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Lung functions pre- and post-endoscopic balloon dilation treatment among patients with subglottic stenosis

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Abstract. – OBJECTIVE: Subglottic stenosis (SGS) is an unusual clinical condition of mucosal wounding, compromising the extra-thoracic part of the tracheal airway below the vocal folds. The diagnosis of SGS is established with a detailed clinical examination and a direct endoscopic examination, and the role of spirometry is also often acknowledged. This study aimed to investigate the impact of SGS on lung functions before and after the balloon dilation procedure.

PATIENTS AND METHODS: The respiratory functions were performed in the Department of Clinical Physiology and the Department of Otolaryngology College of Medicine, King Saud University, Riyadh, Saudi Arabia. In this study, 50 patients with SGS were referred from the Department of Otolaryngology, and lung functions before and after the balloon dilation procedure among patients with SGS were performed using an electronic spirometer.

RESULTS: The results revealed that the mean values for lung function test parameters VC (p=0.01), FVC (p=0.01), FEV_1 (p=0.004), FEV_1/FVC Ratio (p=0.01), PEFR (p=0.01), FEF-25% (p=0.01), FEF-50% (p=0.01), and FEF-75%, (p=0.01) were significantly improved in both male and female patients with SGS on one month after the balloon dilation procedure.

CONCLUSIONS: It is concluded that the lung function test parameters were increased after the balloon dilation procedure among patients with SGS. The findings showed the impact of SGS on lung function test parameters. Spirometry is a valuable test in patients with SGS and is an appropriate marker to reveal post-airway outcomes. Physicians must suggest lung function tests in patients with SGS before and after the balloon dilation procedure.

Key Words:
Lung function, Subglottic stenosis, Fixed extrathoracic airway obstruction.

Introduction

Subglottic stenosis (SGS) is characterized by the narrowing of the airway in the subglottic space, which can lead to respiratory distress. SGS can be a congenital, acquired, or idiopathic condition. Acquired SGS is primarily due to intubation injury. SGS is an unusual disorder of mucosal wounding, consisting of the extrathoracic part of the tracheal airway below the vocal folds. The inflammatory condition leading to fibrosis may be caused by long-term intubation, traumatic intubation, tracheostomy, gastroesophageal reflux disease (GERD), or autoimmune disorders[1].

Trachea trauma is the most common and frequent cause of stenosis in children and adults. Approximately ninety percent of all the acquired cases of chronic subglottic stenosis are due to endotracheal intubation. The intubation causes an injury at compound levels, developing pressure on the arytenoid cartilage and pressure at the tip of the tube alongside the subglottic cartilage, causing ischemia and necrosis. Moreover, the stenosis severity has been linked with the intubation period and the tube size. A patient with an inflamed trachea and septic condition is the additional risk factor likely to be predisposed to SGS[1].

Patients with SGS present unspecific clinical features, such as chronic cough, wheezing, exertional dyspnea, and dysphonia. In some patients, it is difficult to treat, and the clinical presentation may be misinterpreted as lower airway obstruction, resulting in a delay in the diagnosis and management of patients[2]. The treatment modalities for subglottic stenosis include dilation with local corticosteroid injection or mitomycin, and laryngotracheal resection and reconstruction[3,4]. It is vital to exclude other conditions that can mimic

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subglottic stenosis, such as asthma and gastro-oesophageal reflux disease[5]. In addition, obesity and diabetes mellitus have been identified as significant risk factors for acquiring subglottic stenosis6. The diagnosis of SGS heavily relies on the appropriate medical history and physical examination, including a fiberoptic laryngoscope with a high index of suspicion and on the assessment of the subglottic area under general anaesthesia.

The diagnosis of SGS was based on the Meyer-Cotton Grading Scale[7,8]. The clinical features of SGS depend on the degree of stenosis. In the early stage of stenosis, patients complain of a mild degree of cough or dyspnea; these symptoms are not regular but sometimes have no clinical symptoms. However, in advanced stages 1-3, the clinical features become severe, and sometimes patients are presented with life-threatening stenosis[7,8]. The present study classified the cases based on the Meyer-Cotton scale, and they were of grades 2 and 3.

Tracheobronchial stenosis is a fundamental problem and a multifactorial condition[9]. Endoscopy may be considered the first choice for simple stenoses, while complex stenoses require a multidisciplinary approach[10]. Interventional bronchoscopy may play a role in the effective management of simple tracheal stenosis[11]. Moreover, spirometry is vital in diagnosing and monitoring tracheal stenosis[12].

The appropriate and timely diagnosis of SGS is essential since it may be missed and could be a hurdle to satisfactorily managing patients with respiratory conditions that may be under-appreciated and misdiagnosed in clinical practice. Patients with SGS may be misdiagnosed with asthma as clinical features are often associated with asthma[13].

The management of SGS could be directed at minimizing known aggravating factors, thereby minimizing the use of unnecessary asthma medications, and forming the critical basis for clinicians to differentiate both conditions. The study aimed to investigate the impact of SGS on lung functions among patients with SGS conditions.

Patients and Methods

Study Design and Settings

This study was conducted in the Department of Physiology (Clinical Physiology) and the Department of Otolaryngology, College of Medicine, King Saud University, Riyadh, Saudi Arabia.

Inclusion and Exclusion Criteria

Male and female patients with subglottic stenosis, aged above 12 years, were included in the study. However, subjects with known cases of thoracic cage abnormalities, musculoskeletal disease, vertebral column disorders, neuromuscular diseases, smokers, diabetes mellitus, COPD, and malignancy were excluded from the study. Moreover, subjects with a previous known history of any significant surgery were excluded from the study[14].

Sample Size

The power formula was employed to calculate the sample size; as per earlier studies[15,16], the sample size for both groups was 35; but in this study, the sample size of 50 was selected to detect the effect size at 80% power.

Spirometry

After getting ethical approval from the Institutional Review Board, College of Medicine, King Saud University, Riyadh, the research project started. The ventilatory lung function test parameters before and one month after the balloon dilation treatment of SGS were performed using an Electronic Spirometer (Schiller Vitalograph, UK). The lung function test procedure and its clinical significance were carefully discussed with patients before performing the test. The device was daily calibrated and was operated as per the required procedure. The present study test procedure was based on the strategies of the instrument and concerning the American Thoracic Society and European Respiratory Society Technical guidelines[17]. After the detailed clinical history and anthropometric data, and reviewing their electronic data system, patients were informed about the test maneuver. The patients were advised to practice the test procedure before performing the lung function test. The test was performed with the subject in the sitting position with a nose clip. After adequate rest of about 5 min, the patient avoided exertion, and the test procedure was repeated three times. The lung function test parameters Forced Vital Capacity (FVC); Forced Expiratory Volume in the first second (FEV_1); Forced Expiratory Ratio (FEV_1/FVC %); Peak Expiratory Flow Rate (PEFR); Forced Expiratory Flow 25% (FEF 25%); Forced Expiratory Flow 50% (FEF 50%); and Forced Expiratory Flow 75% (FEF 75%) were recorded.

Statistical Analysis

The data were analyzed using the Statistical Package for Social Sciences (SPSS) version

10.0 programs for Windows (Chicago, IL, USA). The paired sample *t*-test was applied to calculate the difference in the means between the variables. *p*-value less than 0.05 was considered significant.

Results

Table I shows the demographic characteristics of the study participants. A total of 50 patients with SGS were recruited in the study, among them 32 (64%) were males and 18 (32%) were females. The mean age of the study participants was 30.2 ±2.0 years.

Lung Functions Before and After the Balloon Dilation Treatment of Subglottic Stenosis

The overall ventilatory lung function test parameters were recorded before and after the balloon dilation treatment of subglottic stenosis. The results revealed that the mean values for the lung function test parame-ters VC (p=0.01), FVC (p=0.01), FEV_1 (p=0.004), FEV_1/FVC Ratio (p=0.01), PEFR (p=0.01), FEF-25% (p=0.01), FEF-50% (p=0.01), and FEF-75%, (p=0.01) were significantly increased after the balloon dilation treatment of subglottic stenosis compared to before the balloon dilation treatment (Table II).

Lung Functions in Male Patients Before and After the Balloon Dilation Treatment of Subglottic Stenosis

The ventilatory lung function test parameters were recorded in male patients before and after the balloon dilation treatment of subglottic stenosis. The results revealed that the mean values for the lung function test parameters VC (p=0.001), FVC (p=0.002), FEV_1 (p=0.05), FEV_1/FVC Ratio (p=0.01), PEFR (p=0.01), FEF-25% (p=0.01), FEF-50% (p=0.01), FEFR-75%, (p=0.01), and MMEFR (p=0.01) were significantly increased in male patients after the balloon dilation treatment of subglottic stenosis compared to before the balloon dilation treatment (Table III).

Lung Functions in Female Patients Before and After the Balloon Dilation Treatment of Subglottic Stenosis

The ventilatory lung function test parameters were recorded in female patients before and after the balloon dilation treatment of subglottic stenosis. The results show that the mean values for the lung function test parameters VC (p=0.001), FVC (p=0.050), FEV_1 (p=0.001), FEV_1/FVC Ratio (p=0.017), PEFR (p=0.01), FEF-25% (p=0.01), FEF-50% (p=0.001), FEFR-75%, (p=0.01), were significantly increased in female patients after the balloon dilation treatment of subglottic stenosis compared to before the balloon dilation treatment (Table IV).

Table I. The age and gender of the study participants (n=50).

Variable	Frequency (%)
Age (years)	30.2 ±2.0
Gender	
Male	32 (64%)
Females	18 (32%)
Total	50 (100%)

Table II. Comparison of lung function parameters before and after the balloon dilation treatment of subglottic stenosis (n=50).

Parameters	Before dilation		After dilation		95% Confidence Interval		Significance level
	Mean	SD	Mean	SD	Lower	Upper	
VC (Lit)	1.73	0.10	2.03	0.09	-.41468	-.18932	0.01
FVC (Lit)	2.28	0.13	2.61	0.14	-.50932	-.16188	0.01
FEV_1 (Lit/Sec)	1.65	0.17	2.13	0.12	-.79423	-.16497	0.004
FEV_1/FVC Ratio (%)	68.67	2.86	82.57	2.20	-19.47572	-8.32748	0.01
PEFR (Lit /Sec)	1.83	0.12	3.23	0.23	-1.85066	-.95734	0.01
FEF-25% (Lit/Sec)	1.71	0.12	3.10	0.23	-1.84203	-.92917	0.01
FEF-50% (Lit/Sec)	1.50	0.10	2.54	0.19	-1.26755	-.62965	0.01
FEF-75% (Lit/Sec)	1.19	0.16	1.46	0.11	-1.39621	-.67499	0.01
MMEFR (Lit/Sec)	1.41	0.10	2.36	0.17	-.61293	.05853	0.103

"Forced Vital Capacity (FVC); Forced Expiratory Volume in the first second (FEV_1); Forced Expiratory Ratio (FEV_1/FVC %); Peak Expiratory Flow Rate (PEFR); Forced Expiratory Flow 25% (FEF 25%); Forced Expiratory Flow 50% (FEF 50%); and Forced Expiratory Flow 75% (FEF 75%)".

Table III. Comparison of lung function parameters in male patients before and after the balloon dilation treatment of subglottic stenosis (n=32).

Parameters	Mean	SD	95% Confidence Interval Lower	95% Confidence Interval Upper	Significance level
VC B-VC A(Lit)	-.26875	.41773	-.41936	-.11814	0.001
FVCB – FVC-A (Lit)	-.40813	.68136	-.65378	-.16247	0.002
FEV_1 - FEV_1-A (Lit/Sec)	-.46344	1.33700	-.94548	.01860	0.059
FEV_1 /FVC Ratio (%)	-14.94313	19.95103	-22.13624	-7.75001	0.01
PEFR B- PEFR-A (Lit /Sec)	-1.40219	1.75238	-2.03399	-.77039	0.01
FEF-25% -B FEF25-A (Lit /Sec)	-1.36031	1.79273	-2.00666	-.71397	0.01
MMEF % B- MMEF%-A (Lit /Sec)	-.96219	1.21874	-1.40159	-.52278	0.01
FEF-75 % B- FEF-75%-A (Lit /Sec)	-1.03062	1.41239	-1.53984	-.52141	0.01
MMEF-B MMEF-A (Lit /Sec)	-.49000	.67307	-.73267	-.24733	0.01

"Forced Vital Capacity (FVC); Forced Expiratory Volume in the first second (FEV_1); Forced Expiratory Ratio (FEV_1/FVC %); Peak Expiratory Flow Rate (PEFR); Forced Expiratory Flow 25% (FEF 25%); Forced Expiratory Flow 50% (FEF 50%); and Forced Expiratory Flow 75% (FEF 75%)". A=After; B=Before.

Table IV. Comparison of lung function parameters in female patients before and after the balloon dilation treatment of subglottic stenosis (n=18).

Parameters	Mean	SD	95% Confidence Interval Lower	95% Confidence Interval Upper	Significance level
VC B-VC A(Lit)	-.36111	.35929	-.53978	-.18244	0.001
FVCB – FVC-A (Lit)	-.20667	.45048	-.43068	.01735	0.050
FEV_1 - FEV_1-A (Lit/Sec)	-.50833	.52128	-.76756	-.24911	0.001
FEV_1 /FVC Ratio (%)	-12.05000	19.42430	-21.70947	-2.39053	0.017
PEFR B- PEF-A (Lit /Sec)	-1.40722	1.23286	-2.02031	-.79414	0.01
FEF-25% -B FEF25-A (Lit /Sec)	-1.43056	1.25329	-2.05380	-.80731	0.01
FEF-50% % B- FEF-50%%-A (Lit /Sec)	-.92444	.95961	-1.40165	-.44724	0.001
FEF-75 % B- FEF-75%-A (Lit /Sec)	-1.04444	1.00152	-1.54249	-.54640	0.01
MMEFR-B, MMEFR A (Lit /Sec)	.10111	1.72037	-.75441	.95663	0.806

"Forced Vital Capacity (FVC); Forced Expiratory Volume in the first second (FEV_1); Forced Expiratory Ratio (FEV_1/FVC %); Peak Expiratory Flow Rate (PEFR); Forced Expiratory Flow 25% (FEF 25%); Forced Expiratory Flow 50% (FEF 50%); and Forced Expiratory Flow 75% (FEF 75%)". A=After; B=Before.

Discussion

The clinical symptoms of upper airway obstruction are sometimes similar to asthma, and it can cause a misdiagnosis. However, spirometry is the best noninvasive screening test for the diagnosis of respiratory diseases, including upper airway obstruction and its specific patterns involving fixed, variable intrathoracic and extrathoracic lesions. This study investigated the impact of balloon dilation treatment of subglottic stenosis on lung functions among patients with subglottic stenosis. It was identified that the lung function test pa-rameters were significantly improved one month after the balloon dilation treatment among patients with subglottic stenosis (Table II-IV, Figure 1).

The ventilatory lung function test parameters and its loop volume curve have been commonly used to diagnose the differentiate the pattern of respiratory conditions and to support the diagnosis of upper airway dysfunctions. The flattening of the flow-volume loop inspiratory curve, while the patient is symptomatic, sometimes indicates a variable extrathoracic obstruction. This abnormal pattern is commonly described in patients with upper respiratory tract disorders[18,19]. It has been reported that lung function tests may be valuable in demonstrating the seriousness of clinical indicators in patients with SGS[20].

Patients with SGS and impaired or disturbed breathing disorders may mimic or coexist with the clinical features of asthma. These conditions lead to overtreatment with unnecessary use of corticosteroids with consequent morbidity. Patients with SGS may have repetitive hospital visits due to shortness of breath with conditions like acute dyspnea attacks

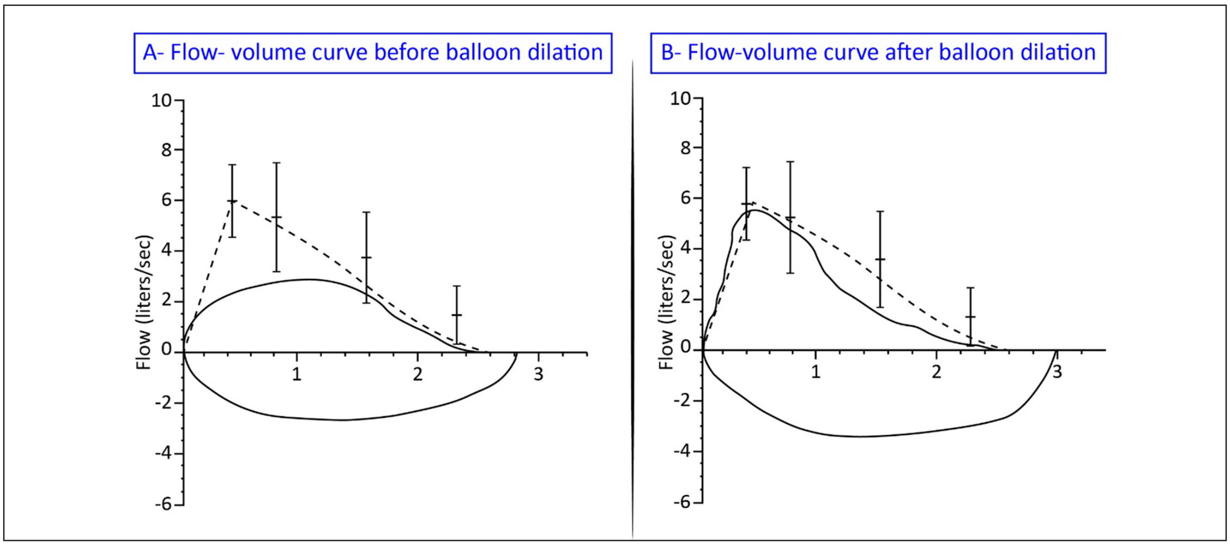

Figure 1. Spirometry revealed a flattened inspiratory and expiratory flow-volume loop (**A**) before and (**B**) after balloon dilation treatment in a patient with subglottic stenosis.

which represent a condition similar to asthma[5]. The literature highlights that spirometry and flow volume loops can be used to distinguish conditions like Paradoxical Vocal Fold Movement Disorder (PVFMD) from Subglottic Stenosis (SGS)[21].

Lung function testing is an important marker in patients with follow-up SGS revealing the post-balloon dilation and post-surgery outcomes in airway surgery candidates. Moreover, the literature also highlights the importance and clinical use of spirometry values as a non-invasive assessment of the upper airway obstruction to measure the outcomes of balloon dilatation[22].

The present study identified that the lung function test parameters VC, FVC, FEV_1, FEV_1/FVC Ratio, PEFR, FEF-25%, FEF-50%, and FEF-75%, were significantly improved in both male and female patients with SGS about one month after the balloon dilation (BD) procedure. Immediately after surgery, it is better to avoid involving the patient in any forceful test procedure including spirometry. Spirometry can be suggested after a minimum period of two weeks. It is also important to highlight that the spirometry timing after surgery, balloon dilation (BD), varies depending on multiple factors, including the patient's overall health condition, the severity of the stenosis, and the treatment plan.

The clinical presentation of SGS varies extensively, extending from mild clinical symptoms to difficulty in breathing. The clinical features may be intermittent and have been wayward to prior prescribed medical therapy, such as asthma treatment. Hoetzenecker et al[23] found that clinical symptoms of subglottic stenosis include respiratory distress, stridor, hoarseness, and recurrent respiratory infections. The literature also highlights that the patient mostly described a history of exercise-induced dyspnea, intermittent wheezing, and inspiratory stridor. Moreover, the spirometry low-volume loop demonstrated a flattened inspiratory and expiratory pattern and bronchoscopy revealed subglottic stenosis[24].

Crosby et al[25] identified the pattern of changes that occur in spirometry findings between the surgical involvements in patients with recurrent laryngotracheal stenosis and investigated the efficiency of tracing these changes in predicting the necessity to return to surgery. The authors found that deviations in PEF, PIF, and FIV_1 had predictive power in determining return to surgery. The findings indicate the importance of the trends of spirometry parameters for the individuals and the trends have greater importance than fixed measures alone. Tie et al[26] assessed the role of spirometry measures and the dyspnea index in response to the management of subglottic stenosis. The authors identified that all spirometry measures were markedly changed from preoperative to postoperative visits. The lung function parameters, PIFR, PEFR, and FEV_1/FVC, were significantly improved after the treatment for SGS. Similarly in the present study, the mean values for lung function test parameters VC, FVC, FEV_1, FEV_1/FVC Ratio, PEFR, FEF-25%, FEF-50%, and FEF-75%, were significantly improved in both male and female patients with SGS one month after the balloon dilation treatment. Although the clinical importance and value of the flow volume curve have been explored for various respiratory illnesses. The authors considered the pulmonary function test as the single best test for identifying upper airway stenosis. Miller and Hyatt[27] demonstrated that in the year 1969, a plateau-shaped F-V curve occurred with progressively smaller airways. While the shape of the F-V curve has been considered in clinical diagnosis and localized upper airway stenosis[28]. Abdullah et al[22] investigated the various lung function values about anatomical grading and the severity of SGS cases. The authors performed PFT pre- and postoperative parameters and found a post-dilatation significant increase in the spirometry parameters (FEV_1, PEF, FEV_1/PEF, FEF 25-50%, and FEF-75%) and MMEF rate was im-proved. In lung function, assessing the diagnosis of subglottic stenosis is aided by the flow volume loop curve. The flow volume loops are especially important to understand as they provide great support in long-term follow-up and monitoring for restenosis. Pulmonary function testing can show obstruction and reduced lung function test parameters. However, the most important is the flattening of both the inspiratory and expiratory limb of the flow-volume curve[29]. Similarly, Kraft et al[30] examined the respiratory function test parameters that may be used to quantify the outcomes in diagnosing idiopathic subglottic stenosis (iSGS). The lung function test parameters PEF, PIF, FEV_1/PEF, and FIF50% were significantly increased after endoscopic incision and dilation of iSGS. The lung function parameters provide vital information about the diagnostic and prognostic information on SGS. The main therapeutic options for treating patients with SGS are endoscopic balloon dilation (EBD), endoscopic laser therapy, mitomycin-c application, and steroid injection. EBD is a less invasive procedure to dilate the narrowed area in the subglottic region. The therapeutic options for subglottic stenosis depend on the site, severity, and individual patients' condition. Moreover, the therapeutic plan could be developed by a multidisciplinary team, including otolaryngologists, and respiratory therapists, to ensure optimal outcomes for the patient. It is also important to understand the Empey index[29]. The Empey index will provide a prediction of whether the patient has upper airway obstruction or not. This calculation is based on the ratio of FEV_1 (ml)/PEFR (l/min). In a normal person, the Empey index ratio is less than 10; however, in a person with upper airway obstruction, the ratio will be more than 10. The higher the empty index, the more severe the obstruction[31]. Pulmonary function testing can demonstrate obstruction, reduced peak expiratory flow, reduced maximum voluntary ventilation, or flattening of the flow-volume curve's inspiratory and expiratory limb. The spirometry values and loop volume curve shape are useful tools for establishing the diagnosis of upper airway dysfunctions[32,33]. Although the flow-volume loop is a reliable, low-cost, and easily accessible means of test assessing upper airway obstruction, in some patients, it is difficult to perform the spirometry test procedure as it requires a good understanding of the test procedure and the greatest effort and the flow reduction during forced ventilation may be partly due to the effort dependency of the test procedure. This finding may mimic the fixed lesions that cause plateaus in the flow volume loop's inspiratory and expiratory limbs. The variable intrathoracic lesions are characterized by expiratory slowing and flattening of the expiratory limb. However, the variable extrathoracic lesions cause inspiratory slowing and a plateau on the inspiratory limb of the flow volume loop. The clinician must remember that the quality of the flow volume loop is dependent on the patient's effort and cooperation, hence the tracings obtained in the pulmonary function laboratory may not have the classic shapes[34].

Study Strengths and Limitations

This study investigated lung functions before and after balloon dilation treatment among patients with subglottic stenosis. Spirometry provides evidence about the physiological linkage of the SGS during the lung function test procedure. Spirometry can provide useful information in the management of SGS. This test is one of the components for the evaluation and management of SGS, clinical assessment, imaging studies such as laryngoscopy or imaging of the airway, patient symptoms, and clinical history are important in the overall management of SGS. The limitations of this study included first this is a small sample size study. Second, spirometry is a patient-dependent and force-dependent test. Third, patient cooperation and proper execution are highly necessary for this test procedure.

Conclusions

The lung function test parameters were significantly improved one month after the balloon dilation procedure among patients with SGT. Spirometry is a useful test in patients with SGS and a good indicator for determining post-airway treatment outcomes. Physicians must suggest lung function tests in patients with SGS before and after the treatment option modalities. PFT provides a precise and objective assessment of the obstruction. The lung function test values are valuable metrics to follow the disease progression and treatment effectiveness.

Authors' Contribution

S.A.M.: study design, writing, and editing the manuscript; I.M.MU.: F.A.R. T.A.K.: M.S.A.: literature review, data collection, analysis, S.F.A.: data checking and verification.

Conflict of Interest

The authors declare no conflicts of interest.

Ethics Approval

Ethical approval was obtained from the Institutional Review Board, College of Medicine, King Saud University, Riyadh, KSA (Ref # 18/0673/IRB).

Informed Consent

Informed consent was obtained from the participants.

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Data Availability

Data may be provided on reasonable request to the corresponding author.

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