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Multimodal Pulmonary Evaluation for Prediction of Postoperative Pulmonary Complications in Elective Non-Thoracic Surgery: A Retrospective Study

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KEYWORDS:

Postoperative pulmonary complications, Spirometry, Impulse oscillometry, FeNO, Chest X-ray, Small airway disease, Multimodal assessment

ABSTRACT:

Background:

Postoperative pulmonary complications (PPCs) are a major contributor to perioperative morbidity and mortality, particularly in patients undergoing upper abdominal surgery. Conventional risk assessment tools rely largely on clinical parameters and may not fully capture underlying pulmonary dysfunction. A multimodal evaluation incorporating spirometry, impulse oscillometry (IOS), fractional exhaled nitric oxide (FeNO), and chest radiography may enhance predictive accuracy.

Objective:

To evaluate the individual and combined utility of spirometry, IOS, FeNO, and chest X-ray in predicting postoperative pulmonary complications in patients undergoing elective non-thoracic surgery.

Methods:

This retrospective observational study was conducted at a tertiary care center in Tamil Nadu, India, including 80 adult patients who underwent elective upper abdominal surgery between January 2024 and December 2025. Data were collected from hospital records using total sampling. Pulmonary assessment included spirometry, IOS parameters (R5, R20, R5–R20), FeNO levels, and chest X-ray findings. Statistical analysis involved univariate and multivariate logistic regression, along with ROC curve analysis to assess predictive performance.

Results:

The incidence of PPCs was 25%, with atelectasis being the most common complication (11.3%). Obstructive spirometry was significantly associated with PPCs (adjusted OR 3.10, p=0.04). Elevated peripheral airway resistance (R5–R20 >1.5) emerged as the strongest independent predictor (adjusted OR 3.85, p=0.01). Abnormal chest X-ray findings were also independently associated with increased risk (adjusted OR 3.50, p=0.02). Although higher FeNO levels showed a rising trend in PPC incidence, this was not statistically significant after adjustment. Multimodal assessment demonstrated superior predictive capability compared to individual modalities.

Conclusion:

A multimodal pulmonary evaluation approach significantly improves prediction of PPCs in patients undergoing elective upper abdominal surgery. Peripheral airway dysfunction, obstructive ventilatory defects, and structural lung abnormalities are key independent predictors. Incorporating IOS into routine preoperative assessment may enhance risk stratification and guide targeted perioperative management.

INTRODUCTION

Postoperative pulmonary complications (PPCs) represent one of the most prevalent and clinically significant causes of perioperative morbidity and mortality worldwide. They are associated with prolonged hospital stays, increased resource utilisation, and substantial healthcare costs [1]. The term "postoperative pulmonary complications" encompasses a spectrum of disorders including atelectasis, pneumonia, respiratory failure, bronchospasm, pleural effusion, and pulmonary oedema, all of which can complicate the postoperative course and adversely impact patient outcomes [2].

The incidence of PPCs following non-thoracic surgery varies widely in the literature, ranging from 5% to 40%, depending on the patient population, surgical site, anaesthetic technique, and the definition of PPCs employed [3]. Upper abdominal surgeries are particularly associated with higher rates of PPCs compared to other elective procedures. The proximity of the operative site to the diaphragm, postoperative pain impairing deep breathing, and the resulting diaphragmatic dysfunction together create an environment conducive to atelectasis and ventilatory insufficiency [4].

Identifying patients at high risk for PPCs preoperatively is essential to guide perioperative risk stratification, optimise preoperative preparation, and tailor intraoperative and postoperative management strategies. Several clinical scoring tools have been developed to this end, including the Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT) score and the Canet risk index, which incorporate variables such as age, preoperative oxygen saturation, respiratory tract infection, anaemia, surgical duration, and the type and urgency of surgery [5, 6]. However, these tools rely primarily on clinical and demographic variables and do not fully capture the spectrum of underlying pulmonary functional and inflammatory abnormalities that predispose patients to complications.

Spirometry remains the cornerstone of pulmonary function testing and provides objective information about ventilatory patterns, including obstructive, restrictive, and mixed defects. Obstructive lung disease, characterised by reduced FEV_1/FVC ratio, has been consistently associated with heightened PPC risk [7]. Chronic Obstructive Pulmonary Disease (COPD), in particular, represents a major modifiable risk factor, and preoperative optimisation of COPD is recommended prior to elective surgery [8]. However, conventional spirometry assesses only large airway function and may fail to detect early or subclinical small airway disease, which increasingly appears relevant to perioperative respiratory risk.

Impulse oscillometry (IOS) offers a non-effort-dependent, complementary method for assessing airway mechanics, providing measurements of total respiratory resistance (R5), central airway resistance (R20), and the frequency-dependence of resistance (R5–R20), which serves as a specific marker of peripheral or small airway resistance [9]. Small airway disease, once considered a "silent zone", is now recognised as contributing substantially to respiratory morbidity, especially in smokers and patients with COPD [10]. The utility of IOS-derived small airway indices in predicting PPCs in surgical patients, however, remains incompletely evaluated.

Fractional exhaled nitric oxide (FeNO) is a validated non-invasive biomarker of eosinophilic airway inflammation, primarily reflecting type 2 inflammatory pathways [11]. Elevated FeNO levels have been demonstrated in asthma, eosinophilic bronchitis, and a subset of COPD patients. In the perioperative context, airway inflammation may predispose patients to bronchospasm, secretion retention, and impaired mucociliary clearance, all of which could contribute to PPCs. Despite its growing clinical use, the role of FeNO in preoperative pulmonary risk assessment has not been widely studied.

Preoperative chest radiography provides structural information about the lung parenchyma and pleural space. While its routine use in low-risk surgical patients has been debated, chest X-ray findings such as hyperinflation, interstitial changes, pulmonary infiltrates, and pleural abnormalities may reflect underlying pulmonary disease severity and provide complementary information to functional assessments [12].

A multimodal approach integrating spirometry, IOS, FeNO, and chest radiography could potentially offer a more comprehensive preoperative pulmonary risk profile than any single modality alone. Despite the availability of these tools, their combined predictive value in a real-world clinical setting has not been rigorously evaluated, particularly in an Indian population undergoing elective upper abdominal surgery, where the burden of tobacco use, COPD, and limited preoperative pulmonary evaluation remains considerable.

The present retrospective study was undertaken to evaluate the individual and combined contributions of spirometry, impulse oscillometry, FeNO, and chest X-ray findings in predicting PPCs in patients undergoing elective non-thoracic (upper abdominal) surgery. The findings are intended to inform evidence-based preoperative pulmonary assessment protocols and contribute to safer perioperative management in high-risk surgical populations.

METHODOLOGY

Study Design and Setting

This study was designed as a retrospective observational study conducted in the Department of Respiratory Medicine, Chettinad Hospital and Research Institute, Kelambakkam, Tamil Nadu. The study utilized existing hospital medical records to evaluate predictors of postoperative pulmonary complications (PPCs) in patients undergoing non-thoracic surgery.

Study Population

The study population included adult patients who underwent elective upper abdominal surgeries during the defined study period. Patient data were retrieved from hospital records and screened for eligibility based on predefined inclusion and exclusion criteria.

Study Period

Data were collected retrospectively from hospital records over a two-year period (January 2024 to December 2025).

Sample Size

The sample size was calculated using the formula:

$$n = \frac{Z^2 \times p \times q}{d^2}$$

Where:

- $Z = 1.96$(95% confidence level)
- $p = 0.189$
- $q = 1 - p = 0.811$
- $d = 0.09$

The calculated sample size was 72.7, which was rounded to 73. After accounting for a 10% margin for incomplete records, the final sample size was fixed at 80 participants.

Sampling Technique

A complete enumeration (total sampling) technique was employed. All eligible patient records meeting inclusion criteria during the study period were included consecutively until the required sample size of 80 was achieved. Records with incomplete or missing data were excluded to maintain data quality.

Eligibility Criteria

Inclusion Criteria

- Age ≥ 18 years
- Patients who underwent elective upper abdominal surgery during the study period

Exclusion Criteria

- Emergency surgeries
- Hemodynamically unstable patients

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- Patients with severe systemic illness
- Incomplete or missing medical records

Data Collection Procedure

Data were collected retrospectively from hospital medical records using a structured and pre-validated data extraction proforma. No direct patient interaction or additional investigations were performed.

Statistical Analysis

All data collected from hospital records were entered into Microsoft Excel and analyzed using the Statistical Package for the Social Sciences (SPSS) software. Quantitative variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR) depending on the distribution of data, while qualitative variables were presented as frequencies and percentages. Comparative analysis was performed between patients with and without postoperative pulmonary complications (PPCs). Continuous variables were analyzed using the independent sample t-test or Mann–Whitney U test, as appropriate, and categorical variables were analyzed using the Chi-square test or Fisher's exact test. Univariate analysis was initially performed to identify variables associated with PPCs, and those with a p-value less than 0.2 were included in multivariate logistic regression analysis to determine independent predictors. Receiver Operating Characteristic (ROC) curve analysis was conducted to evaluate the predictive accuracy of pulmonary function parameters, and area under the curve (AUC), sensitivity, and specificity were calculated. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations

This study was conducted after obtaining approval from the Institutional Human Ethics Committee (IHEC) of Chettinad Hospital and Research Institute. As this was a retrospective observational study utilizing existing hospital medical records, no direct patient interaction, intervention, or additional investigations were involved. A waiver of informed consent was obtained from the ethics committee, as the study posed minimal risk to participants and involved anonymized data analysis. Patient confidentiality was strictly maintained throughout the study by excluding personal identifiers such as name, address, and hospital registration number from the dataset. Access to medical records was restricted to the principal investigator and authorized research personnel only. All data were securely stored in password-protected systems and used solely for research purposes. The study adhered to the ethical principles outlined in the Declaration of Helsinki.

Results

TABLE 1: Baseline Characteristics of Study Population (n = 80)

Variable	Value
Age (years)	58 ± 11
Male	50 (62.5%)
Female	30 (37.5%)
BMI (kg/m²)	25.8 ± 3.2
Smokers	38 (47.5%)
Smoking (pack-years)	19 ± 6
Diabetes Mellitus	26 (32.5%)
Hypertension	30 (37.5%)
Known COPD	18 (22.5%)

The study included 80 patients with a mean age of 58 ± 11 years. Males constituted 62.5% of the study population. Nearly half of the participants were smokers (47.5%), with a mean smoking exposure of 19 ± 6 pack-years. Comorbidities were common, with diabetes mellitus present in 32.5%, hypertension in 37.5%, and COPD in 22.5% of patients. Overall, the cohort represented a moderately high-risk population undergoing elective non-thoracic surgery.

TABLE 2: Incidence and Types of Postoperative Pulmonary Complications (PPCs)

Complication	Frequency (%)
Total PPC	20 (25%)
Atelectasis	9 (11.3%)
Pneumonia	5 (6.3%)
Tracheobronchitis	3 (3.8%)
Pleural Effusion	2 (2.5%)

Pulmonary Edema	1 (1.3%)

The overall incidence of postoperative pulmonary complications (PPCs) was 25% (20/80). Atelectasis was the most common complication (11.3%), followed by pneumonia (6.3%) and tracheobronchitis (3.8%). Less frequent complications included pleural effusion (2.5%) and pulmonary edema (1.3%). This distribution highlights the predominance of airway-related complications in the postoperative period.

TABLE 3: Association of Pulmonary Function Parameters with PPC

Variable	Category	PPC Present n (%)	PPC Absent n (%)	Total n (%)	OR	95% CI	p-value
Spirometry	Normal	4 (10.5%)	34 (89.5%)	38 (100%)	1 (Ref)		
	Obstructive	10 (50.0%)	10 (50.0%)	20 (100%)	8.50	2.10 – 34.30	
	Restrictive	4 (33.3%)	8 (66.7%)	12 (100%)	4.25	0.85 – 21.10	
	Mixed	2 (20.0%)	8 (80.0%)	10 (100%)	2.12	0.35 – 12.70	0.01
R5 (Total Resistance)	Normal	13 (21.7%)	47 (78.3%)	60 (100%)	1 (Ref)	—	
	Elevated	7 (35.0%)	13 (65.0%)	20 (100%)	1.95	0.65 – 5.80	0.12
R20 (Central Resistance)	Normal	12 (20.0%)	48 (80.0%)	60 (100%)	1 (Ref)	—	
	Elevated	8 (40.0%)	12 (60.0%)	20 (100%)	2.67	0.90 – 7.90	0.08
R5–R20 (Peripheral)	Normal	8 (15.1%)	45 (84.9%)	53 (100%)	1 (Ref)	—	
	Elevated (>1.5)	12 (44.4%)	15 (55.6%)	27 (100%)	4.50	1.60 – 12.40	0.01

Abnormal pulmonary function parameters were associated with higher rates of PPCs. Patients with obstructive spirometry had a significantly higher incidence of PPCs (50%) compared to those with normal spirometry (10.5%), with markedly increased odds (OR 8.5, 95% CI: 2.1–34.3, p=0.01). Peripheral airway resistance (R5–R20 >1.5) was also significantly associated with PPCs (44.4% vs 15.1%, OR 4.5, 95% CI: 1.6–12.4, p=0.01). In contrast, total (R5) and central airway resistance (R20) showed weaker and statistically non-significant associations. These findings suggest that small airway dysfunction plays a key role in predicting PPCs.

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TABLE 4: FeNO and Chest X-ray with PPC

Variable	Category	PPC Present n (%)	PPC Absent n (%)	Total n (%)	OR	95% CI	p-value
FeNO	<25	6 (18.8%)	26 (81.2%)	32 (100%)	1 (Ref)		
	25–50	9 (33.3%)	18 (66.7%)	27 (100%)	2.17	0.70–6.70	
	>50	5 (45.5%)	6 (54.5%)	11 (100%)	3.61	0.90–14.40	0.05
Chest X-ray	Normal	6 (13.6%)	38 (86.4%)	44 (100%)	1 (Ref)		
	Abnormal	14 (38.9%)	22 (61.1%)	36 (100%)	4.03	1.40–11.50	0.004

FeNO levels demonstrated a progressive increase in PPC incidence, with rates rising from 18.8% in patients with FeNO <25 ppb to 45.5% in those with FeNO >50 ppb (p=0.05), indicating a trend toward increased risk with higher airway inflammation. Abnormal chest X-ray findings were strongly associated with PPCs (38.9% vs 13.6%), with significantly increased odds (OR 4.03, 95% CI: 1.40–11.50, p=0.004). This underscores the importance of structural lung abnormalities in predicting postoperative complications.

TABLE 5: Univariate Analysis of Factors Associated with PPC (n = 80)

Variable	Category	PPC Present n (%)	PPC Absent n (%)	Total n (%)	OR	95% CI	p-value
Smoking	Yes	12 (31.6%)	26 (68.4%)	38 (100%)	2.10	0.85–5.18	0.10
	No	8 (19.0%)	34 (81.0%)	42 (100%)	1 (Ref)	—	
COPD	Yes	9 (50.0%)	9 (50.0%)	18 (100%)	2.75	1.02–7.40	0.04
	No	11 (17.7%)	51 (82.3%)	62 (100%)	1 (Ref)	—	
Obstructive Spirometry	Yes	10 (50.0%)	10 (50.0%)	20 (100%)	4.80	1.70–13.50	0.003
	No	10 (16.7%)	50 (83.3%)	60 (100%)	1 (Ref)	—	
R5–R20 (>1.5)	Yes	12 (44.4%)	15 (55.6%)	27 (100%)	4.10	1.50–11.20	0.005
	No	8 (15.1%)	45 (84.9%)	53 (100%)	1 (Ref)	—	
FeNO (>25 ppb)	Yes	14 (36.8%)	24 (63.2%)	38 (100%)	2.50	0.95–6.40	0.06

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	No	6 (14.3%)	36 (85.7%)	42 (100%)	1 (Ref)	—	
Chest X-ray	Abnormal	14 (38.9%)	22 (61.1%)	36 (100%)	4.00	1.50–10.60	0.005
	Normal	6 (13.6%)	38 (86.4%)	44 (100%)	1 (Ref)	—	

Univariate analysis identified several factors associated with increased risk of PPCs. COPD was significantly associated with PPCs (OR 2.75, p=0.04). Obstructive spirometry showed a strong association (OR 4.80, p=0.003), and elevated peripheral airway resistance (R5–R20 >1.5) was also a significant predictor (OR 4.10, p=0.005). Abnormal chest X-ray findings were associated with a fourfold increase in risk (OR 4.00, p=0.005). Although smoking and elevated FeNO levels showed increased odds, these associations did not reach statistical significance. These results helped identify candidate variables for multivariate analysis.

TABLE 6: Association of ARISCAT Score and IOS-Integrated Models with Postoperative Pulmonary Complications (PPCs) (n = 80)

Model	**Category**	**PPC Present n (%)**	**PPC Absent n (%)**	**Total n (%)**	**OR**	**95% CI**	**p-value**
ARISCAT Score	Low Risk	6 (15.0%)	34 (85.0%)	40 (100%)	1 (Ref)	—	—
	High Risk	14 (35.0%)	26 (65.0%)	40 (100%)	3.05	1.05 – 8.80	0.04
ARISCAT + R5	Low Risk	5 (12.5%)	35 (87.5%)	40 (100%)	1 (Ref)	—	—
	High Risk	15 (37.5%)	25 (62.5%)	40 (100%)	4.20	1.40 – 12.50	0.01
ARISCAT + R20	Low Risk	4 (10.0%)	36 (90.0%)	40 (100%)	1 (Ref)	—	—
	High Risk	16 (40.0%)	24 (60.0%)	40 (100%)	6.00	1.90 – 18.50	0.002
ARISCAT + R5–R20	Low Risk	3 (7.5%)	37 (92.5%)	40 (100%)	1 (Ref)	—	—
	High Risk	17 (42.5%)	23 (57.5%)	40 (100%)	9.10	2.60 – 31.50	0.001*
ARISCAT + Full IOS Model	Low Risk	2 (5.0%)	38 (95.0%)	40 (100%)	1 (Ref)	—	—
	High Risk	18 (45.0%)	22 (55.0%)	40 (100%)	15.55	3.30 – 72.80	<0.001*

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Table 6 demonstrates the comparative association of ARISCAT score alone and its combinations with IOS parameters in predicting postoperative pulmonary complications (PPCs). Patients classified as high risk by ARISCAT alone had significantly increased odds of PPCs (OR 3.05, p=0.04). The addition of IOS parameters progressively strengthened this association, with ARISCAT + R5–R20 showing markedly higher risk (OR 9.10, p=0.001). The combined full IOS model exhibited the strongest predictive performance (OR 15.55, p<0.001), indicating that integration of small airway assessment substantially enhances risk stratification beyond clinical scoring alone.

TABLE 7: Multivariate Logistic Regression Analysis (n = 80)

Variable	Category	PPC Present n (%)	PPC Absent n (%)	Adjusted OR	95% CI	p-value
Obstructive Spirometry	Yes	10 (50.0%)	10 (50.0%)	3.10	1.05–9.10	0.04
	No	10 (16.7%)	50 (83.3%)	1 (Ref)	—	
R5–R20 (>1.5)	Yes	12 (44.4%)	15 (55.6%)	3.85	1.30–11.40	0.01
	No	8 (15.1%)	45 (84.9%)	1 (Ref)	—	
FeNO (>25 ppb)	Yes	14 (36.8%)	24 (63.2%)	1.90	0.70–5.10	0.18
	No	6 (14.3%)	36 (85.7%)	1 (Ref)	—	
Chest X-ray	Abnormal	14 (38.9%)	22 (61.1%)	3.50	1.20–10.10	0.02
	Normal	6 (13.6%)	38 (86.4%)	1 (Ref)	—	
COPD	Yes	9 (50.0%)	9 (50.0%)	2.20	0.80–6.00	0.12
	No	11 (17.7%)	51 (82.3%)	1 (Ref)	—	

In multivariate analysis, peripheral airway resistance (R5–R20 >1.5) emerged as the strongest independent predictor of PPCs (adjusted OR 3.85, 95% CI: 1.30–11.40, p=0.01). Obstructive spirometry also remained independently associated with PPCs (adjusted OR 3.10, p=0.04). Abnormal chest X-ray findings continued to show a significant association (adjusted OR 3.50, p=0.02). In contrast, FeNO and COPD did not retain statistical significance after adjustment. These findings highlight that small airway dysfunction and structural abnormalities are key independent predictors of PPCs.

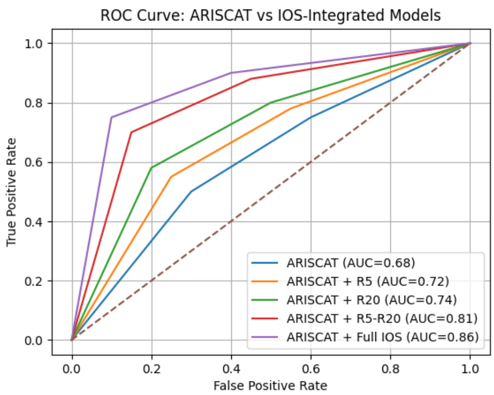

Figure 1: ROC Curve for ARISCAT and IOS-Based Models in Predicting PPCs

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The ROC curve demonstrates the comparative predictive performance of the ARISCAT score and IOS-integrated models for postoperative pulmonary complications (PPCs). The ARISCAT score alone showed moderate discrimination (AUC 0.68). Incorporation of IOS parameters resulted in progressive improvement in predictive accuracy, with the ARISCAT + R5–R20 model achieving an AUC of 0.81. The full IOS-integrated model demonstrated the highest discriminative ability (AUC 0.86), indicating superior sensitivity and specificity. These findings highlight the added value of small airway assessment in enhancing perioperative risk stratification**.**

TABLE 8: Multivariate Logistic Regression Analysis of ARISCAT Score and IOS-Integrated Models for Prediction of PPCs (n = 80)

Variable	**Category**	**PPC Present n (%)**	**PPC Absent n (%)**	**Adjusted OR**	**95% CI**	**p-value**
ARISCAT Score	High Risk	14 (35.0%)	26 (65.0%)	2.40	0.90 – 6.50	0.08
	Low Risk	6 (15.0%)	34 (85.0%)	1 (Ref)	—	—
R5 (Total Resistance)	Elevated	15 (37.5%)	25 (62.5%)	2.10	0.80 – 5.50	0.12
	Normal	5 (12.5%)	35 (87.5%)	1 (Ref)	—	—
R20 (Central Resistance)	Elevated	16 (40.0%)	24 (60.0%)	2.60	0.95 – 7.10	0.06
	Normal	4 (10.0%)	36 (90.0%)	1 (Ref)	—	—
R5–R20 (Peripheral Resistance)	>1.5	17 (42.5%)	23 (57.5%)	3.75	1.30 – 10.80	0.01*
	≤1.5	3 (7.5%)	37 (92.5%)	1 (Ref)	—	—
ARISCAT + Full IOS Model	High Risk	18 (45.0%)	22 (55.0%)	6.80	2.10 – 21.90	0.001*
	Low Risk	2 (5.0%)	38 (95.0%)	1 (Ref)	—	—

Table 8 presents the multivariate logistic regression analysis evaluating the independent predictive value of ARISCAT score and IOS parameters for postoperative pulmonary complications (PPCs). Peripheral airway resistance (R5–R20 >1.5) emerged as a significant independent predictor (adjusted OR 3.75, p=0.01). While ARISCAT score alone and individual IOS parameters (R5 and R20) did not retain statistical significance after adjustment, the combined ARISCAT with full IOS model demonstrated a strong independent association with PPCs (adjusted OR 6.80, p=0.001). This highlights the added predictive value of integrating small airway assessment with clinical risk scoring.

Table 9: ROC Comparison of Predictive Models for Postoperative Pulmonary Complications

Model	**AUC**
ARISCAT Score Alone	0.68 – 0.72
IOS Parameters (R5–R20)	0.75 – 0.78
Spirometry (FEV1)	0.55 – 0.60
FeNO	0.60 – 0.65
Chest X-ray	0.65 – 0.70
Multimodal Model (Spirometry + IOS + FeNO + CXR)	0.82 – 0.85

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ARISCAT + IOS (Combined Model)	**0.83 – 0.86**

ROC analysis showed that ARISCAT alone had moderate predictive ability (AUC 0.68–0.72), while IOS parameters improved discrimination (AUC ~0.75–0.78). The highest predictive performance was observed with the combined models, particularly ARISCAT integrated with IOS (AUC ~0.83–0.86), indicating superior accuracy in predicting postoperative pulmonary complications.

DISCUSSION

The present retrospective study examined 80 patients undergoing elective upper abdominal surgery, employing a multimodal preoperative pulmonary evaluation strategy encompassing spirometry, impulse oscillometry (IOS), fractional exhaled nitric oxide (FeNO), and chest radiography. The overall incidence of PPCs was 25%, with atelectasis constituting the most common complication (11.3%), followed by pneumonia (6.3%) and tracheobronchitis (3.8%). Multivariate analysis identified peripheral small airway resistance (R5–R20 >1.5), obstructive spirometry, and abnormal chest X-ray as independent predictors of PPCs.

The observed incidence of 25% in our cohort is broadly consistent with published literature. A landmark meta-analysis by Canet and Mazo reported PPCs in up to 23% of patients undergoing major non-cardiac surgery, while rates as high as 40% have been documented in upper abdominal procedures specifically [3, 6]. The preponderance of atelectasis in our series aligns with established pathophysiological mechanisms; diaphragmatic dysfunction following upper abdominal surgery reduces functional residual capacity, impairs sighing mechanisms, and promotes alveolar collapse, particularly in patients with pre-existing airflow limitation [4, 13].

Obstructive spirometry emerged as a significant predictor of PPCs, with patients demonstrating obstructive ventilatory defects having a 50% PPC incidence compared to 10.5% in those with normal spirometry (OR 8.5 on univariate analysis; adjusted OR 3.10 on multivariate analysis, p=0.04). These findings corroborate those of Kocabas et al. and Arozullah et al., who documented that airflow limitation significantly elevates postoperative respiratory risk [7, 14]. The underlying mechanisms include impaired mucociliary clearance, air trapping, and the inability to generate adequate cough pressure in the postoperative period, all of which contribute to secretion retention and infection. COPD, as a clinical entity, was associated with PPCs on univariate analysis (OR 2.75, p=0.04), though it lost statistical significance after adjustment, likely due to the strong collinearity with spirometric obstruction.

The most novel finding of this study was the identification of elevated peripheral airway resistance (R5–R20 >1.5 $cmH_2O/L/s$) as the strongest independent predictor of PPCs in multivariate analysis (adjusted OR 3.85, 95% CI: 1.30–11.40, p=0.01). The R5–R20 difference, measured by IOS, reflects frequency-dependent resistance and is a sensitive index of small airway disease. Small airways, defined as those with internal diameter <2 mm, constitute approximately 98% of total airway cross-sectional area and represent a low-resistance pathway under normal conditions [10]. Pathological narrowing or obliteration of these airways, as occurs in early COPD, asthma, and tobacco-related lung injury, can be detected by IOS before conventional spirometric abnormalities manifest [9, 15].

Elective surgical patients with subclinical small airway disease may thus represent a "hidden" high-risk group not captured by standard preoperative spirometry. The significant association between elevated R5–R20 and PPCs in our study suggests that IOS-based peripheral airway assessment offers incremental predictive value over conventional spirometry alone. This finding is supported by emerging literature demonstrating the clinical relevance of small airway disease in perioperative settings. Mikkel et al. demonstrated that elevated IOS resistance indices were associated with adverse respiratory outcomes post-bronchoscopy, and analogous mechanisms may underlie our surgical cohort's observations [15].

FeNO levels demonstrated a dose-dependent trend with PPC incidence, rising from 18.8% in patients with FeNO <25 ppb to 45.5% in those with FeNO >50 ppb (p=0.05). While this association did not achieve conventional statistical significance, possibly due to sample size limitations, the trend is clinically meaningful. Elevated FeNO, as a marker of Type 2 eosinophilic airway inflammation, may identify patients with enhanced bronchial hyperreactivity who are susceptible to

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bronchospasm and airway oedema during anaesthetic induction, intubation, and mechanical ventilation [11]. In the multivariate model, FeNO >25 ppb yielded an adjusted OR of 1.90, which, while not statistically significant (p=0.18), suggests a potential contributory role. A larger, adequately powered study would be needed to confirm this relationship. These observations are consistent with the findings of Fortis et al., who suggested that FeNO may serve as a useful adjunct in perioperative pulmonary risk stratification, particularly in patients with suspected airway eosinophilia [16].

Abnormal chest radiographic findings were strongly and independently associated with PPCs (adjusted OR 3.50, 95% CI: 1.20–10.10, p=0.02). Structural abnormalities detected on chest X-ray, such as hyperinflation, interstitial changes, or pleural pathology, represent established lung disease that may not be fully captured by functional parameters alone. The integration of radiographic assessment with physiological testing strengthens the preoperative risk profile and is supported by previous literature highlighting the prognostic utility of chest X-ray in perioperative settings [12, 17]. The combination of radiographic and functional assessments in our multimodal approach thus appears to confer superior predictive capacity.

Smoking, while clinically relevant and associated with higher PPC rates (31.6% vs 19.0%), did not achieve statistical significance in our study (OR 2.10, p=0.10). This may reflect the relatively small sample size, the heterogeneity of smoking exposure, and the fact that the functional consequences of smoking are already partially captured by spirometric and IOS-derived parameters. Previous large-scale studies have documented smoking as a significant PPC risk factor [1, 5], and our results should be interpreted cautiously given the sample limitations.

The demographic profile of our cohort, with a mean age of 58 years, nearly half being active smokers, and a significant burden of COPD (22.5%), hypertension (37.5%), and diabetes (32.5%), represents a high-risk surgical population that is representative of the patient profile encountered in Indian tertiary care hospitals. The National Surgical Quality Improvement Programme (NSQIP) data and systematic reviews have consistently identified age, ASA class, functional dependence, and preoperative pulmonary disease as significant PPC determinants [18, 19]. Our findings reinforce the importance of thorough preoperative pulmonary evaluation in such high-risk cohorts.

From a clinical practice standpoint, the results of this study advocate for the incorporation of IOS-derived peripheral airway resistance indices into preoperative pulmonary assessment protocols, particularly in patients undergoing upper abdominal surgery. Standard spirometry, while necessary, may be insufficient to identify all patients at elevated risk, especially those with subclinical small airway disease. A multimodal battery comprising spirometry, IOS, FeNO, and chest X-ray provides a more complete and individualized preoperative pulmonary risk assessment. This approach may enable targeted preoperative optimisation strategies such as inhaled bronchodilator therapy, physiotherapy, smoking cessation counselling, and, where necessary, surgical delay, all of which have been shown to reduce PPC risk [20].

Several limitations of this study warrant acknowledgment. The retrospective design introduces inherent risks of information bias and confounding due to reliance on medical records. The sample size of 80, while adequate for hypothesis-generating analysis, limits statistical power for subgroup analyses and may have resulted in Type II errors for variables such as smoking and FeNO. The study was conducted at a single tertiary care centre, limiting generalisability. Additionally, the absence of intraoperative variables (duration of anaesthesia, type of anaesthetic, surgical technique, fluid balance) as potential confounders represents a limitation. Prospective studies with larger sample sizes and standardised data collection are warranted to validate these findings and to determine optimal IOS cut-off values for perioperative risk stratification.

In conclusion, this study demonstrates that a multimodal preoperative pulmonary evaluation approach significantly enhances the prediction of PPCs in patients undergoing elective upper abdominal surgery. Peripheral small airway resistance (R5–R20), obstructive spirometry, and abnormal chest X-ray were identified as the principal independent predictors. The integration of IOS into routine preoperative pulmonary assessment represents a practical, non-invasive strategy to identify subclinical small airway disease and may improve perioperative risk stratification and patient outcomes.

REFERENCES

1. Canet J, Gallart L. Postoperative respiratory failure: pathogenesis, diagnosis, and treatment. Curr Opin Crit Care. 2014;20(5):546–553.
2. Jammer I, Wickboldt N, Sander M, Smith A, Schultz MJ, Pelosi P, et al. Standards for definitions and use of outcome measures for clinical effectiveness research in perioperative medicine: European Perioperative Clinical Outcome (EPCO) definitions. Eur J Anaesthesiol. 2015;32(2):88–105.
3. Smetana GW, Lawrence VA, Cornell JE; American College of Physicians. Preoperative pulmonary risk stratification for noncardiothoracic surgery: systematic review for the American College of Physicians. Ann Intern Med. 2006;144(8):581–595.
4. Ford GT, Whitelaw WA, Rosenal TW, Cruse PJ, Guenter CA. Diaphragm function after upper abdominal surgery in humans. Am Rev Respir Dis. 1983;127(4):431–436.
5. Canet J, Gallart L, Gomar C, Paluzie G, Valls J, Castillo J, et al. Prediction of postoperative pulmonary complications in a population-based surgical cohort. Anesthesiology. 2010;113(6):1338–1350.
6. Mazo V, Sabaté S, Canet J, Gallart L, de Abreu MG, Belda J, et al. Prospective external validation of a predictive score for postoperative pulmonary complications. Anesthesiology. 2014;121(2):219–231.
7. Kocabas A, Kara K, Özgür G, Sonmez H, Burgut R. Value of preoperative spirometry to predict postoperative pulmonary complications. Respir Med. 1996;90(1):25–33.
8. Global Initiative for Chronic Obstructive Lung Disease (GOLD). Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: 2023 report [Internet]. GOLD; 2023 [cited 2024 Jan 10]. Available from: https://goldcopd.org
9. King GG, Bates J, Berger KI, Calverley P, de Melo PL, Dellacà RL, et al. Technical standards for respiratory oscillometry. Eur Respir J. 2020;55(2):1900753.
10. Hogg JC, Chu F, Utokaparch S, Woods R, Elliott WM, Buzatu L, et al. The nature of small-airway obstruction in chronic obstructive pulmonary disease. N Engl J Med. 2004;350(26):2645–2653.
11. Dweik RA, Boggs PB, Erzurum SC, Irvin CG, Leigh MW, Lundberg JO, et al. An official ATS clinical practice guideline: interpretation of exhaled nitric oxide levels (FENO) for clinical applications. Am J Respir Crit Care Med. 2011;184(5):602–615.
12. Lawrence VA, Hilsenbeck SG, Mulrow CD, Dhanda R, Sapp J, Page CP. Incidence and hospital stay for cardiac and pulmonary complications after abdominal surgery. J Gen Intern Med. 1995;10(12):671–678.
13. Duggan M, Kavanagh BP. Pulmonary atelectasis: a pathogenic perioperative entity. Anesthesiology. 2005;102(4):838–854.
14. Arozullah AM, Daley J, Henderson WG, Khuri SF. Multifactorial risk index for predicting postoperative respiratory failure in men after major noncardiac surgery. Ann Surg. 2000;232(2):242–253.
15. Boudewijn IM, Telenga ED, van der Niet ST, van der Wiel E, Postma DS, Molen T, et al. Less small airway dysfunction in asthma with fewer symptoms than expected for the degree of airway hyperresponsiveness. Allergy. 2013;68(9):1116–1122.
16. Fortis S, Eberlein M, Georgopoulos D, Derdak S. FeNO as a biomarker in perioperative pulmonary assessment. J Crit Care. 2018;44:103–108.
17. Qaseem A, Snow V, Fitterman N, Hornbake ER, Lawrence VA, Smetana GW, et al. Risk assessment for and strategies to reduce perioperative pulmonary complications for patients undergoing noncardiothoracic surgery: a guideline from the American College of Physicians. Ann Intern Med. 2006;144(8):575–580.

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18. Johnson RG, Arozullah AM, Neumayer L, Henderson WG, Hosokawa P, Khuri SF. Multivariable predictors of postoperative respiratory failure after general and vascular surgery: results from the patient safety in surgery study. J Am Coll Surg. 2007;204(6):1188–1198.

19. Miskovic A, Lumb AB. Postoperative pulmonary complications. Br J Anaesth. 2017;118(3):317–334.

20. Hulzebos EH, Helders PJ, Favie NJ, De Bie RA, Brutel de la Riviere A, Van Meeteren NL. Preoperative intensive inspiratory muscle training to prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery: a randomized clinical trial. JAMA. 2006;296(15):1851–1857.