Evaluation of forced oscilometry technique's parameters in severe obstructive sleep apnea patients without breathing disorder

Besharat Rahimi[1], Maryam Edalatifard[1], Khosro Sadeghniiat Haghighi[2], Hossein Kazemzadeh[1]

[1]Advance Thoracic Research Center, [2]Occupational Sleep Research Center, Tehran University of Medical Sciences, Tehran, Iran

Abstract

Background: Forced oscillometry technique (FOT) is a noninvasive technique that measures reactance and resistance capacity of the lung and is a practical and less time-consuming technique for respiratory effort assessment. Recently, FOT has provided beneficial data regarding the screening of the patients with obstructive sleep apnea (OSA) and assessing the disease progression. The current study aimed to evaluate the correlation of FOT parameters with severity of the apnea-hypnea index (AHI). **Methods:** In the current case series, all patients who had a body mass index ranging between 30 and 35, suffering severe OSA with AHI of more than 30 times per hour, were enrolled. Patients underwent FOT before treatment to measure the following FOT parameters: Respiratory resistance at 5 and 20 Hz (R5 and R20, respectively), resistance difference between R5 and R20, reactance at 5 Hz (X5), and resonant frequency (Fres). **Results:** In the current study, 22 patients were enrolled; whereas 12 (54.5%) were male and 10 (45.5%) were female with a mean age of 5.27 ± 4.34. A statistically significant, strong negative correlation was observed between Fres and AHI, during Pearson correlation analysis (r (20) =0.59, $P < 0.0001$). However, the relationship between the AHI and R5, R20, R5-R20 and X5 was not statistically significant. Similarly, the multiple regression model showed that, only Fres variable added statistically significantly to the prediction, $P = 0.01$. **Conclusion:** FOT is a useful tool in evaluation of AHI severity in patients suffering OSA and can be used as a diagnostic material in monitoring and management of these patients.

Keywords: Apnea-hypopnea index, oscillometry, resonant frequency, sleep apnea

Introduction

Obstructive sleep apnea (OSA) is a common condition, which develops due to the constant collapse of the pharyngeal airway during sleeping.[1,2] Obesity and craniopharyngeal malformation are considered as the main risk factors for the OSA.[3-5] However, the incomplete or complete obstruction of the large airways results in a reduced or absent airflow at the nose and mouth orifices that contributes to hypopnea or apnea, respectively.[6] As a result, the individuals suffering OSA are obligated to transient arousal from sleep, to compensate for the airflow reduction and to restore the upper airway patency.[7] Several techniques have been introduced to evaluate the pathophysiology of OSA. Of these, nocturnal polysomnography has been suggested as the gold standard diagnostic technique in patients, who suffer OSA; however, despite its accuracy, time-consuming, expensiveness, and unfeasible in many institutes and centers.[8] In recent decades, the forced oscillation technique (FOT) is introduced to be a more user friendly and applicable technique in the evaluation of the respiratory functions.[9,10] During the FOT examination, the airway responses to pressure and flow of the inhaled and

Address for correspondence: Dr. Maryam Edalatifard, Department of Pulmonology, Imam Khomeini Hospital, Tehran University of Medical Sciences, Tehran, Iran. E-mail: m-edalatifard@tums.ac.ir

Received: 29-10-2019 **Revised:** 29-01-2020
Accepted: 07-02-2020 **Published:** 26-03-2020

Access this article online

Quick Response Code:

Website: www.jfmpc.com

DOI: 10.4103/jfmpc.jfmpc_954_19

How to cite this article: Rahimi B, Edalatifard M, Haghighi KS, Kazemzadeh H. Evaluation of forced oscilometry technique's parameters in severe obstructive sleep apnea patients without breathing disorder. J Family Med Prim Care 2020;9:1492-6.

exhaled air to small forced oscillations delivered at the mouth or nose are being analyzed that provides a remarkable priority over previously used approaches.[11] In order to fulfill this aim, sound waves are being transmitted through the airways in different frequencies. Therefore, in FOT, the resistance of the airways is being measured concerning the resistance at 5 Hz (R5), resistance at 15 Hz or higher (R15), area of a reactance with low frequency integrated impedance (AX).

Besides, thank its ability to measure the reactance of both large and small airways and resistance capacity of the lung, FOT turns out to be a practical and less time-consuming technique for respiratory effort assessment.[12] On the contrary, analysis of FOT is being performed through tidal breathing, which makes FOT as a practical technique in all ages and any patients, even in individuals with altered consciousness.[13] Considering the several advantages of the FOT in the diagnosis of the respiratory diseases that are in association with the airways resistance, it can be suggested that FOT might be capable of providing beneficial data regarding the screening of the patients with OSA and assessing the disease progression.

Hence, the aim of this study was to evaluate the correlation of the forced oscillometry technique's parameters with severity of the apnea-hypnea index (AHI) in patients suffering severe obstructive sleep apnea without breathing disorder.

Methods and Materials

In the current case series, for 6 months, all patients referred to a sleep laboratory with OSA diagnosis to underwent complete nocturnal polysomnography were evaluated according to the inclusion and exclusion criteria. Patients with body mass index (BMI) ranging between 30 and 35, suffering severe OSA with AHI of more than 30 times per hour were enrolled. However, individuals, who had a complete history and physical manifestations of respiratory diseases, such as asthma, chronic obstructive pulmonary diseases, infiltrative pulmonary diseases, and cardiac diseases, were excluded, as well as the patients with obesity hypoventilation syndrome. All patients provided informed consent before enrollment, and the study protocol was confirmed by the ethics committee of the Tehran University of Medical Sciences.

Before therapeutic interventions administration, such as continuous positive airway pressure, patients underwent FOT examination, which required no specific cooperation or effort from the patients, and is feasible through normal breathing. During the examination, sound waves were transmitted through the load speaker in a frequency ranging between 5 Hz to 25 Hz into patients' lungs, while the patient breathed normally, to measure pulmonary impedance, which includes resistance and reactance. With due attention to the capability of the low-frequency sound waves traveling a long way, these waves were used to evaluate the small and large airways resistance. However, high-frequency sound waves travel a shorter route; therefore, they were used to evaluate the considerable airway resistance. For assessing the airway's reactance, including inertance and capacity, the lung tissue elasticity and airway stenosis were evaluated.

All patients underwent FOT before treatment to measure the following FOT parameters: Respiratory resistance at 5 and 20 Hz (R5 and R20, respectively), resistance difference between R5 and R20, reactance at 5 Hz (X5), and resonant frequency (Fres), which were subsequently compared to reference values.

Statistical analysis

All results were expressed by mean ± SE for quantitative variables. The Pearson product-moment correlation was used to determine the strength and direction of a linear relationship between AHI and FOT parameters. Besides, a multiple regression was run to predict AHI from variables obtained through FOT. There was linearity as assessed by partial regression plots and a plot of studentized residuals against the predicted values. There was independence of residuals, as assessed by a Durbin–Watson statistic of 2.66. There was homoscedasticity, as assessed by visual inspection of a plot of studentized residuals versus unstandardized predicted values. There was no evidence of multicollinearity, as assessed by tolerance values greater than 0.1. There were no studentized deleted residuals greater than ±3 standard deviations, no leverage values greater than 0.2, and values for Cook's distance above 1. The assumption of normality was met, as assessed by a Q-Q Plot. Finally, the level of significance was set at 0.05.

Ethical Consideration

This article was approved by ethical coommite of Tehran university of Medical Sciences with code IR.TUMS.VCR.REC.1398.72.

Results

In the current study, 22 patients with severe OSA, who had AHI higher than 30, were enrolled. Of these patients, 12 (54.5%) were male, and 10 (45.5%) were female with a mean age of 50.27 ± 4.34. Patients' demographic data, including body height and weight, BMI, AHI, and mean values of FOT parameters are summarized in Table 1. The FOT parameters were respiratory resistance at 5 and 20 Hz (R5 and R20, respectively), resistance difference between R5 and R20, reactance at 5 Hz (X5), and resonant frequency (Fres).

Pearson's product-moment correlation was run to assess the relationship between AHI and FOT parameters, including, R5, R20, R5-R20, X5, and Fres. The relationship between the AHI and R5, R20, R5-R20, and X5 was not statistically significant [Table 2].

However, preliminary analyses showed the relationship to be linear between AHI and Fres, with both variables normally distributed, as assessed by Shapiro-Wilk's test (P >.05), and there were no outliers. Therefore, there was a statistically significant, strong negative correlation between Fres and AHI, r (20) =0.59, P < 0.0001, with Fres value explaining 45% of the variation in AHI severity.

Subsequently, a multiple regression was run to predict AHI from FOT parameters of R5, R20, R5-R20, X5, and Fres. The multiple regression model statistically significantly predicted AHI, F (5, 17) =3.542, P = 0.02, adj. R2 = 0.32. Similar to correlation analysis, only Fres variable added statistically significantly to the prediction, P = 0.01. Regression coefficients and standard errors are shown in Table 3.

Discussion

Since its introduction in the 1960s,[6] FOT has been used as a noninvasive measurement method for evaluating function and elasticity of airways.[14] Although FOT was primarily used to assess obstructive pulmonary conditions, particularly in asthmatic patients, currently, benefiting its unique features, FOT provides considerable advancement in the assessment of respiratory system resistance and reactance, not only in patients who are able to cooperate with the examination, but also during anesthesia and sleep, considering its performance independence to patients interaction.[11,15-17] On this basis, the technique has been favorably administered in patients with respiratory disorders during sleep time, to monitor the dysfunction of both upper and lower airway obstruction.[18] Therefore, the current study aimed to test the feasibility of the FOT system to measuring respiratory resistance in patients with severe sleep apnea during sleep, to examine the efficacy of the technique in the diagnosis of the disease severity in victims. The results of the study showed that in patients suffering severe OSA according to the AHI, FOT parameters fail to predict the severity of the sleep apnea, except Fres, which was negatively correlated with the AHI of patients; whereas, increased resonant frequency was associated with decreased values of the AHI. The novel feature of the study was taking the correlation of FOT findings with AHI in patients suffering sleep apnea during an overnight sleep study, into consideration.

Resonant frequency or Fres is described as the intermediate frequency at which the total reactance is null in the lungs. Therefore, similar magnitudes of capacitative and inertive pressure drops result in Fres. Fres is commonly used to discriminating between low-frequency and high-frequency reactance values: Below the Fres, the elastic properties of the lung (represented by capacitance) are dominant, which is opposed by intertance dominance above the Fres.[19] On this basis, Bickel *et al.* suggested a higher Fres values in children, which decreases with aging and elevates concomitantly, in both restrictive and obstructive pulmonary conditions.[20] Thus, it was not of great surprising that in our study, a negative correlation was established between AHI and Fres. On this basis, it can be hypothesized that FOT derived Fres is not only a valid and reliable predictor of AHI severity in patients with severe OSA, but also might be useful in monitoring the disease progression and screening the patients manifestation during follow-up periods.

In an early investigation, Badia *et al.* administered FOT for the evaluation of severe sleep apnea and hypopnea syndrome and suggested it as a noninvasive tool for the diagnosis of respiratory disturbances that makes physicians capable of approaching a quantitative for continuous monitoring of airflow alterations during sleep in patients with sleep apnea.[21] Similarly, our results showed that Fres can be obtained through FOT, which is known as a non-invasive tool, and considering the significant correlation between Fres and AHI, FOT can be used as a beneficiary technique in evaluation of the sleep apnea severity.

In a previous study by Abdeyrim *et al.*, obese and preobese patients with healthy spirometry outcomes, underwent impulsed oscillometry in sitting and supine position, and airway resistance and reactance in patients with obstructive sleep apnea were associated with severity of the obstruction according to the

Table 1: Mean values of patients demographic data and FOT outcomes

Variable	Mean±SD
Age	50.27±4.34
Body weight	85.68±7.11
Body height	1.7±0.08
BMI	29.56±1.93
AHI	42.42±7.74
R5	5.88±1.43
R20	4.98±1.31
R5-20	0.99±0.99
FRES	10.77±3.02
X5	3.81±0.69

BMI: Body mass index; AHI; Apnea-hypnea index; R5: Respiratory resistance at 5 Hz; R20: Respiratory resistance at 20 Hz; R5-20: Resistance difference between R5 and R20; X5: Reactance at 5 Hz; Fres: Resonant frequency

Table 2: Pearson's correlation for main study variables

Variable	Correlation (AHI)	
	Pearson	Pv
R5	0.292	0.187
R20	0.399	0.066
R5-20	-0.178	0.429
Fres	-0.593**	0.004
X5	-0.071	0.755

AHI; Apnea-hypnea index; R5: Respiratory resistance at 5 Hz; R20: Respiratory resistance at 20 Hz; R5-20: Resistance difference between R5 and R20; X5: Reactance at 5 Hz; Fres: Resonant frequency

Table 3: Summary of multiple regression analysis

Variable	*B*	Std. error	Beta
Constant	45.387	9.759	
R5	0.766	4.543	0.142
R20	0.315	4.869	0.054
R5-20	-1.555	2.507	-0.198
Fres	-1.616	0.62	-0.631*
X5	2.599	2.78	0.232

AHI; Apnea-hypnea index; R5: Respiratory resistance at 5 Hz; R20: Respiratory resistance at 20 Hz; R5-20: Resistance difference between R5 and R20; X5: Reactance at 5 Hz; Fres: Resonant frequency. *P<0.05

AHI classification.[22] Besides, the authors carried out a study on obese patients, who had no history of pulmonary and respiratory diseases, regarding the presence and absence of OSA according to polysomnography, which showed a higher resistance and reactance in patients suffering OSA.[23] Hence, concerning the results of the previous studies, it could be assumed that OSA affects pulmonary elasticity. Since, Fres is in correlation with the elasticity of the airways, with due attention to our findings, it can be estimated that FOT results are in association with the severity of AHI that might be helpful in the primary assessment of the patients with OSA.

Our study had a few numbers of limitations. First, a technical concern during FOT is the more massive contribution of the upper airway resistance in the total resistance, which might influence the evaluation of changes in lower airway resistance during sleep. Second, although, the resistance of the chest wall does not vary significantly during sleep, respiratory system resistance has been made up of both chest wall resistance and airway resistance that prohibited us from the individual evaluation of involved airways structures. Third, due to the high costs of the sleep laboratory, a few numbers of patients are referred to undergo sleep analysis and evaluation of the obstructive sleep apnea; therefore, we obligated to carry on our survey with low sample size. Forth, patients with severe AHI are at risk of irreversible and serious pathological alterations to airways and pulmonary function; therefore, enrollment of these patients concerning their pulmonary function might resulted in an inevitable bias, which prohibited us from evaluating the role of FOT in screening of the patients with sleep apnea.

Conclusion

In summary, FOT could be a useful tool in evaluation of AHI severity in patients suffering OSA, since Fres, obtained via FOT measurement, was in strong correlation with AHI of patients; thus, AHI severity is predictable by acquiring FOT. Besides, monitoring Fres changes at different sessions can be used as a diagnostic technique to evaluate disease progression. However, further studies and randomized trials are needed to conclude FOT overall advantages and disadvantages in patients with OSA.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Bradley TD, Floras JS. Obstructive sleep apnoea and its cardiovascular consequences. Lancet 2009;373:82-93.
2. Chen X, Zhou T, Li D, Zhang C, Jia P, Ma J, *et al.* Evaluating the clinical value of oscillatory cardiopulmonary coupling in patients with obstructive sleep apnea hypopnea syndrome by impedance cardiogram. Sleep Med 2016;19:75-84.
3. Sagar P, Singh S. Pediatric sinonasal disorders: Surgical perspective. Clinico Radiological Series: Sinonasal Imaging; 2018. p. 290.
4. Blackman A, Foster G, Zammit G, Rosenberg R, Aronne L, Wadden T, *et al.* Effect of liraglutide 3.0 mg in individuals with obesity and moderate or severe obstructive sleep apnea: The SCALE sleep apnea randomized clinical trial. Int J Obes (Lond) 2016;40:1310-9.
5. Jehan S, Zizi F, Pandi-Perumal SR, Wall S, Auguste E, Myers AK, *et al.* Obstructive sleep apnea and obesity: Implications for public health. Sleep Med Disord 2017;1:00019.
6. Faverio P, De Giacomi F, Bonaiti G, Stainer A, Sardella L, Pellegrino G, *et al.* Management of chronic respiratory failure in interstitial lung diseases: Overview and clinical insights. Int J Med Sci 2019;16:967-80.
7. Senaratna CV, Perret JL, Lodge CJ, Lowe AJ, Campbell BE, Matheson MC, *et al.* Prevalence of obstructive sleep apnea in the general population: A systematic review. Sleep Med Rev 2017;34:70-81.
8. Kapur VK, Auckley DH, Chowdhuri S, Kuhlmann DC, Mehra R, Ramar K, *et al.* Clinical practice guideline for diagnostic testing for adult obstructive sleep apnea: An American academy of sleep medicine clinical practice guideline. J Clin Sleep Med 2017;13:479-504.
9. Kolsum U, Borrill Z, Roy K, Starkey C, Vestbo J, Houghton C, *et al.* Impulse oscillometry in COPD: Identification of measurements related to airway obstruction, airway conductance and lung volumes. Respir Med 2009;103:136-43.
10. Oostveen E, MacLeod D, Lorino H, Farre R, Hantos Z, Desager K, *et al.* The forced oscillation technique in clinical practice: Methodology, recommendations and future developments. Eur Respir J 2003;22:1026-41.
11. Shirai T. Oscillation technique (FOT). Advances in Asthma: Pathophysiology, Diagnosis and Treatment; 2018. p. 83.
12. Mikamo M, Fujisawa T, Oyama Y, Kono M, Enomoto N, Nakamura Y, *et al.* Clinical significance of forced Oscillation technique for evaluation of small airway disease in interstitial lung diseases. Lung 2016;194:975-83.
13. de Sa PM, Castro HA, Lopes AJ, de Melo PL. Early diagnosis of respiratory abnormalities in asbestos-exposed workers by the forced oscillation technique. PLoS One 2016;11:e0161981.
14. Zerah F, Lorino A-M, Lorino H, Harf A, Macquin-Mavier I. Forced oscillation technique vs spirometry to assess bronchodilatation in patients with asthma and COPD. Chest 1995;108:41-7.
15. Milesi I, Porta R, Cacciatore S, Vitacca M, Dellacà R, Barbano L. Effects of automatic tailoring of Positive end expiratory pressure (PEEP) by Forced oscillation technique (FOT) during nocturnal Non-Invasive ventilation (NIV) in Chronic Obstructive pulmonary disease (COPD). Eur Respiratory Soc 2017.
16. Milesi I, Porta R, Vitacca M, Cacciatore S, Trentin R, Barbano L, *et al.* Overnight monitoring of lung mechanics and Tidal

expiratory flow limitation (EFLT) by Forced oscillation technique (FOT) in Chronic obstructive pulmonary disease (COPD) receiving non-invasive ventilation (NIV): The impact of sleep and posture. Eur Respiratory Soc 2018.

17. Cottee AM, Seccombe L, Watts JC, King G, Thamrin C, Peters M, *et al*. The Relationship Between Forced Oscillation Technique Measurements and the COPD Assessment Test in Stable Chronic Obstructive Pulmonary Disease. American Journal of Respiratory and Critical Care Medicine 2017;195:A6484.
18. Nigro CA, González S, Arce A, Aragone MR, Nigro L. Accuracy of a novel auto-CPAP device to evaluate the residual apnea-hypopnea index in patients with obstructive sleep apnea. Sleep Breath 2015;19:569-78.
19. Smith H, Reinhold P, Goldman M. Forced oscillation technique and impulse oscillometry. Eur Respir J 2005;31:72.
20. Bickel S, Popler J, Lesnick B, Eid N. Impulse oscillometry: Interpretation and practical applications. Chest 2014;146:841-7.
21. Badia JR, Farré RO, John Kimoff R, Ballester E, Hernandez L, Rotger M, *et al*. Clinical application of the forced oscillation technique for CPAP titration in the sleep apnea/hypopnea syndrome. Am J Respir Crit Care Med 1999;160:1550-4.
22. Abdeyrim A, Tang L, Muhamat A, Abudeyrim K, Zhang Y, Li N, *et al*. Receiver operating characteristics of impulse oscillometry parameters for predicting obstructive sleep apnea in preobese and obese snorers. BMC Pulm Med 2016;16:125.
23. Abdeyrim A, Li N, Shao L, Heizhati M, Wang Y, Yao X, *et al*. What can impulse oscillometry and pulmonary function testing tell us about obstructive sleep apnea: A case-control observational study? Sleep Breath 2016;20:61-8.