Original Article

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Anaesthesia Section

Prediction of Postoperative Pulmonary Complications in Patients undergoing Functional Endoscopic Sinus Surgery: A Cohort Study

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ABSTRACT

Introduction: Considering the pathophysiology of nasal obstruction, changes in certain parameters such as Peripheral Blood Eosinophil Count (PBEC), bedside pulmonary function test, Peak Expiratory Flow Rate (PEFR), and Electrocardiography (ECG) may have some correlation with postoperative pulmonary complications such as upper airway obstruction, loss of pharyngeal muscle tone, and postobstructive pulmonary oedema.

Aim: To observe and analyse the changes in PBEC, bedside pulmonary function test, PEFR, and ECG in patients undergoing Functional Endoscopic Sinus Surgery (FESS).

Materials and Methods: A prospective cohort study was conducted at Bharati Hospital, Pune, Maharashtra, India over a two-year duration from December 2020 to October 2022. A total of 50 patients aged above 18 years undergoing FESS surgery were included in the study. The statistical analysis was performed using the Chi-square test and student's t-test. After thorough preoperative evaluation, the aforementioned predictors were recorded. General anaesthesia management for FESS surgery was done according to the standard protocol. Vigilant intraoperative monitoring of vital parameters including peak airway pressure and plateau pressure was performed. After shifting the patients to the recovery room, they were observed for: 1) Hypoxia; 2) Hypercarbia; 3) Laryngospasm; 4) Bronchospasm; and 5) Pulmonary oedema.

Results: A total of 50 patients aged between 18 years and 65 years with the mean age was 41.7±15.4 years were included in the study, with 32 males and 18 females. Only 24% of the study population showed postoperative hypoxia, while the rest of the complications were not observed in any patient. Changes in eosinophil count, PEFR, and ECG did not have any correlation with postoperative hypoxia and were statistically insignificant. Bedside pulmonary function tests, including the Sabrasez breath-holding test and the Sabrasez single breath count test, showed changes in 30% and 76% of patients, respectively. Forced Expiratory test change was seen in 72% of patients. Among these, 19.4% showed hypoxia. Out of the 12 cases showing postoperative hypoxia, seven had a disease duration of less than six months.

Conclusion: The Sabrasez breath-holding test and Sabrasez single breath count are good predictors for postoperative hypoxia in patients undergoing FESS surgery. Shorter duration of nasal obstruction also showed postoperative hypoxia.

Keywords: Peripheral blood eosinophil count, Postoperative hypoxia, Pulmonary function test

INTRODUCTION

The internal ostium (or nasal valve) is the narrowest portion of the entire airway, accounting for approximately 50% of the total resistance to respiratory airflow. It plays a crucial role in preventing the collapse of the lower respiratory tract [1]. Nasal obstruction can lead to increased oral breathing, reduced filtered air, and increased exposure of the lower airways to allergens, resulting in bronchial hyperresponsiveness and postoperative laryngospasm. Additionally, there is a possibility of undiagnosed obstructive sleep apnoea and the potential presence of the Samter triad (nasal polyps, asthma, and sensitivity to aspirin and NSAIDs), which may cause deadly bronchospasm [2]. This occult pulmonary hypertension is more problematic than fully recognised disease because symptoms may be attributed to other diseases, and perioperative decompensation may occur unexpectedly, sometimes leading to right-sided heart failure (cor pulmonale) [3].

Patients who are muscularly healthy are at an increased risk of postobstructive pulmonary oedema due to their ability to generate significant inspiratory force. The resultant arterial hypoxaemia is usually observed within 90 minutes of upper airway obstruction [4]. According to Westreich R et al., in 2006, surgical operations involving the upper aerodigestive tract have a higher risk of Negative Pressure Pulmonary Oedema (NPPE) than other procedures. Prompt diagnosis and treatment are required to prevent significant patient morbidity [5].

Many times, a young patient with shorter duration of nasal obstruction and classified as American Society of Anaesthesiologists (ASA) I/II, there is possibiity of inadequate counselling and optimisation. This study aimed to predict postoperative pulmonary complications in patients undergoing FESS preoperatively using specific predictors, in order to avoid any untoward effects of these complications. The objective of this study is to predict the possibility of postoperative pulmonary complications (such as hypoxia, hypercarbia, bronchospasm, laryngospasm, and pulmonary oedema) using specific predictors, including: a) PBEC; b) Bedside pulmonary function test; c) PEFR; and d) ECG changes preoperatively in FESS patients.

MATERIALS AND METHODS

A prospective cohort study was conducted at Department of Anaesthesia, Bharati Vidyapeeth Deemed to be University, Pune, Maharashtra, India over a two-year duration from December 2020 to October 2022. This study was conducted after obtaining approval from the Institutional Ethical Committee (BVDUMC/IEC/71) and obtaining informed consent from each study participant who met the inclusion criteria, had nasal obstruction, and underwent FESS.

Inclusion and Exclusion criteria: The study included 50 patients aged over 18 years of both genders. Patients who were not willing to participate or had interstitial lung diseases, COPD, lung fibrosis, or cardiac diseases were excluded from the study.

Sample size calculation: It was calculated using the formula:

$$n=\{Z(\alpha/2)^2\times SD\}/d^2$$

where n represents the sample size estimation, d is the allowable error, $Z\alpha/2$ is the standard normal variate at a 5% level of significance, and SD is the standard deviation from previous studies [6].

Study Procedure

Specific evaluation: The investigator performed the following bedside pulmonary function tests preoperatively:

1) Sabrasez breath-holding test: The patient was asked to take a deep breath and hold it for as long as possible. A duration of >40 seconds was considered as normal cardiopulmonary reserve.

2) Sabrasez single breath count: The patient was asked to take a deep breath followed by counting 1, 2, 3, and so on until they could no longer hold their breath. A count of >30 indicated normal vital capacity.

3) Forced Expiratory Time (FET): The patient was asked to take a deep breath and exhale maximally and forcefully. A stethoscope was placed on the trachea to appreciate the exhalation sounds. A normal FET duration is 3-5 seconds [7].

Along with routine investigations, three specific investigations were recorded: PEFR, PBEC and ECG. The PEFR was measured using a Mini Wright peak expiratory flowmeter, as shown in [Table/Fig-1]. The normal peak flow is 450-550 L/min in adult males and 320-470 L/min in adult females [8].

[Table/Fig-1]: Mini wright peak expiratory flow meter.

Raised PBEC (serum eosinophilia) was defined as an eosinophil count greater than 6% or >0.60 th/µL [9]. Preoperative ECG changes, such as ST-T changes and T-wave changes, were recorded.

General anaesthesia management for FESS surgery followed the standard protocol. Induction was done with Inj. Propofol 2 mg/kg, and intubation was performed under the effect of Inj. Atracurium/ Vecuronium. Maintenance was carried out with Sevoflurane 1-2% and Inj. Dexmedetomidine 0.5-1 mcg/kg as required.

Intraoperative monitoring of vital parameters, including pulse rate, blood pressure, oxygen saturation, end-tidal carbon dioxide, ECG, peak airway pressure, plateau pressure, and positive end-expiratory pressure, was conducted during induction, 30 minutes, 1 hour, 2 hours of surgery, and during reversal. Variations in these parameters and clinical findings in the cardiorespiratory system were recorded.

Following extubation, patients were observed for two hours in the Postoperative Care Unit (PACU) for the following:

1. Hypoxia
2. Hypercarbia
3. Laryngospasm
4. Bronchospasm
5. Pulmonary oedema.

Considering the residual effects of sedatives and oral breathing in FESS patients postoperatively, all patients received supplemental oxygen therapy with a Hudson mask at a rate of 4-5 litres per minute for the first hour. Hypoxia was detected using pulse oximetry, while continuous monitoring of hypercarbia was not possible. Laryngospasm, bronchospasm, and pulmonary oedema were ruled out through auscultation and clinical examination.

STATISTICAL ANALYSIS

Descriptive statistics were used to describe the data. The mean and Standard Deviation (SD) were used to describe the numerical data, while frequency and percentage were used to describe categorical data. The intergroup statistical comparison of the distribution of categorical variables was tested using the Chi-square test. The inter-group statistical comparison of means for normally distributed continuous variables was performed using independent sample t-test. Throughout the entire study, a p-value <0.05 was considered to indicate statistical significance. The data was analysed using the Statistical Package for the Social Sciences (SPSS ver 22.0, IBM Corporation, USA) for MS Windows.

RESULTS

In this study, the mean age was 41.7±15.4 years. Out of the 50 patients, 64% were male and 36% were female. There was no statistically significant difference observed in terms of age (p=0.32), gender (p=0.246), American Society of Anaesthesiologists (ASA) grading (p=0.171), and postoperative hypoxia. Only 24% of the patients experienced postoperative hypoxia. Among patients aged 18-30 years with a disease duration of less than six months, changes in predictors were observed. Out of the total 21 patients with a disease duration of less than six months, 7 (33%) experienced postoperative hypoxia, as shown in [Table/Fig-2].

Variables		Event		Total	p-value
		Hypoxia (n=12)	No hypoxia (n=38)		
Age (years)	18-30	2	12	14	0.352
	31-40	3	7	10	
	41-50	2	10	12	
	51-60	1	5	6	
	>60	4	4	8	
Gender	Female	6	12	18	0.246
	Male	6	26	32	
ASA	I	6	26	32	0.171
	II	6	9	15	
	III	0	3	3	
Duration of disease	<6 months	7	14	21	0.05
	6-12 months	0	12	12	
	1-5 years	5	5	10	
	5-10 years	0	4	4	
	10-15 years	0	2	2	
	15-20 years	0	1	1	

[Table/Fig-2]: Descriptive analysis of demographics, ASA, duration of disease preoperatively.
p-value by Chi-square test; p-value <0.05 was considered to be statistically significant; p-value >0.05 non significant

[Table/Fig-3] displays the changes in eosinophil count, ranging from 7-13%, seen in 5 (10%) patients. Among them, 2 (40%) experienced hypoxia. PEFR change was observed in 31 (62%) patients, with 11 (35.4%) experiencing hypoxia. ECG changes were seen in 10 (20%) patients, with 2 (20%) experiencing hypoxia.

Bedside pulmonary function tests, including the Sabrasez breath-holding test, showed changes in 15 (30%) patients, among whom 8 (53.3%) experienced hypoxia. Changes in the Sabrasez single breath count test were observed in 38 (76%) patients, with 12 (31.5%) experiencing hypoxia. Forced expiratory test changes were seen in 36 (72%) patients, with 7 (19.4%) experiencing hypoxia, as shown in [Table/Fig-3].

[Table/Fig-4,5] indicate no significant changes in intraoperative parameters such as Pulse Rate (PR), Blood Pressure (BP), Respiratory Rate (RR), Oxygen Saturation (SpO_2), End-Tidal Carbon Dioxide ($ETCO_2$), peak airway pressure, and plateau pressure, monitored at various intervals. However, patients showed significant changes in postoperative parameters such as SpO_2 (p-value=0.0018), RR (p-value=0.002), and postoperative oxygen requirement (p-value=0.0001), with no significant change in $ETCO_2$ at different intervals.

Patients who experienced hypoxia showed a mean saturation of 92.75±2.3, which was statistically significant (p-value=0.001). These patients also exhibited an increased requirement for prolonged oxygen support, which was statistically significant (p-value=0.001), as shown in [Table/Fig-6].

[Table/Fig-7] demonstrates no statistically significant correlation between individual predictors and the duration of the disease. Only PBEC showed a positive correlation (r value=1) with disease duration, while the other predictors showed weakly negative or no correlation.

Predictors		Event		Total	p-value
		Hypoxia (n=12)	No hypoxia (n=38)		
Peripheral Blood Eosinophil Count (PBEC)	Normal (<6%)	10	35	45	0.582
	Abnormal (>6%)	2	3	5	
Peak Expiratory Flow Rate (PEFR)	>350 L/min	1	18	19	0.468
	250-350 L/min	9	14	23	
	<250 L/min	2	6	8	
Sabrasez breath-holding test	Normal Cardiac reserve (>40 sec)	4	31	35	0.003
	Limited Cardiac reserve (15-20 sec)	7	7	14	
	Very poor cardiac reserve (<15 sec)	1	0	1	
Sabrasez single breath count	Normal (>30)	0	12	12	0.047
	Abnormal	12	26	38	
Forced expiratory test	Normal (3-5 sec)	5	9	14	0.226
	Obstructive (>6 sec)	7	29	36	
ECG changes	Normal	10	30	40	0.999
	Abnormal	2	8	10	

[Table/Fig-3]: Descriptive analysis of predictors with hypoxia.
p-value by chi-square test. p-value <0.05 is considered to be statistically significant; p-value >0.05 non significant

Parameters	Preinduction	Postindution	30 min	1 hr	2 hrs	Reversal	p-value
Pulse Rate (/min) (PR)	81.7±5.1	80.3±5.4	78.5±5.0	77.6±4.6	77.3±4.6	88.2±3.9	0.891
Systolic Blood Pressure (mmHg) (SBP)	119.5±7.1	115.6±7.5	113.4±7.4	112.6±7.4	113.0±7.5	121.9±5.9	0.923
Diastolic Blood Pressure (mmHg) (DBP)	78.2±7.2	75.8±7.3	74.1±7.0	73.6±6.4	73.8±6.3	81.2±6.5	0.944
Respiratory rate (/min) (RR)	15.5±1.5	15.5±1.7	15.6±2.01	15.5±2.07	15.2±2.4	15.4±1.83	0.168
SPO_2 (%) (Oxygen saturation)	97.9±1.1	99.3±0.7	99.4±0.67	99.4±0.67	99.4±0.67	99.4±0.7	0.641
End tidal carbon dioxide (mmHg) ($ETCO_2$)	34.3±2.8	37.3±2.4	36.9±2.3	36.7±2.3	36.3±2.4	36.5±2.4	0.592
peak airway pressure (cmH_2O)		14.5±2.3	15±2.2	14.6±3.6	15.2±2.4	15.3±2.6	0.237
Plateau pressure (cmH_2O)		25±3.4	26±2.6	26.2±2.0	26.4±2.2	25±2.6	0.386

[Table/Fig-4]: Descriptive analysis of preoperative and intraoperative parameters.
Values presented as Mean±SD; Chi-square test applied, p-value >0.05 non significant

Parameters	0 minute	15 minutes	30 minutes	45 minutes	1 hour	2 hours	p-value
Pulse Rate (/min) (PR)	81.5±0.8	81.4±0.7	81.6±0.7	81.8±0.7	81.9±0.7	81.9±0.7	0.07
Systolic Blood Pressure (mmHg) (SBP)	120.5±1.0	119.3±1.0	118.8±1.0	118.4±1.0	119.0±1.0	118.2±0.9	0.389
Diastolic Blood Pressure (mmHg) (DBP)	78.2±1.0	75.8±1.0	74.1±0.9	73.6±0.9	73.8±0.8	81.2±0.9	0.944
SPO_2 (%)	98.3±2.4	98.4±2.2	98.3±1.9	98.2±1.8	98.1±1.6	98.1±1.4	0.0018
$ETCO_2$ (mmHg)	26.8±1.4	27.6±1.8	27.5±1.97	27.3±2.03	27.1±2.0	27±1.9	0.380
RR (/min)	17.5±1.8	17.2±1.7	16.6±1.6	16±1.7	15.8±1.6	15.8±1.6	0.002
Postoperative oxygen requirement (Lit/min)	8±1.6	7.8±1.5	7.16±1.0	6.5±1.3	5.6±1.3	5.3±1.3	0.0001

[Table/Fig-5]: Descriptive analysis of postoperative parameters.
Values presented in Mean±SD; Chi-square test applied, p-value <0.05 significant, p-value >0.05 non significant

Parameters	Hypoxia (n=12) {Mean±SD}	No hypoxia (n=38) {Mean±SD}	p-value
Oxygen saturation on room air (Pre-op) (%)	98±1.27	97.89±1.13	0.745
Post-op O_2 Requirement (Lit/min)	8±1.9	4.21±1.9	0.0001

Oxygen saturation on room air (Post-op) (%)	92.75±2.30	99.63±0.58	0.0001
Duration of O_2 Requirement	11.3±7.54	2.42±1.76	0.0001

[Table/Fig-6]: Descriptive analysis of postoperative parameters in patients.
Student t-test applied, p-value <0.05 significant, p-value >0.05 non significant

Predictors		Duration of disease (months)						r value (Pearson coefficient)	p-value
		≤12 months		>12 months		Total			
		n	%	n	%	n	%		
Peripheral Blood Eosinophil Count (PBEC)	Normal	29	64.4	16	35.6	45	100.0	1	0.650
	Abnormal	4	80.0	1	20.0	5	100.0		
Peak Expiratory Flow Rate (PEFR)	Normal	8	57.1	6	42.9	14	100.0	-0.01	0.410
	Abnormal	25	69.4	11	30.6	36	100.0		
ECG	Normal	27	67.5	13	32.5	40	100.0	-0.17	0.717
	Abnormal	6	60.0	4	40.0	10	100.0		
Sabrasez breath-holding test	Normal	24	68.6	11	31.4	35	100.0	-0.083	0.558
	Abnormal	9	60.0	6	40.0	15	100.0		
Sabrasez single breath count	Normal	8	66.7	4	33.3	12	100.0	-0.13	0.999
	Abnormal	25	65.7	13	34.2	38	100.0		
Forced expiratory test	Normal	7	50.0	7	50.0	14	100.0	-0.254	0.187
	Abnormal	26	72.2	10	27.8	36	100.0		

[Table/Fig-7]: Correlation of duration of disease with specific predictors.
p-value by Chi-square test. p-value >0.05 non significant

DISCUSSION

Out of the 50 patients, 14 were in the age group of 18-30 years, and 10 were in the age group of 31-40 years. Even the younger age group displayed deranged predictor values preoperatively. Yancey KL et al., in 2019, stated that age may have a substantial impact on the pathogenesis of chronic rhinosinusitis, the severity of symptoms (which is more common in the middle-aged group), and the outcomes of surgery. Older patients tend to report smaller improvements in disease-specific and general health quality of life after surgery [10].

A total of 21 (42%) patients had a disease duration of less than six months. In younger patients with a shorter disease duration, there is a possibility of failure to anticipate functional limitations and face critical situations without adequate preparation. The sudden hyperresponsiveness of the airways in the perioperative period and reduced hypoxic reserve in such patients can lead to postoperative pulmonary complications. Lukannek C et al., in 2019, stated that postoperative pulmonary complications are associated with an increase in mortality, morbidity, and healthcare utilisation. They validated the Score for the Prediction of Postoperative Respiratory Complications (SPORC-2), an instrument for stratified assessment of a patient's risk of early tracheal reintubation after surgery. It may also prove beneficial in supporting clinicians in their efforts to advance patient safety and decrease the risk of early postoperative tracheal re-intubation [11].

In this study, five patients showed eosinophil count changes ranging from 7-13%. A similar study conducted by Bachert C et al., in 2000, stated that eosinophils are the major effector cells in the pathogenesis of nasal polyps [12].

In this study, PEFR changes were observed in 36 patients. Out of these, a total of 25 had a disease duration of less than 12 months (p-value=0.05). Among them, 10 (27.8%) experienced hypoxia. Additionally, 28 patients (56%) had PEFR values ranging from 250-350 L/min, and 9 (75%) of them experienced hypoxia. Eight patients (16%) displayed reduced PEFR values <250 L/min preoperatively, and 2 (16.7%) of them experienced hypoxia. Therefore, even in patients with a shorter duration of disease, the respiratory system does not function optimally during anaesthesia management. In 2005, Dikshit MB et al., stated that PEFR is a measurement of ventilatory function and was accepted as an index of spirometry in 1949. By definition, it is "The largest expiratory flow rate achieved with a maximally forced effort from a position of maximal inspiration, expressed in litres/min" [13]. Sitalaxmi R et al., in 2013, stated that the functioning of the larger airways is reflected by PEFR, and any stress, infection, or inflammation in these airways can cause adverse reactions [8]. Ehnhage A et al., in 2009, concluded that FESS has beneficial effects on asthma in patients with nasal polyposis, as it improves asthma symptoms, PEFR, and olfaction [14].

Out of the 10 patients displaying preoperative ECG changes (T wave inversion and ST-T changes), six of them had a disease duration of less than 12 months. Among them, 2 (20%) experienced hypoxia. Bhattacharyya N in 2020 stated that Chronic Rhinosinusitis (CRS) alone does not objectively contribute to systemic hypoxaemia, although a subset of Chronic Rhinosinusitis with Nasal Polyposis (CRSwNP) may have abnormally low SpO_2, possibly warranting SpO_2 assessment in such patients [15]. Fidan V and Aksakal E, in 2011, stated that upper respiratory tract obstruction has been reported to increase mean Pulmonary Artery Pressure (mPAP), leading to pulmonary hypertension and cor pulmonale. Surgical intervention improves mPAP, pulmonary function tests, and oxygen saturation [16]. Şimşek E et al., in 2017, stated that treatment of upper airway obstruction in adult patients with nasal polyps may result in improved right ventricular systolic functions and provide a substantial decrease in Pulmonary Artery Systolic Pressure (PASP) values [6].

The changes observed in the Sabrasez breath-holding test and Sabrasez single breath count test were significant. Out of 50 patients, a change in the forced expiratory test was seen in 36 patients. Among them, 26 had a disease duration of less than 12 months. These patients showed a forced expiratory test of >6 seconds, suggesting obstructive lung disease. Additionally, 7 of these patients (58.3%) showed hypoxia. A total of 14 patients had a normal forced expiratory test ranging from 3 to 5 seconds, and 5 of them (41.6%) showed hypoxia. It is important to note that the number of cases included was limited due to availability. The duration of the disease did not significantly impact the predictor change, as changes were observed in both patients with disease duration <12 months and >12 months, with a non significant p-value.

Zhang L et al., proposed that a decrease in FEV1 and FEV25-75 was more frequent in patients with raised PBEC (peripheral blood eosinophil count) who had CRSwNP. This suggests that PBEC in these patients can reflect decreased lung function [17]. In a study conducted by Karuthedath S et al., preoperative pulmonary function tests were compared with postoperative values in patients with chronic rhinosinusitis. It was concluded that chronic rhinosinusitis affected patients in their fourth decade of life. Furthermore, there was a significant improvement in the FEV1/FVC ratio postoperatively in the third month [18].

In 2000, Lamblin C et al., stated that patients with steroids non responsive Nasal Polyposis (NP) treated by nasal surgery were associated with a progressive decline in FEV1 and the appearance of airflow obstruction four years after intranasal ethmoidectomy, regardless of the existence of non specific Bronchial Hyper-Responsiveness (BHR) [19]. Therefore, anticipation of functional limitation of the cardiorespiratory system and adequately preparing with predictors is the wise approach. Lee SY et al., concluded that decreased lung function was correlated with CT findings suggesting chronic sinusitis and nasal polyps in subjects without lower respiratory disease, and the severity of CT findings of sinusitis was related to the degree of airway obstruction [20]. Additional relevant information regarding the airway can be obtained from X-ray head and neck and Computed Tomography (CT) scan findings, which are usually performed preoperatively by the surgeon.

Limitation(s)

A limited number of cases were included in the study due to Coronavirus Disease-2019 (COVID-19), and cases complicated by COVID-19 infection were not considered. Continuous monitoring of end-tidal CO_2 on spontaneous ventilation was unavailable, and the minimal oxygen requirement for individual patients could not be assessed due to the inability to use nasal prongs.

CONCLUSION(S)

Preoperative risk anticipation can be achieved with the help of predictors such as the Sabrasez single breath count and Sabrasez breath-holding test to assess postoperative hypoxia in patients undergoing FESS. Additionally, these patients may require oxygen support for a longer duration. Other predictors, such as Peripheral Blood Eosinophil Count (PBEC), Peak Expiratory Flow Rate (PEFR), and ECG changes, did not show a significant change in relation to this sample size. Interestingly, even patients with a shorter duration of disease (<6 months) exhibited changes in these predictors.

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