and 17.9% were reported depending on lobar location. The similarity is particularly notable for upper lobectomies, where both studies observed greater functional loss compared to lower lobectomies, supporting the hypothesis that upper lobe resections are associated with more significant postoperative impairment due to bronchial kinking and altered airflow dynamics. Our slightly higher percentage reductions in lower lobectomies compared to other reports[14], which documented a modest 4.66% decline, may reflect differences in underlying disease pathology, as our cohort included patients with chronic infectious and structural lung conditions that could limit compensatory mechanisms post-surgery. Similar reductions in FEV1 have also been documented globally[1], reinforcing the consistency of this pattern across diverse populations. The minimal change observed in the right middle lobe group in our study mirrors its relatively smaller contribution to total lung function, as noted in previous literature.

Our study demonstrated a consistent postoperative decline in FVC across all lobectomy groups, with percentage reductions ranging from 8.8% to 19.4%, which aligns closely with findings in other studies[2], where decreases between 7.2% and 16.6% were reported depending on the lobe resected. The slightly higher reduction observed in bilobectomy cases in our study may be explained by the larger volume of lung tissue removed and the reduced compensatory reserve in patients with non-malignant pathologies. The pattern of greater functional loss following upper lobe resections also reflects trends described in previous research.[1,14] While minimal change in FVC was reported after right lower lobectomies in other studies[14], our findings showed moderate reductions, likely influenced by the chronic infectious and structural lung diseases prevalent in our cohort. These parallels reinforce the validity of our results, while slight differences highlight the impact of disease etiology and surgical extent on postoperative pulmonary function.

Conclusion:

This study highlights the profound impact of lobar location on postoperative pulmonary function in patients undergoing lobectomy for non-malignant lung diseases, highlighting that the site of resection plays a critical role in determining the extent of functional loss. We observed consistent reductions in FEV1, FVC, and FEV1/FVC across all groups, with upper lobe and bilobectomy patients experiencing more pronounced declines, reflecting the complex interplay of anatomical, physiological, and compensatory factors unique to different lobes. These findings emphasize the need for careful preoperative planning and patient counseling, particularly in non-malignant conditions where preserving lung function is key for long-term quality of life. The study's interpretation is tempered by certain limitations, including its single-center design, a relatively small sample size due to the Covid-19 pandemic, and the absence of long-term follow-up to assess functional recovery over time. Future multicenter studies with larger cohorts and extended follow-up periods are recommended to validate these observations and guide surgical decision-making more comprehensively. Despite these limitations, our results strongly advocate for the consideration of lobar site as a major determinant of postoperative outcomes in the surgical management of benign lung diseases.

Acknowledgement:

The authors would like to express their deepest gratitude to the Department of Thoracic Surgery, National Institute of Diseases of the Chest and Hospital (NIDCH) for providing the necessary support and facilities to conduct this study. Heartfelt thanks are extended to all the doctors, anesthesiologists, and nursing staff whose expertise and cooperation made this research possible. The authors also acknowledge the participation of the patients and their parents, whose trust and consent formed the foundation of this work. The authors remain indebted to their mentors and colleagues for their continuous guidance, encouragement, and constructive feedback throughout the course of this study.

Conflict of interest: There is no conflict of interest.

References:

1. Yokoba M, Ichikawa T, Harada S, Naito M, Sato Y, Katagiri M. Postoperative pulmonary function changes according to the resected lobe: a 1-year follow-up study of lobectomized patients. *Journal of Thoracic Disease* [Internet]. 2018 Dec 1;10(12):6891–902. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6344756/

2. Matsumoto R, Takamori S, Yokoyama S, Hashiguchi T, Murakami D, Yoshiyama K, et al. Lung function in the late postoperative phase and influencing factors in patients undergoing pulmonary lobectomy. *Journal of Thoracic Disease* [Internet]. 2018 May 1;10(5). Available from: https://jtd.amegroups.org/article/view/21532/16494#:~:text=Results%3A%20A%20mean%20postoperative%20decreased.

3. Rea G, Rudrappa M. *Lobectomy* [Internet]. PubMed. Treasure Island (FL): StatPearls Publishing; 2020. Available from: https://www.ncbi.nlm.nih.gov/books/NBK553123/

4. WEISER T. *Lobar Resections*. Elsevier eBooks [Internet]. 2006 Jan 1;671–84. Available from: https://www.sciencedirect.com/science/article/abs/pii/B9781416029519500827

5. Feliciano DV. *Cardiac, Great Vessel, and Pulmonary Injuries*. Elsevier eBooks [Internet] 2015 May 22;71–99. Available from: https://www.sciencedirect.com/science/article/abs/pii/B9781455712618000096?via%3Dihub

6. Rakovich G, Éric Fréchette, Deslauriers J. *Thoracic Surgical Anatomy and Procedures*. Elsevier eBooks [Internet]. 2009 Nov 18;95–105. Available from: https://www.sciencedirect.com/science/article/abs/pii/B9781416039938000088

7. Harmouchi H, Lakranbi M, Issoufou I, Belliraj L, Ammor F, Rabiou S, et al. Clinics in Surgery Pulmonary Lobectomies for Benign Diseases: Results and Complications about 120 Cases *OPEN ACCESS* [Internet]. 2019 [cited 2025 Jul 3]. Available from: https://www.clinicsinsurgery.com/open-access/pulmonary-lobectomies-for-benign-diseases-results-and-complications-about-120-cases-4921.pdf

8. Shibazaki T, Mori S, Harada E, Shigemori R, Kato D, Matsudaira H, et al. Measured versus predicted postoperative pulmonary function at repeated times up to 1 year after lobectomy. *Interactive cardiovascular and thoracic surgery* [Internet]. 2021;33(5):727–33. Available from: https://pubmed.ncbi.nlm.nih.gov/34115872/

9. Fuzhi Y, Dongfang T, Wentao F, Jing W, Yingting W, Nianping M, et al. Rapid Recovery of Postoperative Pulmonary Function in Patients With Lung Cancer and Influencing Factors. *Frontiers in Oncology*. 2022 Jul 11;12.

10. Barone M, Frontera R, Liouras RV, Guetti L, Dell'Atti I, Vetrugno L, et al. Postoperative pulmonary compensation after lung cancer surgery: a shift towards a modern and comprehensive model—a narrative review. *Shanghai Chest*. 2024 Jan 1;8:5–5.

11. Tu DH, Yi C, Liu Q, Huang L, Yang G, Qu R. Longitudinal changes in the volume of residual lung lobes after lobectomy for lung cancer: a retrospective cohort study. *Scientific Reports*. 2024 May 27;14(1).

12. Ueda K, Hayashi M, Tanaka N, Tanaka T, Hamano K. Long-term pulmonary function after major lung resection. *General Thoracic and Cardiovascular Surgery*. 2013 Nov 22;62(1):24–30.

13. Kushibe K, Kawaguchi T, Kimura M, Takahama M, Tojo T, Taniguchi S. Influence of the site of lobectomy and chronic obstructive pulmonary disease on pulmonary function: a follow-up analysis. *Interactive Cardio Vascular and Thoracic Surgery*. 2009 Feb 23;8(5):529–33.

14. Sahin B, Celenk C, Basoglu A, Sengul AT. Postoperative Lung Volume Change Depending on the Resected Lobe. *Thoracic Cardiovascular Surg*. 2013 Mar 9;61(02):131–7.