Stoimenova, P., Mandadzhieva, S., & Marinov, B. (2024). Forced oscillation technique (fot) – a novel method for the detection of early airway changes, *MEDIS - Medical Science and Research, 3*(1), 41-46. doi: 10.35120/medisij030141s
UDK: 616.24-002.2-072.7

FORCED OSCILLATION TECHNIQUE (FOT) – A NOVEL METHOD FOR THE DETECTION OF EARLY AIRWAY CHANGES

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Abstract: According to the World Health Organization in 2019 chronic obstructive pulmonary disease (COPD) was the third leading cause of death worldwide, causing more than 3 million deaths whereas bronchial asthma affected more than 250 million people and caused 455 000 deaths. Both diseases are chronic obstructive conditions which need to be diagnosed early in order to prevent or slow down the complications. Consequently the world requires new effortless methods for diagnosis of airway obstructions, especially for small children and people who cannot perform the spirometry maneuver. The purpose of this report is to describe the objectives of the forced oscillation technique (FOT) and to establish its applications in the clinical practice. Studies and clinical cases regarding pulmonary function testing are summarized and analyzed. They are found in the following databases - PubMed, Google Scholar and Science Direct. Spirometry is the 'gold standard' for the diagnosis of airflow obstruction but it requires effort and can be difficult for patients to perform. Forced oscillation technique (FOT) on the other hand is a relatively new method that may hold the key to identifying smoking-related respiratory early alterations and childhood asthma. FOT requires tidal breathing while applying external, small amplitude oscillations in order to determine the response of the respiratory system. Therefore, it is easy for pre-school children to perform. The benefit of FOT should be taken into account for patients who cannot perform spirometry or other pulmonary function ttests. The minimal cooperation of the patient and the easy tidal breathing maneuvers make this method a great option for every pulmonologist. Compared to spirometry this technique may be more sensitive in the detection of disturbances of the peripheral airways and may be effective for the control of therapy at a long term. The Forced oscillation technique has been successfully applied in many pediatric respiratory disorders, such as asthma, cystic fibrosis, and chronic lung disease. Considering these qualities FOT may be used as an alternative of spirometry in heterogenous ventilatory disturbances of the small airways.

Keywords: Forced oscillation technique, airway obstruction, heterogenous ventilatory conditions

Field: Medical sciences and Health

1. INTRODUCTION

The bronchoobstructive diseases are different conditions in which there is obstruction of airflow of the respiratory tract and heterogeneous ventilation of the alveoli. They result from the narrowing of the bronchial lumen and smaller bronchioles due to inflammation or bronchospasm. (Yaegashi, 2006) Obstructive lung diseases include bronchial asthma, COPD, cystic fibrosis and bronchitis. According to the World Health Organization in 2019 chronic obstructive pulmonary disease (COPD) was the third leading cause of death worldwide, causing more than 3 million deaths whereas bronchial asthma affected more than 250 million people and caused 455 000 deaths. (Boers, 2023) The "golden" standard in the diagnosis of these diseases nowadays is spirometry, but this method turns out to be complicated and unsuitable for certain groups of people such as pre-school children (especially <6 years old), elderly people and minority groups. Performing good spirometry test is often a problem among these groups because the maneuvers involve forced exhalations and very close adherence to the health professional's instructions. Due to these limitations the diagnosis and treatment of these diseases are sometimes delayed.

The forced oscillation technique (FOT) is a relatively new but reliable diagnostic tool used for assessment of bronchial hypersensitivity in adults and children. (Yaegashi, 2006)(Alblooshi, 2017, p.129-138) This method doesn't inquire deep inspirations and forced expirations like in spirometry therefore it doesn't affect the smooth muscle tone of the bronchial tree. Along with the increasing numbers of smoking children and teenagers it is essential FOT is sensitive enough to detect early impairments in the lung functions and can be used for prevention and early diagnosis of COPD in adults. (Faria, 2009)

The aim of this literature review is to present this method as a new option for easier diagnosis of obstructive lung disease and to show the possibilities for the inclusion of FOT in the everyday clinical practice.

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2. METHODS

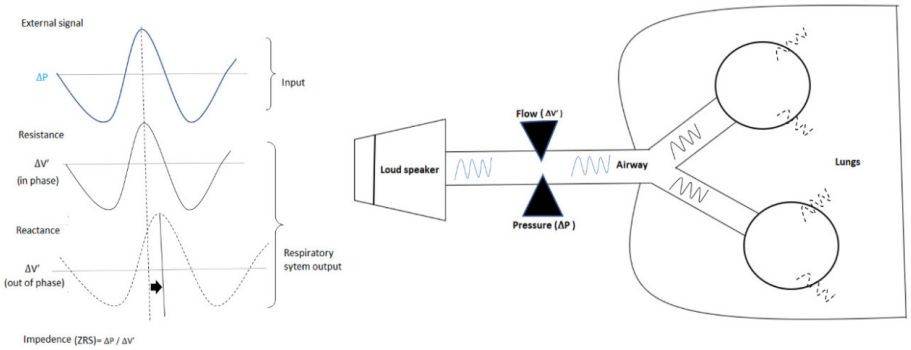
Forced oscillation technique (FOT) is a non-invasive method to assess lung function that uses an oscillating signal and requires only quiet tidal breathing. Measurements were carried out through a mouthpiece. The patient is seated comfortably with a well-straightened back and a slightly extended head position. He is invited to breathe calmly with a tidal volume, the nose is occluded with a nose clip, and the palms and fingers of the patient are on his cheeks lightly pressing them in order to avoid any upper airways artifacts. FOT is processed for 30 seconds tidal breathing and a total of three to five technically acceptable measurements are required. (Kaminsky, 2004) (Bickel, 2014)

Figure 1: Both pictures show the right position of the patient (adult or child). The position of the head is slightly extended, the nose is clipped and the hands of the medical technician lightly compress the cheeks.

Source: www.mgcdiagnostics.com

Oscillometry stimulates the respiratory system with external pressure created by a loudspeaker that is distributed faster than the normal breathing rate. That allows the flow generated by the apparatus to be measured. The “speed” of an oscillation is measured in Hz that is the number of times pressure/ flow oscillates in a second. FOT easily assesses the respiratory system’s response to small pressure oscillations sent to the opening of the airway into the lungs at different frequencies. (Kaminsky, 2004)

Figure 2: Forced oscillation technic apparatus - schematic picture.

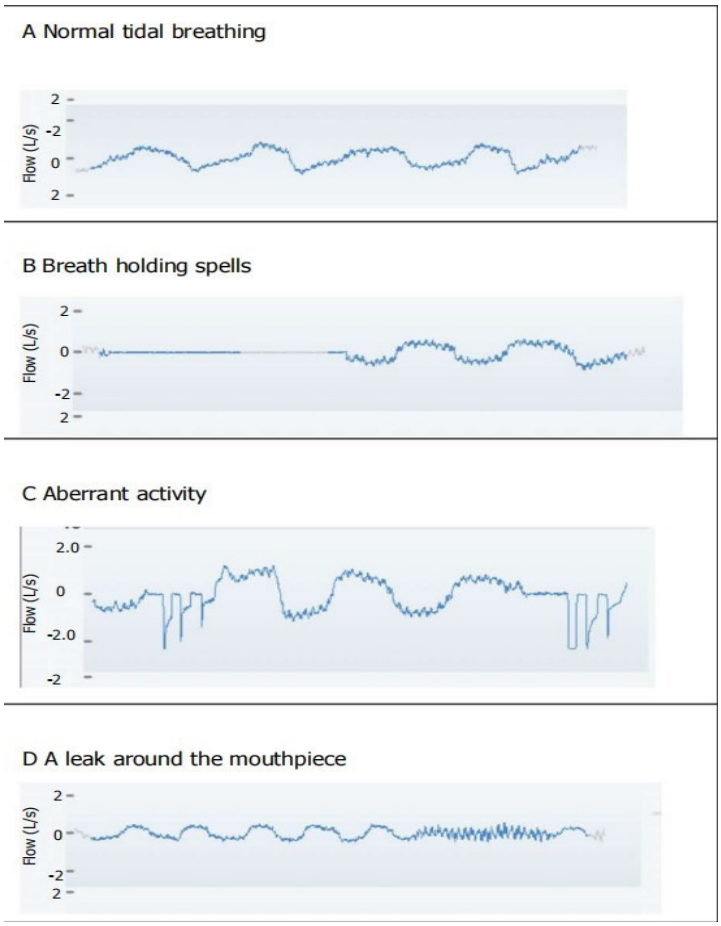


Source: J. Clin. Med. 2020, 9, 2778

It is an effort-independent way to detect airways obstruction and localize it as peripheral, central or heterogeneous. During the test the apparatus measures small and central airway function and assesses tidal expiratory flow limitation (EFL) in adults while aiding in bronchial reversibility testing or trending it over time for therapeutic monitoring. The main parameters that are clinically significant are Rrs (respiratory resistance) and Xrs (respiratory reactance). The respiratory resistance (Rrs) is a measurement of the

degree of obstruction and is a sum of the resistances of all the stimulated segments. It specifically detects central obstruction of the bigger airways and is very informative in cases of bronchoconstriction, excessive mucus production and airway inflammation. Respiratory reactance (Xrs), especially at low frequencies (5 Hz – 8 Hz), measures the elasticity of the air and the structures in the airways and alveoli being stimulated. It is a useful parameter for detection of peripheral obstruction.

Figure 3: The graphs are picturing the oscillations (Flow (L/s) in the airways shown on the screen of the FOT apparatus. A.Normal tidal breathing, B. Breath holding spells, C. Aberrant activity, D. A leak around the mouthpiece (Alblooshi, 2017, p. 129-138)



Source: World J Methodol. Dec 26, 2017; 7(4): 129-134

3. FORCED OSCILLATION TECHNIQUE AND COPD

Chronic obstructive pulmonary disease (COPD) is common progressive lung disease that includes emphysema and chronic bronchitis. COPD is associated strongly with prolonged exposure to harmful particles and gases, among which the most significant cause is cigarette smoke. According to CDC, 8 out of 10 people who die from COPD are smokers.

The chronic inflammation and alveoli destruction are leading to continuous airflow limitation and tissue destruction. This destruction is considered to involve oxidative stress and imbalances in protease-antiprotease enzymes and as a result the protease-mediated reduction of elastin leads to a loss of elastic recoil and airway collapse during exhalation. The inflammatory response and airway obstruction induce a decrease in the forced expiratory volume (FEV1) as well as impaired gas exchange due to severe changes of the aalveoi and pulmonary capillaries.

The standard for COPD severity is defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) and grounded on constant airflow limitation tested on spirometry. Unfortunately, spirometry has at least three main drawbacks that should be considered:

1. It is not suitable for detection of early changes of the airways, because this method focuses on the larger airways, whereas the early disease starts from smaller airways.

2. The spirometry indices don`t always correlate with the symptoms of the patient.
3. The method is requiring effort and forced expiration, which are complicated and exhausting for children and elderly people.

Forced Oscillation Technique is a non-invasive, effort-independent test to assess the respiratory resistance and reactance. The study of Dellacà et al. shows that the use of the index expiratory flow limitation (EFL) in COPD patients and the within-breath reactance (ΔXrs5Hz) provide a valid information for airway changes. (Dellacà, 2004) FOT can also be used for evaluation of post-bronchodilator response and for monitoring and control of the disease. Some scientists even suggest the option of home monitoring (telemonitoring) as a method for detection of acute exacerbations of COPD (AECOPD). (Walker, 2018) (Zimmermann, 2020) During hospitalization due to AECOPD, FOT was proven useful and Alqahtani et. al discover that the severity of EFL negatively corresponded with the obstrucion of the airflow. They also noticed position-dependent changes in the patient's EFL – the limitation increased in supine position The reduction of dyspnea also was corresponding with improvements in EFL. (Alqahtani, 2021)

Several studies evaluate different FOT parameters in order to analyze their effectiveness in detecting early airway changes in smokers. (Ribeiro, 2018) (Bhattarai, 2020) These studies have certainly implied that the sensitivity of FOT for detecting early airflow obstruction increases with the use of multiple frequencies - lower frequency (5 Hz) going to the peripheral airways, whereas higher frequencies (20 Hz) are limited to proximal airways. Therefore, the resistance (Rrs) and the reactance (Xrs) at low frequency (4–6 Hz) is comparably more relevant in identifying the smoking linked airway changes as they mainly start from the small airways. Sensitive parameters for passive smoking are changes in R5 and R5–20 examined in adolescents who were exposed to maternal smoking. (Faria, 2010) (Kolsum, 2009)

When compared to spirometry FOT appears to be more efficient in the detection of early abnormalities of the small airways and is proven to be a useful diagnostic tool.

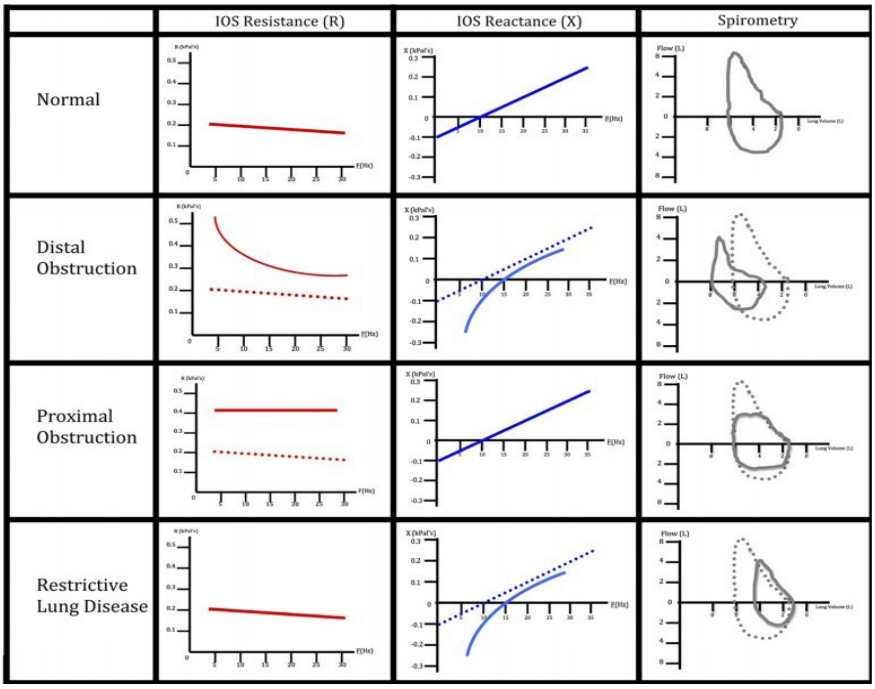
4. FORCED OSCILLATION TECHNIQUE AND BRONCHIAL ASTHMA IN CHILDREN

Bronchial asthma is a chronic inflammatory disease of the airways characterized with episodes of bronchial obstruction caused by inflammation, bronchospasm and mucus production. Often asthma is linked to seasonal allergies and eczema. This is the leading purpose for chronic disease and missed days at school in children.

The "golden" standard in the diagnosis of asthma is spirometric measurement of lung function but it acquires forced techniques and the patient`s cooperation. Whole bodyplethysmography also is difficult for the patient and needs expensive devices. Consequently, FOT is suitable for asthma diagnosis, treatment control and follow-up especially for preschool children, elderly patients, minority groups and people with neuromuscular diseases who cannot perform spirometry properly. Alblooshi et al. in their article for the methodology of FOT advice the clinicians to "understand the emerging role of FOT in clinical practice and how to interpret its results in order to improve management of children with asthma." (Alblooshi, 2017, p.129-138) The tidal breathing and the shortness of the test allow experienced physicians to examine children as young as two years of age, which is not possible in standard spirometry. The success rate in 4 years of age is around 80%, whereas in healthy children older than 6 years is close to 100%. In children with asthma aged between 3 to 5 years the success is from 57-100%.

Several studies established that young children with bronchial astma had impaired baseline lung function even when asymptomatic. Bronchodilator response assessed by FOT can also be used in identifying bad asthma control, which is especially suitable in the clinical management of asthma. (Delacourt, 2001) FOT`s feasibility has been assessed also in bronchoprovocation challenge testing in children with inhaled adenosine monophosphate (AMP), free running, methacholine, hypertonic saline, cold air or mannitol challenge. Actually, significant bronchospasm can be accomplished with lower doses of bronchoprovocative methods. Schulze et al reported that oscillation techniques are more efficient than spirometry because at lower doses of methacholine the resistance had a relevant increase before a change in FEV1 was observed. People with neuromuscular diseases and muscle weakness who are not able to perform forced expirations are also indicated for FOT. The study of Gauld et al. describes 12 children (mean age of 6 years) with spinal muscle atrophy that had abnormal respiratory reactance (Xrs 8) and resistance at 8 Hz (Rrs 8) and in the follow-up of these children the Xrs 8 z-score and Rrs 8 z-score worsened. Only 4 of the patients succeeded in performing spirometry.

Figure 4 Graphs of Impulse Oscillometry (IOS) and spirometry in patients with normal, obstructive, and restrictive lung disease. Dotted lines indicate the normal tracing, whereas solid lines show pathological tracings.



Source: Ann Allergy Asthma Immunol. 2011 Mar; 106(3): 191–199.

5. CONCLUSION

The forced oscillation technique (FOT) is a novel method that is easy to perform during quiet breathing and is perfect for preschool children. This method is very informative and should be broadly used in the diagnosis, control and progression follow-up of chronic obstructive diseases as COPD and bronchial asthma. Many studies suggest that compared with spirometry FOT is quick, effort-independent test that is more sensitive to early changes in the airways and can be used as a screening method for cigarette smoke-induced COPD.

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