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Pulmonary Function of Patients with Chronic Rhinosinusitis and the Impact of Endoscopic Sinus Surgery

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Abstract

Objective. The aim of this study was to compare pulmonary function tests (PFTs) among control subjects and patients with chronic rhinosinusitis (CRS) and to investigate the outcomes of endoscopic sinus surgery (ESS) on PFTs among patients with CRS.

Study Design. Prospective study conducted from June 2015 to June 2016.

Setting. Tertiary referral hospital.

Subjects and Methods. The study is based on 2 groups: adult control subjects (group 1, n = 25) and adult patients with medically resistant CRS (group 2, n = 25). PFTs were used to compare the lower airway condition between the groups. Another comparison in PFTs was made among patients with CRS at 1 week preoperatively and 1 month postoperatively to evaluate the effectiveness of ESS.

Results. In group 1, all subjects had an FEV1/FVC ratio $\geq$80% (forced expiratory volume in 1 second / forced vital capacity) with a mean of 0.84 $\pm$ 0.07, as compared with group 2, from 61% to 70% for 5 (20%) patients, 71% to 79% for 10 (40%), and $\geq$80% for 10 (40%). FEV1/FVC was significantly lower in group 2 than group 1 (P = .04). At 1 month postoperatively, the FEV1/FVC values of group 2 was from 61% to 70% for 2 (8%) patients, 71% to 79% for 13 (52%), and $\geq$80% for 10 (40%). The mean FEV1/FVC was 0.9 $\pm$ 0.50, and these values were significantly higher (P = .02) when compared with preoperative values.

Conclusion. This study provides objective evidence that patients with CRS may have nonmanifest lower airway affection when compared with control subjects and that ESS is efficacious in the improvement of such affection.

Keywords

chronic rhinosinusitis, pulmonary function tests, endoscopic sinus surgery

Chronic rhinosinusitis (CRS) is an inflammatory disease of the mucosa of the nasal cavity and paranasal sinuses, with symptoms lasting >12 weeks. It is a common disease and represents a public health problem resulting in socioeconomic burden throughout the world.[1,2] The pathogenesis of CRS is poorly understood; however, genetic susceptibility, infection, anatomic abnormalities, and local immunologic imbalance have been postulated to play roles in its pathogenesis.[3-5] Treatment options for CRS include medical therapy, surgical intervention, or both. According to current guidelines, the surgical approach is reserved for patients who fail to respond adequately to medical therapy. The most frequently used surgical technique is endoscopic sinus surgery (ESS).[6]

A close association has been suggested between sinusitis and lower respiratory disorders such as bronchial asthma.[7-9] Clarifying and understanding the relationship between diseases of the upper and lower respiratory tract is important because of the prevalence of rhinosinusitis and asthma and the resulting burden on patients and the health care system.[10]

Although clinical evidence is accumulating that CRS exacerbates lower airway disease, more direct and objective studies are needed to elucidate the important role that CRS may play in lower airway disease.[11] Direct evidence of an association could be obtained by examining the effect of CRS treatment on pulmonary symptoms and functions. Appropriate medical treatment for CRS has been reported to

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have a beneficial effect on asthma symptoms.[12,13] The present study focuses on the difference of lung functions among patients with resistant CRS as compared with control subjects; it also focuses on the benefits of ESS on the lung functions of these patients.

Methods

Our prospective study was conducted in the Department of Otolaryngology–Head and Neck Surgery, Minia University Hospital, Minia, Egypt, between January 2014 and January 2015. The study was approved by the Institutional Review Board at Minia University (registration NBA5574884). All participants provided informed consent. The sampling was conducted according to the nonprobability sample (quota sample). We selected patients with CRS without nasal polyps using strict inclusion and exclusion criteria. Fifty adult subjects were enrolled in the study and were divided into 2 groups (n = 25 each): group 1, control subjects; group 2, patients with CRS.

Inclusion Criteria

The study included 25 adult control subjects and 25 adult patients with medically resistant CRS, diagnosed according to the definition of the consensus report of the Rhinosinusitis Task Force,[14] as the presence of symptoms and classic physical examination findings confirmed by soft tissue involvement of the paranasal sinuses on computed tomography (CT) scan lasting for at least 3 months after maximal medical therapy.

Exclusion Criteria

Patients with any of the following conditions were excluded: nasal polyps, nasal allergy, bronchial asthma, allergic fungal sinusitis, chronic obstructive pulmonary disease, cystic fibrosis, primary ciliary dyskinesia, immunodeficiency, pregnancy, coexistent systemic diseases (eg, diabetes, hypertension, neoplasia), and prior paranasal sinus surgery. Patients who were lost to follow-up were also excluded.

CRS Assessment

Subjective CRS assessment was obtained from all patients reporting the following symptoms: nasal congestion, facial pain or pressure, headache, nasal discharge, olfactory disturbance, and overall discomfort.

The Lund-Mackay CT scoring system[15] was used to separately assess the extent of the opacification of the individual sinuses and osteomeatal complex, and a score of 2, 1, or 0 was respectively assigned if there was complete, partial, or no opacification.

Allergy assessment was based on the presence of at least 1 positive skin test result on the Regional Area 10 Allergy Test Panel with an allergenic extract from Allergy Laboratories, Inc (Oklahoma City, Oklahoma).

Intensity of smoking was assessed according to a smoking index that was calculated by multiplying the number of packs of cigarettes smoked per day by the number of years that a person had smoked: mild (<10 cigarettes/day), moderate (10-20), and heavy (>20).

Lower Airway Assessment

Clinical Assessment. Symptoms of the lower airway were reported, including cough, sputum, dyspnea, chest pain, wheezes, and hemoptysis. We excluded patients with the diagnosis of asthma according to guidelines per the National Institutes of Health for the diagnosis and management of asthma.[16] To establish the diagnosis and to differentiate between asthma and chronic obstructive pulmonary disease, reversibility was tested with short-acting bronchodilators and, when the forced expiratory volume in 1 second (FEV1) was <60%, with corticosteroids. Reversibly was a diagnostic potential for bronchial asthma. Chest x-ray (posterior-anterior and lateral views) were obtained for each patient to identify any concomitant disease in the lungs.

Pulmonary Function Tests. Pulmonary function tests were performed with a spirometer (Lab Digital Spirometer 762600; Sensormedics, Homestead, Florida) according to the standardization of lung function tests of the European Respiratory Society.[17] In a normal case, forced vital capacity (FVC) and FEV1 should be ≥80% of the predicted value for a patient's age, height, and weight. An obstructive ventilatory defect was defined as a decrease in FEV1 out of proportion to any decrease in FVC (ie, a decrease in the FEV1/FVC ratio). The severity of lower airway obstruction was assessed as follows: an FEV1/FVC ratio from 71% to 79% was regarded as mild obstruction; 61% to 70%, moderate; and ≤60%, severe.[18]

Pulmonary function tests (PFTs) were done for group 2 patients at 1 week pre-ESS and 1 month post-ESS.

Surgical Steps

Written informed consent was obtained from the patients with CRS before ESS, and patients were provided with all information, including the details of their disease, the procedure, the risks of the procedure, and the possible outcomes. ESS was performed under general anesthesia by the Messerklinger technique.[6]

Five patients with marked septal deviation obstructing 1 nasal cavity had septoplasty. An infundibulectomy was performed by incising the anterior attachment of the uncinate process; then, the ethmoidal bulla was opened and removed piecemeal. The decision to open the maxillary antrum and explore the frontal recess, the posterior ethmoids, and the sphenoid depended on the extent of the disease as evidenced by the CT scan and operative findings. Merocel packs were left in the nasal cavities, and the patient was kept in the hospital overnight and discharged in the morning.

Follow-up

Packs were removed after 48 hours, and patients were prescribed antibiotics for 7 to 10 days with alkaline nasal douching and intranasal corticosteroid spray for 1 month

Table 1. Population Characteristics in Group 1 vs Group 2.[a]

Demographics	Group 1	Group 2	P Value[b]
Age, y			.494
Mean ± SD	28.95 ± 9.83	27.1 ± 6.86	
Range	18-49	18-39	
Sex, n (%)			.525
Male	15 (60)	12 (48)	
Female	10 (40)	13 (52)	
Weight, kg			.391
Mean ± SD	67.45 ± 6.3	69.7 ± 9.72	
Range	55-78	60-88	
Height, cm			.449
Mean ± SD	166.2 ± 8.55	164 ± 3.68	
Range	147-180	158-170	
Smoking index, n (%)			.0264
Heavy smokers	6 (43)	7 (44)	
Moderate smokers	4 (28.5)	5 (31)	
Mild smokers	4 (29.5)	4 (25)	
Nonsmokers	11	9	

[a]Group 1 (n = 25), control subjects; group 2 (n = 25), patients with chronic rhinosinusitis.
[b]$P \leq .05$ (*t* test).

Table 2. Frequency of Common Chronic Rhinosinusitis Symptoms in Group 2.

Symptom	Patients, n (%)
Need to blow nose	10 (40)
Sneezing	5 (20)
Runny nose	3 (12)
Difficulty falling asleep	4 (16)
Facial pain/pressure	20 (80)
Headache	15 (60)
Postnasal discharge	12 (48)

Table 3. Computed Tomography Sinus Score in Group 2 Patients (Chronic Rhinosinusitis).[a]

	Right Side			Left Side		
	0	1	2	0	1	2
Frontal	80	15	5	90	5	5
Maxillary	5	80	15	10	80	10
Anterior ethmoidal	15	70	15	15	70	15
Posterior ethmoidal	25	65	10	20	70	10
Sphenoid	80	10	10	80	10	10
Osteomeatal complex	20	—	80	20	—	80

[a]Values are presented as percentages.

postoperatively. None of our patients in group 2 had systemic corticosteroids throughout the study period.

Statistical Analysis

Statistical analysis was performed with SPSS 12.0 (IBM Inc, Chicago, Illinois). Results are expressed as the mean and standard deviation for continuous variables and as percentages for categorical variables. Data were compared with the *t* test or a Mann-Whitney test and a χ^2 test as appropriate. $P \leq .05$ was considered statistically significant.

Results

Our study included 2 groups: group 1, control (n = 25); group 2, patients with CRS who had undergone ESS (n = 25). PFTs were measured in both groups: comparison was made between group 1 and group 2 preoperatively; another comparison was made between group 2 pre- and postoperatively.

Subjects Characteristics

Table 1 presents the age, sex, and demographic data distribution, with no statistically significant difference between the 2 groups. Smoking history presented a significant difference between the 2 groups.

CRS Symptoms

Table 2 presents the common symptoms of patients with CRS, with facial pain and headache the most frequent symptoms.

CT Lund-Mackay Sinus Score

The maximum number of patients had a score of 14 (9 cases; **Table 3**). The most affected group of sinuses was the maxillary sinuses, and the least affected group was the sphenoid. The osteomeatal complex was affected in 80% of patients.

Lower Airway Assessment

Lower Airway Symptoms. We assessed lower airway symptoms with a visual analog score; chronic cough was the most frequent symptom in 10 (40%) patients of group 2.

Preoperative PFTs: Group 1 vs Group 2. **Table 4** presents PFTs values in group 1 subjects versus group 2 preoperative PFT values. There was a statistically significant difference regarding FEV1 mean and percentage between the 2 groups (P = .05 and $P < .001$, respectively), with better values in group 1. There was also a statistically significant difference regarding FVC mean and percentage between the 2 groups (P = .02 and $P < .001$, respectively), with better values in group 1. FEV1/FVC was significantly lower in group 2 patients than in group 1 subjects (P = .04). Patients who had marked septal deviation and required septoplasty as a step in ESS had no significant differences (P = .4) in their preoperative PFTs as compared with other patients with CRS.

Pre- vs Postoperative Change of PFTs: Group 2. **Table 5** presents change of PFTs in group 2 (pre- and postoperative values). There was a statistically significant difference regarding FEV1 mean and percentage (P = .03 and P = .001, respectively), with better postoperative values. There

Table 4. Preoperative Pulmonary Function Tests: Group 1 vs Group 2.[a]

	Group 1	Group 2	*P* Value[b]
FVC			
Mean ± SD (range)	3.94 ± 0.88 (2.5-5.17)	3.45 ± 0.78 (2.39-5.04)	.02
Mean ± SD (range), %	99.95 ± 9.27 (87-113)	84.8 ± 11.51 (60-99)	<.001
FEV1			
Mean ± SD (range)	3.35 ± 0.87 (1.91-4.24)	3 ± 0.54 (2.17-4.05)	.05
Mean ± SD (range), %	103.15 ± 9.84 (90-116)	89.9 ± 9.91 (74-109)	<.001
FEV1/FVC: mean ± SD (range)	0.84 ± 0.07 (0.76-0.95)	0.88 ± 0.7 (0.78-1)	.04

Abbreviations: FEV1, forced expiratory volume in 1 second; FVC, forced vital capacity.
[a]Group 1 (n = 25), control subjects; group 2 (n = 25), patients with chronic rhinosinusitis.
[b]*P* ≤ .05 (Mann-Whitney test; all values are significant).

Table 5. Pre- vs Postoperative Pulmonary Function Tests: Group 2.[a]

	Pulmonary Function Tests		
	Preoperative	Postoperative	*P* Value[b]
FVC			
Mean ± SD (range)	3.45 ± 0.78 (2.39-5.04)	3.57 ± 0.81 (2.62-5.02)	.033
Mean ± SD (range), %	84.8 ± 11.51 (60-99)	91.4 ± 11.09 (72-109)	<.001
FEV1			
Mean ± SD (range)	3 ± 0.54 (2.17-4.05)	3.09 ± 0.53 (2.36-3.86)	.033
Mean ± SD (range), %	89.9 ± 9.91 (74-109)	99.1 ± 13.17 (83-125)	.001
FEV1/FVC: mean ± SD (range)	0.88 ± 0.7 (0.78-1)	0.88 ± 0.6 (0.77-0.95)	.02

Abbreviations: FEV1, forced expiratory volume in 1 second; FVC, forced vital capacity.
[a]Group 2 (n = 25), patients with chronic rhinosinusitis.
[b]*P* ≤ .05 (Mann-Whitney test; all values are significant).

was also a statistically significant difference regarding FVC mean and percentage (*P* = .02 and *P* = .001, respectively), with better postoperative values. FEV1/FVC was significantly higher in postoperative values (*P* = .02) versus preoperative values. Patients who had septoplasty had no significant difference (*P* = .08) in their postoperative PFTs when compared with patients who did not have septoplasty.

When we compared the postoperative PFTs of group 2 patients with the PFTs of group 1 patients, we found no significant difference between the 2 groups in the all assessed parameters (**Table 6**).

Discussion

Rhinosinusitis significantly affects quality-of-life measures with decrements in general health perception, vitality, and social functioning comparable with that observed among patients who have angina or chronic obstructive pulmonary disease.[19] This disease is also one of the main reasons for which antibiotics are prescribed and for lost productivity in the workforce.[20] Scientists have long recognized that diseases coexist in the upper and lower airways. The ''united airways'' concept implies that there is a link between upper and lower airway inflammation. In the second century, Galen noted the association between nasal symptoms and asthma and advocated purging the nostrils of secretions to relieve the lower airways.[21] Chen et al[22] reported that asthma was associated with increased risks of CRS, with and without nasal polyps, among 81,462 patients. Chien et al[23] reported that chronic obstructive pulmonary disease was associated with an increased risk of CRS without nasal polyps, independent of a number of potential confounding factors.

Our prospective study was conducted in a tertiary referral institution to compare the PFTs of control subjects and patients with medically resistant CRS and to assess the impact of ESS on PFTs for these latter patients, comparing the pre- and postoperative values. The study included patients of varied age groups, varied socioeconomic status, and both sexes. The results were compared with the available literature.

In our study, 11 (45%) patients had a CT score of about 14. In a study conducted by Wang et al,[24] 51.3% of patients had a CT score in the range of 2 to 4. These findings suggest that the majority of our patients with CRS presented to our hospital at a relatively late stage of the disease. For our study, the most common group of sinuses involved was the maxillary sinus, which was involved in all patients; this finding matches most of the published data.[25]

Table 6. Postoperative Pulmonary Function Tests: Group 1 vs Group 2.[a]

	Group 1	Group 2	*P* Value[b]
FVC			
Mean ± SD (range)	3.94 ± 0.88 (2.5-5.17)	3.57 ± 0.81 (2.62-5.02)	.523
Mean ± SD (range), %	99.95 ± 9.27 (87-113)	91.4 ± 11.09 (72-109)	.321
FEV1			
Mean ± SD (range)	3.35 ± 0.87 (1.91-4.24)	3.09 ± 0.53 (2.36-3.86)	.060
Mean ± SD (range), %	103.15 ± 9.84 (90-116)	99.1 ± 13.17 (83-125)	.325
FEV1/FVC: mean ± SD (range)	0.84 ± 0.07 (0.76-0.95)	0.88 ± 0.6 (0.77-0.95)	.071

Abbreviations: FEV1, forced expiratory volume in 1 second; FVC, forced vital capacity.
[a]Group 1 (n = 25), control subjects; group 2 (n = 25), patients with chronic rhinosinusitis.
[b]$P \leq .05$ (Mann-Whitney test).

Several studies addressed coexistent sinusitis and asthma and reported that a proper treatment of diseased paranasal sinuses can significantly improve asthma symptoms.[26-28] However, there is paucity in the published literature about the nature of lower airway involvement in nonasthmatic patients with CRS. Ragab et al[29] found different kinds of lower airway involvement in 60% of adult patients with CRS who failed medical treatment: some are manifest (eg, asthma), and others are nonmanifest (eg, bronchial hyperreactivity). They also showed that the presence of nasal polyps was a risk factor for the involvement of the lower airways. Kariya et al[30] also reported that pulmonary functions were affected in patients with CRS regardless of their sensitization status. Tanaka et al[31] reported that 13% of patients with CRS with nasal polyps and 20% of patients with CRS with nasal polyps and peripheral blood eosinophilia exhibited obstructive lung dysfunction (FEV1/FVC <70%) despite the absence of an asthma diagnosis. Furthermore, among elderly nonsmokers (≥60 years) who had never been diagnosed with asthma, 50% of those with CRS with nasal polyps and peripheral blood eosinophilia showed a decreased FEV1/FVC ratio (<70%). The authors concluded that asthma is underdiagnosed for patients with CRS who undergo ESS, especially the elderly.

In the present study, we excluded patients with nasal polyps and nasal allergy, and it was clearly evident that there were better lung functions in control subjects when compared with patients having medically resistant CRS.

This nonsymptomatic lower airway involvement in patients with CRS can be explained by the small lower airway dysfunction that involves the terminal and respiratory bronchioles (2-3 mm in diameter).[32] Accordingly, when the disease mainly involves the conducting airways, it is called *small airway disease*. The assessment of lower airway disease is relatively difficult to study; the possible physiologic assessment can be through spirometry, plethysmography, impulse oscillometry, inert gas washout, single-breath nitrogen washout, multiple-breath nitrogen washout, and helium and sulphur hexafluoride washout tests.[33] Forced expiratory flow between 25% and 75% of the FVC is one of the most commonly cited measures of small airways pathology. McFadden and Linden[34] postulated that the latter part of the vital capacity was affected by increased resistance in small airways as lung volume fell. Pathology in these airways causes excessive airway narrowing and collapse at an earlier time and closer to the alveolus during exhalation. This results in a reduction in the maximum expiratory flow that can be achieved. However, forced expiratory flow between 25% and 75% is dependent on the FVC; therefore, changes in FVC will affect the portion of the flow-volume curve examined. The assessment of small airway disease needs multiple studies, and that was not the scope of this study.

Another entity of lower airway functional involvement is the inflammation of the lower airways resulting in bronchial hyperreactivity.[35] Our findings also draw attention to the role of nasal obstruction in the development of lower airway disease, in which nasal function is bypassed—with loss of its function for cleaning, warming, and humidifying the inhaled air and with loss of its protective mechanisms.[36] Nasal obstruction can induce a blockage of the sinus ostia, with a reduction in the availability of nitric oxide in the upper and lower airways, as reported for patients with chronic sinus disease.[37] Shturman-Ellstein et al examined the effect of nasal breathing versus mouth breathing among patients with asthma during exercise or hyperventilation, which resulted in worsened pulmonary function with mouth breathing versus nasal breathing.[38]

There are only a few reports based on lung functions to evaluate the impact of sinus surgery for patients with CRS. Karuthedath et al[39] evaluated the impact of ESS on the PFTs of patients with CRS. On the whole, patients benefited from ESS, with better PFTs; however, their study did not have control group. Other studies have shown that patients with CRS and asthma may benefit from ESS. In a previous study, we reported a significant effect of ESS on the PFTs and asthma outcome parameters for patients with bronchial asthma and nasal polyps.[40] Chen et al[41] also reported that, for patients with CRS with nasal polyps and asthma, ESS may help to improve subjective olfaction and endoscopic appearance.

In a systematic review, Rix et al[42] reported that ESS and medical interventions with systemic anti-inflammatory drugs improved nasal outcomes, although their efficacy in relation to the lower airways remains unclear. The exact mechanism of improvement of PFTs that occurred among patients with CRS after ESS is unclear. It is likely that part of the improvement after ESS is from removing trigger areas in the nose and sinuses that can cause release of leukotrienes, prostaglandins, and other inflammatory mediators that may affect the lower airways.[43] Importantly, there was also a significant improvement in the FEV1/FVC value at 1 month postoperatively in our patients, reflecting the effect of ESS on relieving the nonsymptomatic lower airway obstruction. These results also may be attributed to the postoperative usage of intranasal corticosteroid sprays that may lead to significant reductions in upper and lower airway responses to intense triggers.[44]

Although our study is limited by a relatively small number of patients, we believe that this prospective study, with its well-defined outcome measures and criteria included for patient selection, helps to clarify the true value of ESS for these difficult-to-treat patients and to emphasize that the underuse of objective testing, such as spirometry, for patients with CRS may lead to underdiagnosed lower airway problems. Early diagnosis and good CRS control are important to reduce morbidity and health care costs as well as to minimize the development of chronic illnesses.

Conclusion

This study provides corroborative objective evidence that patients with CRS may have nonmanifest lower airway affection when compared with control subjects and that ESS is efficacious in the improvement of such affection.

Author Contributions

Ahmed M. Youssef, substantial contributions to the conception and design of the work, contributed in drafting the work and revising it critically for important intellectual content, had final approval of the version to be published, has agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved; **Osama G. Abdel-Naby Awad**, data analysis, drafting, final approval, and accountability for the work; **Mohamed Taha**, substantial contributions to the conception and design of the work, contributed in drafting the work and revising it critically for important intellectual content, had final approval of the version to be published, has agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Disclosures

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