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REVIEW

Lung Function Assessment by Impulse Oscillometry in Adults

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Abstract: Over the past decades, impulse oscillometry (IOS) has gained ground in the battery of pulmonary function tests. Performing the test requires minimal cooperation of the patient; therefore, it is a useful tool, especially in evaluating lung mechanics in children, elderly patients, and those who cannot perform spirometry. Oscillometry has also been used in both clinical and research departments. Studies were published mainly in asthma regarding detection of bronchodilator response and the therapeutic response to different drugs. Furthermore, it has been shown to be a sensitive technique to evaluate disease control. Other studied diseases were COPD, interstitial lung diseases, small airway disease, impairment of lung function due to exposure to occupational hazards or smoking, central airways obstruction, cystic fibrosis, monitoring lung mechanics during mechanical ventilation and sleep, neuromuscular diseases, lung transplant, and graft function. The aim of this review is to present the utility of oscillometry on the previously mentioned clinical fields.

Keywords: oscillometry, pulmonary function tests, respiratory resistance, respiratory impedance

Introduction

In the exploration of respiratory mechanics, the forced oscillation technique (FOT) is very often included in routine lung function testing, due to its minimal demand for the patient's cooperation. It is performed during tidal breathing, giving details on the respiratory system's elastic proprieties and homogeneity of ventilation. The principle of the maneuver is using external pressure signals (usually generated by a loudspeaker) to measure flow-response of the respiratory tract. Pressure and the resulting flow are then studied, submitting parameters of oscillatory mechanics (resistance, reactance). The aim of this article is to present clinical applications of oscillometry in adult respiratory pathology.

Structure of the Oscillometry System

There are three perspectives of the forced oscillation technique, one of them is the "typical forced oscillometry technique", which is sometimes applied as a general term describing all oscillometry techniques, but commonly points out a simple one-frequency technique,[1] another one is impulse oscillometry (IOS), using pressure pulses, and the third one is the Pseudo-Random Noise (PRN). IOS and PRN techniques are more often used because their principle allows a quick performance of the test. The one-frequency FOT is appropriate for the use in research because of its ability to determine changes occurring at one precise frequency. The concept of

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oscillometry was published very first by Dubois et al in 1956, describing a technique meant to be useful in acquiring data of the respiratory system's mechanic proprieties.[2] Further studies were published after 1990, due to the development of technology, facilitating the technical approach and the interpretation of clinical data.[3,4]

The main components of the oscillometer (Figure 1) are the loudspeaker, which forms a pulsatile stimulus through the adapter, this way pressure waves get into the airways with the airflow; and the pneumotachograph, usually attached to a mouthpiece, a face mask, or an endotracheal tube. A bias flow is used to eliminate the dead space. Data will be collected by the pressure and flow sensors.[5,6]

Technique Description

Prior to the measurements, reasonable instructions should be given, patients should breathe with tidal volume and respiratory frequency as usually. The procedure should be executed with the subject seated in a relaxed but upright posture. The position of the head and neck should be neutral or a bit extended. The subjects have to support their cheeks firmly, and a nose-clip must be used.[7] The technician must perform a visual check in order to verify that the mouthpiece is sealed and the tongue is in correct position, so there are no leaks around the mouth. During the procedure, the subjects are asked to perform tidal breathing for 30–45 seconds. Provided values of impedance are typically an average of all recorded correct measurements acquired in the course of the testing interval.[3,8] King et al[8] published technical standards for respiratory oscillometry in 2019, including a list of minimum instructions and information that should be provided to the patient prior to testing. Usually three measurements need to be performed, although in a study conducted by Watts et al,[9] published in 2016, analyzing the effect of the period of data gathering during the measurements on FOT results, 22 asthmatics, 18 COPD patients, and 20 healthy patients were used for the control group. Their study showed that two technically sustainable measurements derive the same mean resistance and reactance values as three or more replicate measurements, no matter how long the measurement lasts. Special attention is needed when performing multiple pulmonary function tests. Numerous studies proved that volume history can affect measurements in the case of subjects with pulmonary pathology, and in the case of healthy subjects during bronchoprovocation tests. Jensen et al[10] published a study showing the effects of deep breaths and bronchial challenge on airway caliber. Their study showed that asthmatic subjects cannot maximally dilate their airways during deep inspiration, and this worsens post-constriction considerably. Salome et al[11] also published a study 2 years later demonstrating theeffects of airway re-narrowing for asthmatic and non-asthmatic patients. Slats et al[12] published a study showing that, in the case of asthmatic patients, inflammation in the airways is strongly associated with impaired mechanical function of the lungs through deep inspiration. Therefore, oscillometry should be performed before other pulmonary tests requiring the subject to take deep breaths.

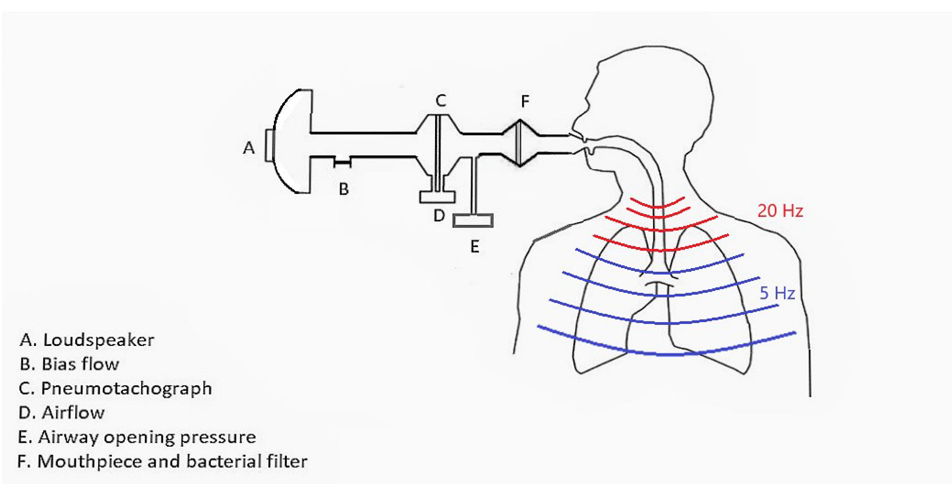

Figure 1

Acceptability Criteria

Although acceptability and reproducibility criteria of oscillometry still need improvement, the accuracy of the impedance measurements can be obtained by quality control, excluding artifacts such as swallowing, glottis closure, poor cheek support, tongue movement, or the presence of leaks. Technicians can identify these artifacts by monitoring the flow, the volume, and the pressure during the procedure, and eventually repeating the measurements, until obtaining three accurate recordings.[8,13] Reproducibility of impedance can be validated with coherence values. An optimal test quality requires values larger than 0.8 cm H_2O measured at 5 Hz or larger than 0.9 cm H_2O measured at 20 Hz.[8]

Parameters

The respiratory tract's resistance and reactance values can be determined by oscillometry at given frequencies. The main parameters are: Impedance (Z) force that has to be defeated in order to mobilize gas in and out of the airways. Mathematically it can be determined as the ratio of pressure (P) to flow (V) in function of oscillation frequency (ω):

$$Z(\omega) = \frac{P(\omega)}{V(\omega)}$$ [14]

Furthermore, impedance can be separated to its components, resistance (R) and reactance (Z):

$$Z(\omega) = R(\omega) + \quad jX(\omega)$$ [14]

where j-imaginary unit, √-1.

Variations of impedance can be detected depending on the respiratory tract area where the pressure is measured (upper airways, distal airways, lungs, or chest-wall).[15,16] Respiratory resistance (Rrs) is the energy needed to move the pressure wave through the airways. An increase in resistance can be found in diseases affecting the airways, for example in asthma or COPD. Respiratory reactance (Xrs) is the energy determined by flow airflow dynamics in the airways, influenced by the elasticity of tissue and the interstitial forces. Values of reactance (Xrs) become more negative in diseases where elastance is increased.

$$X(\omega) = I - \frac{E}{\omega}$$ [14]

where Capacitance (E), component of reactance, determines the elasticity of the lung, and it presents as a negative value. Inertance (I), also part of reactance, is determined by mass-inertive forces of the air movement in airways and it is a positive value.

Resonance frequency (Fres) is the value of Hertz at which inertance and peripheral capacitance of the lungs have equal values, and the total reactance becomes zero.[17] Reference values of resonance frequency for adults are between 7 and 12 Hz.[5,17] Values of resonance frequency can be higher in the case of lung disorders, both restrictive and obstructive.[18,19] The area of reactance (AX) includes the area under the reactance curve from lowest frequency to Fres; increased values were correlated with distal obstruction.

Practically 5 Hz frequency signals reach distal airways so R5 equals the total airway resistance, while high-frequency signals like 20 Hz can only reach the central airways and R20 equals the resistance of the proximal airways (Figure 2). In order to acquire the resistance of the distal airways, the difference between R5 and R20 is needed.[18,20] In practice, a higher increased R5 than R20 means the disease of small airways, and the increase of both parameters (R20 and R5) indicates proximal airway disease.[15,18,20] On the other hand, reactance (Xrs) at low frequencies (5Hz) determines the elastic and interstitial proprieties of the lung. Diseases that affect the elasticity of the lung (for example: interstitial lung diseases) will increase capacitance negatively (X5 will be more negative). Values of reactance are also influenced by age and weight (increase of age and weight will determine a less negative reactance).

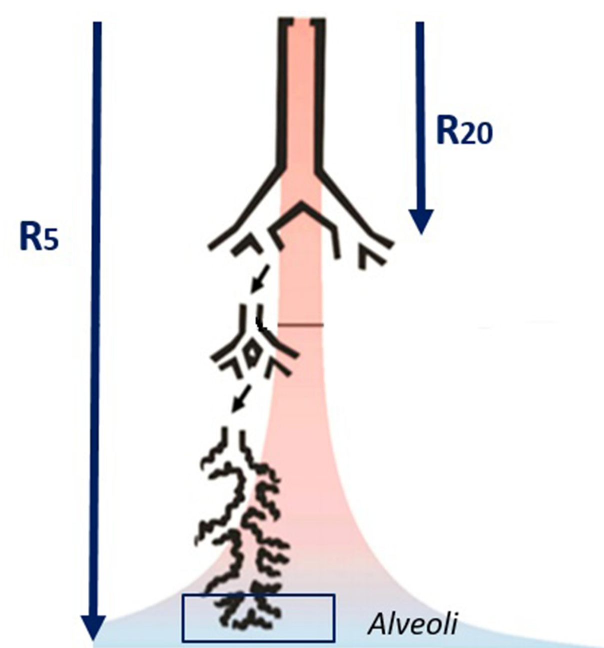

Figure 2

Interpretation and Reference Values

Last year the European Respiratory Society elaborated new "technical standards for respiratory oscillometry". King et al[8,21] recommend in their article determination of predicted values for any oscillometry device in the population where it is used. Values can be different depending from the type of device that is used.[22,23] Although there are publications on reference values, especially in the case of children, but also in the case of adults, normative values have not yet been published.[8] Kalchiem-Dekel and Hines[24] published a review article on reference values for oscillometry collecting published data from 1977 to 2017. In their research they included 14 studies of forced oscillometry technique, 19 studies of impulse oscillometry, and one study providing values for both. The majority of publications were from Europe and Asia, applied on small groups of subjects (median=264 subjects). They concluded that the measurements and the test performance were inconstant. Prediction equations were influenced by the height of the subjects and also by the gender. The age variation was not conclusive due to the poor representation of elderly subjects in the studies. A German study conducted by Sulhz[25] on a large number of subjects (1990), aged between 45–91 years, established significant differences in values of Rrs5 (29%), Rrs20 (33%), and Xrs5 (76%) compared to previous publications. In Table 1 we summarized the main publications on reference ranges since 2010, with over 250 subjects. Difficulties in interpretation may appear in the presence of a lung disorder, due to lack of recognizing different disease patterns. A Canadian study conducted by Dandurand et al[26] demonstrated that there are significant differences between oscillometry devices and measurement performances, reducing the ability to compare between studies using different equipment and formation of oscillometric-parameter databases device-independently. There are also situations when subjects performing the test have multiple lung diseases (overlap).

Clinical Applications

The main areas of clinical application of impulse oscillometry are presented in Figure 3.

Response to Broncho-Dilatators

One of the main utilities of oscillometry is assessing broncho-dilatator (BD) response. Studies showed that FOT has more sensitivity than spirometry in the case of children as a predictor of asthma and response to treatment.[16,27] When evaluating BD response, King et al[8] recommend the definition of a positive response as a decrease in Rrs5 with −40%, an increase in Xrs5 with +50% and decrease in AX with −80%. da Costa et al[28] studied the impedance changes after administration of salbutamol in the case of healthy and COPD patients, showing that oscillometric parameters are highly sensitive to broncho-dilatation, especially in early stages of COPD. Another study conducted in Japan by Inui et al[29] showed that FOT can be as useful as spirometry in assessing treatment response to treatment of COPD patients. An Australian study assessed the broncho-dilatator effects on exertional dyspnea, showing improvement, and also increased conductance values measured by FOT in case of moderate-COPD patients.[30] Milne et al[31] published a small study, on 15 COPD patients assessing correlations

Table 1 Main Publications Reporting Reference Values on Healthy Adults Since 2010

Authors	Technique	Frequency Range (Hz)	Number of Subjects	Age Range	Etnicity/ Nationality	Parameters
Brown et al, 2010[103]	FOT, PRN	6–19	904	18–92	Caucazian	R6, R11, R19, X6, X11, X19
Fujiwara, 2010[104]	IOS	5–35	420	20–89	Japanese	R5, R20, FDRrs, X5
Crim et al, 2011[53]	IOS	5–20	555	55±9	Multinational	R5, R20, FDRrs, X5, AX, Fres
Li and Wang,2012[105]	IOS	5–20	920	56±13	Chinese	R5, R20, FDRrs, X5, Fres
Oostveen et al,2013[21]	IOS, PRN	–	368	18–84	Caucazian	mRrs, mXrs, Fres, AX mRrs, R4–R26, X4–X14, Fres, AX4, AX5
Schulz et al,2013[25]	IOS	5–35	397	45–91	Caucazian	R5, R20, FDRrs, X5, AX, Fres
Xue, 2014[24]	IOS	–	6945	40–65	Chinese	mZrs, R5, X5, Fres
Zheng et al2015[24]	IOS	5–20	362	18–78	Chinese	R5, R20, X5, X20, Fres
Geng et al,2016[24]	IOS	5–20	409	20–60	Chinese	R5, R20, X5, Fres
Shu et al,2016[24]	IOS	5–20	431	48 ± 14	Chinese	R5, R20, FDRrs, X5, Fres
Ribeiro et al,2018[106]	PRN	4–32	288	20–86	Brazilian	R4, R22, X8, X22

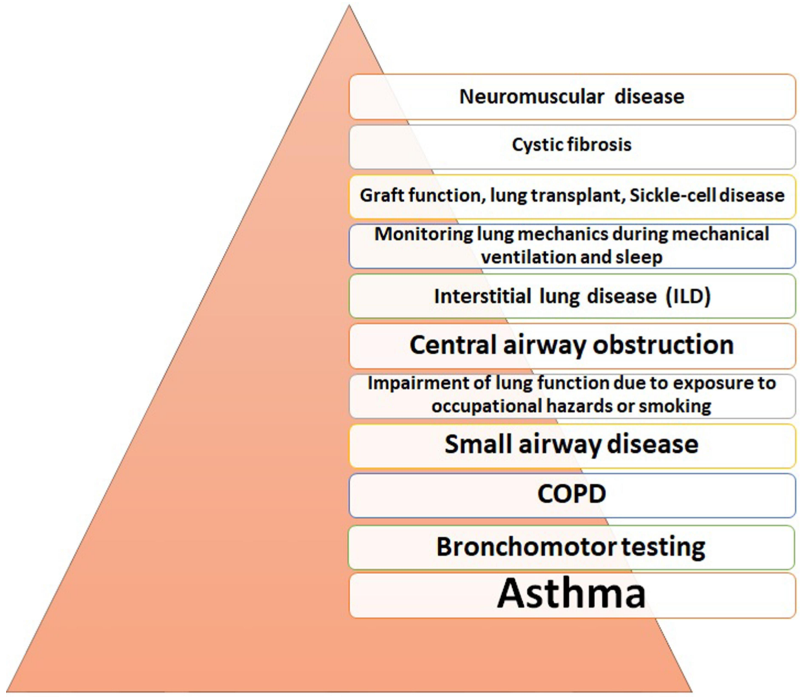

Figure 3

between oscillometry, hyperinflation and air-trapping in response to long-acting broncho-dilatator treatment and demonstrating its utility in treatment response evaluation as a complementary functional test. Assessing the responsiveness of airways to combined therapy (long-acting beta agonists and corticosteroids) in asthma was the subject of numerous publications.[32–34] The improvement of oscillometric parameters, and their prediction of improvement in FEV1 in the case of untreated asthmatic patients after a 2-month-administration of combined therapy (corticosteroids and long acting beta-agonists) was shown in a Japanese study published by Akamatsu et al.[35]

Broncho-Provocation Testing

Broncho-provocation testing can be performed in order to assess airway hyper-responsiveness using various agents like histamine, methacholine, allergens, and also by exercise testing. An increase of oscillometryc parameters like Rrs5, AX, and Fres has been demonstrated; Xrs5 became more negative during exercise-induced bronchoconstriction. Segal et al[36] revealed that hyper-reactivity of distal airways can be connected to methacholine-induced symptoms without any change in FEV1. This study highlights the importance of disparity between proximal and distal airway behavior. A study conducted by Mandelev et al[37] showed that in the case of obese subjects, bronchial challenge is related to higher expiratory flow limitation measured by Xrs. It has been established that the obtained values correspond rather with symptoms than with values of FEV1.[38] Studies have also shown that an increase of initial Rrs5 values of 50% after broncho-provocation may be correlated with a 20% decrease in FEV1.[8,–32,–39–41] A study published by Naji et al[42] concluded that using oscillometry as an alternative method for measuring resistance and obstruction may be useful when patients cannot perform body-plethysmography or spirometry. Figure 2 illustrates the disease variety in which impulse oscillometry has been proved useful.

Asthma and COPD

The most often researched lung diseases with oscillometry of all is asthma. Airway resistance increases (especially in small airways) in the case of patients with asthma, mainly during exacerbations.[17] Usually there are increased values of Rrs5, Fres, normal values of R20, and Xrs5 is more negative[17] In periods between exacerbations all parameters may be normal in the case of children.[43] Oscillometry is also a useful tool in evaluating the control level of asthma. Poor control of the disease can be suspected when parameters Rrs5-Rrs20 and AX are increased.[43] A Spanish study concluded that there were important parameter differences in case of uncontrolled, poorly controlled, and uncontrolled asthma, but patients cannot be organized correctly into control categories only based on oscillometry. They found associations between oscillometric values and spirometry.[27] Similar data was published by Galat et al[44] in a review article on asthma control. Carr et al[45] reviewed literature on the correlation between small airways disease and asthma control, concluding that diagnose of SAD (small airway disease) can occur with various non-invasive tests, including oscillometry, and may improve treatment response. Furthermore, oscillometry may detect small airways impairment even before the presence of symptoms and spirometric changes.[15,46] It can be useful in preventing symptom development by implementing prompt therapy.[46] Detecting treatment response in asthma is also a feature of oscillometry, especially by assessment of the changes in the reactance area (AX).[47]

In contrast, in the case of COPD patients a higher increase in Rrs5 than in Rrs20 was noticed, leading to elevation to the Rrs5-Rrs20 parameter.[48–51] Reference values for this disease were also studied, but there are not any defined values yet. Cut-off pathological values for R5 higher than 0.5 kPa/L/s, R5–20 higher than 0.10 kPa/L/s, AX higher than 1.0 kPa/L were suggested for use, but further studies are required.[48,52] Also in COPD, the magnitude of the changes in Fres, Rrs5, Rrs20, Xrs5, and AX tends to correlate well with GOLD1–GOLD4 severity. This was shown in the largest study (Eclipse study, a 2,054 cohort of COPD patients) performed by Crim et al.[53] A Chinese study performed on 215 subjects with COPD by Wei et al[52] comparing the usefulness of IOS and other pulmonary function tests in determination of the severity of disease showed that there is a good correlation between tests, especially with reactance parameters, and that IOS may be used as an alternative diagnostic test in case of patients with FEV1 lower than 50%. A study published in Poland by Piorunek et al[54] suggests that the severity of obstruction in COPD measured by spirometry (FEV1% pred.) correspond with oscillometric parameters, and lung resistance is influenced by airflow limitation severity. Eddy et al[55] studied the correlation between impulse oscillometry and hyperpolarized gas magnetic resonance imaging (MRI) of ventilation defects. Their study showed that parameters R5–19 and X5 may correspond with airway and parenchymal disease-specific abnormalities causing ventilation defects. The frequency of COPD exacerbations was correlated with increasing parameter AX.[48] Although oscillometry's role in diagnosis of obstructive diseases is known, there are some limitations of this technique in monitoring the disease progress that needs further study.[20]

Interstitial Lung Disease (ILD)

Modified values of reactance and resistance can appear in consequence of small airways inflammation, or in association with modified elastic recoil pressure and reduced lung volume in both obstructive and restrictive diseases.[56] There is an overlap of increased parameters Rrs5, Fres, AX, and a decrease in Xrs5 (more negative) in both obstructive and restrictive lung diseases, this could be a reason why oscillometry has a bigger role in characterizing obstructive diseases.[57] The only parameter that differentiates them is Rrs20, which remains normal in the case of ILD patients, but increases in obstructive diseases.[58,59] In a study by Mori et al,[60] decreased X values (especially X5) were found in patients with ILD, mostly in inspiration, which has more negativity than in expiration, in contrast to patients with COPD, which had decreased values in expiration that is more negative than in inspiration. A Japanese study conducted by Mikamo et al[61] showed that oscillometry may be a useful tool in assessment of small airways disease in interstitial lung disease. A very recent study, conducted by Reham et al,[62] studied correlations between oscillometry and spirometry on patients diagnosed with rheumathoid arthritis accociating ILD, and concluded that IOS can be used as an early screening technique to identify proximal and distal pulmonary tissue affection even before spirometry changes appear. Furthermore it facilitates the selection of patients needing further investigations to confirm the cause of increased lung resistance.

Impairment of Lung Function Due to Exposure to Occupational Hazards or Smoking

In an American study, Berger et al[63,64] showed that the forced oscillometry technique has high capacity in early diagnostis of airway disease. In their study they performed oscillometry and spirometry on symptomatic subjects exposed to the World Trade Center dust, and while spirometry values were normal, they registered modifications on oscillometric parameters. An older study assessing the secondary effects of smoking habits of miners concluded that the effect of occupational exposure on the central airways can be registered by oscillometry, but not the effect of smoking.[65] A study performed in Brazil by de

Sá et al[66] on asbestos exposed workers showed that oscillometry can be used as a screening tool in asbestos management and eradication. Other publications show that oscillometry is as useful as spirometry in analyzing lung function impairment due to smoking or occupational hazards.[6,67]

It is well known that, even with normal spirometry values smokers develop symptoms and small airway impairment in time.[68–70] A study performed on smokers showed that development of symptoms was correlated with spirometry and oscillometry parameters. They did not determine whether there is clinical significance in the obtained altered values.[71] Berger et al[72] conducted a study on asymptomatic smoker subjects, which concluded that there was small airway impairment in oscillometric parameters, in subjects associating emphysema detected on computer tomograph and inflammation. These subjects could not yet be diagnosed with COPD according to Gold criteria.

Assessing Small Airways Proprieties

Small airways disease is one of the current hot topics in publications. The correlation between small airway dysfunction and oscillometry has also been studied.[72,73] High values of R5–R20 may indicate small airway disfunction.[74] A large cohort study (ATLANTIS), conducted in nine countries, on 773 asthmatic subjects, published by Postma et al,[75] revealed that SAD may be present in all GINA stages of asthma, the prevalence is higher in advanced stages (GINA 5). They also showed that oscillometry can be included in routine diagnose testing in clinical practice. Bhatawadekar et al[76] quantified bronchodilator response in the large and the small airways of healthy and asthmatic subjects, revealing that bronchodilator response was more important in the small airways of asthmatic subjects. They found low-frequency reactance and derived elastance relevant for the measurement of distal airway function. A study published by Shi et al[77] revealed that for the detection of poor control in the case of asthmatic children, between the spirometric parameters (FVC, FEV1, and FEF25-75) and the oscillometry parameters, the most suggestive parameters were found in IOS (impulse oscillometry). A Chinese study revealed values of R5–R20 are corelated with distal airways impairment in the case of heavy smokers and early stages of COPD, and also with particularities evidenced on endobronchial optical coherence tomography.[78] Furthermore, another study suggests that both IOS and spirometry have matching value in diagnosing small airway disorders in bronchiectasis in mild and moderate stages.[79] Foy et al[80] very recently published a study that concluded that, although the small airways have increased resistance in moderate-to -severe asthma, their dilatation in deep breathing is not affected (without bronchial challenge), wich leads to the fact that targeted therapy of small airways is also needed for disease improvement.

Central Airways Obstruction

A study published by Hnad et al[81] revealed evidence of the usefulness of oscillometry in the assessment of the central airway obstruction. The advantage of oscillometry, being non-invasive and also effort-independent, makes it a sustainable test for differentiating fixed and variable obstruction of central airways, also for monitoring before and after procedures, like bronchoscopy. Another study concluded that the therapeutic results can also be estimated in the case of patients with central airway obstruction using the oscillometric parameter Rrs20.[82]

Cystic Fibrosis

Most studies regarding cystic fibrosis have been published on children.[83–85] Research on oscillometryc parameters in cystic fibrosis showed an increase in Rrs5, Fres, and a decrease of Xrs5 in phases of the exacerbation of the disease, and an improvement of these parameters after treatment.[86] A Brazilian study on 26 cystic fibrosis patients that consisted in assessment of lung volume by computer tomography and pulmonary function tests, revealed that hypoventilated regions of the lungs correlate with increasing restrictive parameters of oscillometry and also with reduced diffusing capacity of the lungs.[87]

Monitoring Lung Mechanics During Mechanical Ventilation and Sleep

The oscillometry's use in modified lung mechanics during ventilation and sleep studies has been widely researched. The impedance values of the respiratory system may have a contribution in invasive and also non-invasive ventilator settings.[88–93] In sleep apnea impedance it can be followed during the breathing cycle, and changes can be detected when apneas or hypopneas appear.[94] A Chinese study showed that the association between the oscillometric value of reactance and obstructive sleep apnea can be developed in the case of stenosis of the upper airways.[88] Another study published by McDowell[95] revealed data on usefulness of the IOS in monitoring obstructive sleep apnea after CPAP therapy. The study included 18 patients with obstructive sleep apnea that underwent CPAP therapy for 3 months. Their results showed that there was a significant decrease of resistance and reactance parameters after therapy, concluding that IOS can be used for monitoring therapy.

Neuromuscular Diseases

An older Belgian study performed on 16 patients with ankylosing spondylitis and seven with kyphoscoliosis, conducting pulmonary function tests, including oscillometry, revealed differences in the resistance and the reactance of the two diseases correlated with the severity of the restriction.[96,97]

Other Diseases – Graft Function, Lung Transplant, Sickle-Cell Disease

In addition to the disease categories mentioned above, modification patterns in FOT parameters were studied also in the case of patients with lung transplant. A case-report study revealed oscillometry's use in the pulmonary function testing of patients in early stages after lung transplant, who cannot perform spirometry, due to post-operative pain and poor cooperation in forced expiratory maneuvers. Researchers concluded that the test was useful in evaluation of small airways in the case of critically ill patients, and may help in diagnosing acute graft rejection.[98] Another study performed in Poland, on 25 transplanted patients, showed that IOS may be used in the assessment of chronic lung allograft dysfunction.[99] A recent Chinese study, performed on 156 lung-transplanted patients, shows that Oscillometry identified physiological changes associated with grade 2 acute cell rejection that were not observed on spirometry and it's usefor graft monitoring after a lung transplant.[100] Although it's not an adult-based study, a group of researchers from Pennsylvania found that oscillometry was more feasible than spirometry in children with Sickle-Cell disease, because it can be performed on children of young age, and it has greater sensibility to bronchodilatation-response.[101]

Limitations

Lately oscillometry became a trendy and promising tool in lung mechanics' assessment. However, there are substantial limitations of this method. Standardization documents still need improvement, especially on normative values. Also, the comparison between different devices presents difficulty and requires further study. In the absence of this data, the ERS Task Force recommends that reference values should be derived from a device that is most similar to the device in use.[8] Although its utility in obstructive diseases seems clear, there is place for further research in oscillometric parameters in restrictive patterns. When comparing broncho-dilatator response, oscillometry and spirometry parameters may be discordant. Most of the studies published at the time are conducted on a small scale of patients, which makes it difficult to use it as a strong diagnostic tool.[102]

Future Directions

Further research is needed on quality control methods for parameters, covering wide age ranges and in various pulmonary diseases and clinical areas (the intensive care, population screening). Implementing oscillometry to geriatric and pediatric clinics could be important in diagnosis and monitoring diseases, facilitating the adjustments of therapy. Interstitial lung diseases with oscillometry need detailed research, since a radiation-free assessment in monitoring disease progression could be very beneficial. Oscillometry can be a sensitive tool for diagnosing early stages of fibrosis (even before spirometric changes). Furthermore, with new fields being studied, we can anticipate that the use of this technique will continue to expand in research. The development of new easier to use and portable devices and the acquired knowledge on interpreting oscillometry parameters, will hopefully make this technique more accepted and useful for daily practice.

Conclusions

Both methods' (FOT and IOS) measurement techniques are effective in assessment of airflow limitation. Since it is performed on tidal breathing, there is no need for active cooperation of the patients, it is suitable for both children and elderly patients, and for those who cannot perform spirometry. The technique is reproducible, although the variability is more pronounced than in spirometry. Recently, the recommendations for standardization in measurements were updated (ERS 2019), but there is a requirement for elaborating the standardization of reference values and thresholds, especially in the case of adults. It seems that the role of oscillometry is relevant in observation of changes over time in chronic diseases, also in investigating broncho-motor responses of airways, although significant changes in both tests need further study. Interest in impulse oscillometry is expanding worldwide, new applications in physiology and various clinical conditions are arising.

Disclosure

The authors report no conflicts of interest in this work.

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