Impulse Oscillometry in the Diagnosis of Chronic Obstructive Pulmonary Disease: A Literature Review

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ABSTRACT

Introduction: Chronic Obstructive Pulmonary Disease (COPD) is a progressive, poorly reversible obstructive disease affecting mainly the small airways. Spirometry is the current standard diagnostic test for COPD. Impulse Oscillometry (IOS) is the commonest forced oscillation technique (FOT) in use and it shows promise as a diagnostic tool in the diagnosis of COPD. This systematic review aims to review the diagnostic yield of IOS compared to standard spirometry in COPD patients.

Methods: PubMed, OVID, CINAHL, and Cochrane Library databases were searched with Mesh headings to locate studies linking IOS and Spirometry in the diagnosis of COPD. A systematic review is undertaken to assess the diagnostic yield of IOS in COPD.

Results: Four studies were identified that fulfilled the inclusion criteria. A total of 358 patients were included in the data to inform the diagnostic yield of IOS compared with spirometry where R5-R20 and X5 and AX correlated consistently with FEV1 in the diagnosis of COPD.

Conclusions: IOS is useful in the diagnosis of Chronic Obstructive Pulmonary Disease.

Keywords: Spirometry, Impulse Oscillometry, IOS, COPD, Chronic Obstructive Pulmonary Disease

INTRODUCTION

COPD is one of the leading causes of morbidity and mortality worldwide. According to the World Health Organization, an estimated three million deaths are attributable to COPD every year[1]. The prevalence of COPD in KSA based on the Burden of Lung Disease (BOLD) studies was 4.2% while the Breath was 2.4%[2,3]. According to the Global Initiative for Chronic Obstructive Lung Disease (GOLD), spirometry is the gold standard for the diagnosis of COPD which is particularly challenging for elderly patients to perform, patients with cognitive impairment and poor motor coordination[4]. Therefore, more reliable methods are needed.

STUDY METHODOLOGY

Given the increased interest in impulse Oscillometry as an alternative and/or supplementary diagnostic method to spirometry, we conducted a systematic literature review to determine the ability of impulse oscillometry in detecting airway obstruction in Chronic Obstructive Pulmonary Disease and its usefulness as an alternative method to spirometry.

PROTOCOL AND REGISTRATION

The study protocol has been approved by The Johns Hopkins Aramco Healthcare Institutional Review Board (IRB) and is registered on the PROSPERO register of systematic reviews, The registration number CRD42021246907.

SOURCES OF DATA

The electronic databases PubMed, CINAHL, Ovid, and Cochrane databases were searched to February 2020. Search terms were spirometry, impulse oscillometry, IOS, COPD, and obstructive lung disease. No language limitation was used.

DATA SELECTION

The subjects included in the data were adults (18-65 years old) with a diagnosis of COPD and who had IOS and spirometry done with the objective to establish the diagnosis of COPD. All retrieved abstracts were scanned for potential relevance and accordingly the potentially relevant articles were reviewed as full texts. Non-relevant data were excluded. The full-text articles of potentially relevant articles were reviewed by two independent pulmonary physicians to ascertain inclusion in the analysis, which was followed by discussion and mutual agreement.

DATA COLLECTION AND CERTAINTY OF EVIDENCE

This systematic review was conducted following the preferred reporting item for systematic review (PRISMA) as described in figure 1.

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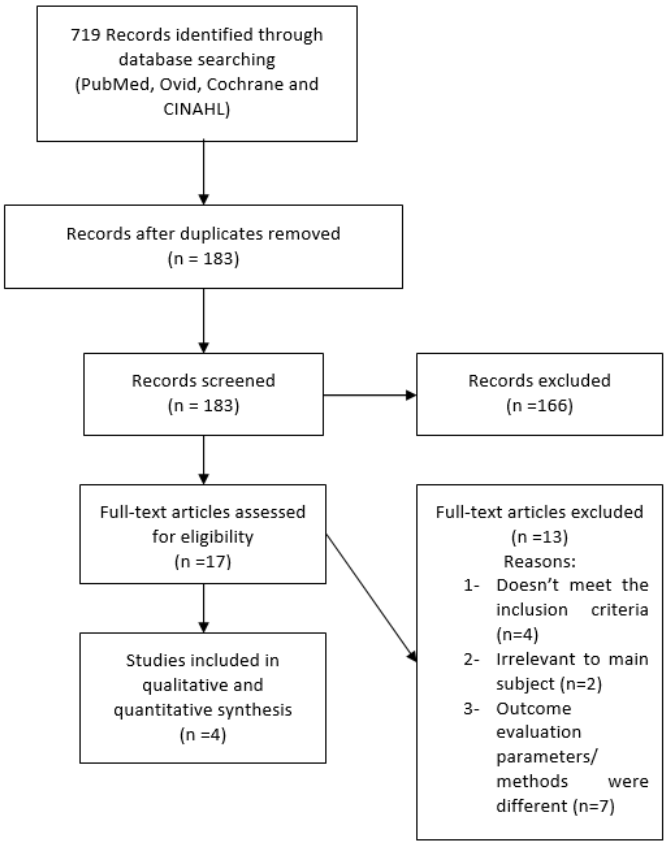

Figure 1: Flowchart of studies comparing IOS and Spirometry in the diagnosis of COPD

DATA ANALYSIS

Overview of reported test techniques

Spirometry: Spirometry is a test that measures lung function, volume, and the flow of air that can be inhaled and exhaled. Patients will be asked to take a deep breath in, and then exhale as hard as he/she can into the spirometer machine for at least 6 seconds followed by taking another deep inhalation.

The spirometry device should be calibrated daily as directed by the manufacturer. Spirometry is performed with the patient sitting upright position with a nose clip in place. Acceptability criteria as described by the American Thoracic Society (ATS) should be applied. The test is repeated at least three times as per the ATS spirometry reproducibility criteria. The test reports a variety of values. More importantly, are forced expiratory volume in the 1st second of expiration (FEV1) and forced expiratory volume (FVC). The ratio of FEV1 to FVC can be calculated.

Impulse Oscillometry: Impulse oscillometry utilizes sound waves applied to the airways at a range of frequencies and multiple components of respiratory impedance are measured including resistance and reactance.

The Impulse oscillometry device should be calibrated daily as directed by the manufacturer. IOS is performed with the patient sitting upright position and breathing tidal volumes in resting condition. A nose clip is in place and cheeks firmly supported by either the patient's own hands or another individual's (caregiver or examiner). During IOS, sound wave signals of various frequencies, typically 5 and 20 Hz, are transmitted along the bronchial tree by oscillating. It provides measures of the total airway resistance (resistance at 5 Hz [R5]), the proximal airway resistance (resistance at 20 Hz [R20]), and the peripheral airway resistance (R5-R20). Reactance at 5 Hz (X5) relates to the physical properties of the lung parenchyma and its ability to expand and facilitate alveolar filling. Resonant frequency (Fres) is the point at which reactance is zero when the forces of inertia and capacitance are equal. The reactance area (Ax) is the sum of all the frequency values from X5 to the resonant frequency and it quantifies the respiratory reactance between 5 Hz and Fres. Fres and Ax are considered sensitive indicators of reactive airflow limitation[5]. The test procedure takes approximately 30 seconds to complete each trial. It reports Resistance at 5 hertz (R5) and Resistance at 20 hertz (R20). The difference between these two values can be calculated (R5-R20).

RESULTS

Of the 183 articles identified from the databases search, 4 articles had relevant content. The significant diagnostic yield of impulse oscillometry in detecting airway obstruction in Chronic Obstructive Pulmonary Disease is summarized in Table 1.

Wei, X et al[6] recruited 215 subjects. Using Spearman correlation analysis, % pred FEV1 showed a moderately positive correlation with X5 (r 0.54 P<0.01). A moderate negative correlation between % pred FEV1 and impedance/ R5-20 (r -0.435, -0.425 respectively P-value <0.01), weak negative correlation with R5 (r -0.35 P<0.01), and no correlation with R20 (P>0.05). In contrast, Anderson WJ et al[7] analyzed spirometry, IOS, from 57 COPD patients and found significant direct strong correlation between FEV1 and R5 /R5-20 (r -0.456 P 0.001, r -0.499 P <0.001 respectively). Nikkah M et al[8] examined 3 study groups (87 healthy subjects, 87 asthmatics, and 56 COPD patients) in relation to their spirometry and IOS measurements. R5 was significantly correlated with FVC as well as R20 (r -0.285 P <0.05 r -0.289 respectively). X5 correlated well with % pred FEV1 (r 0.349). While Saadeh C et al[5] examined 30 COPD patients with mild to moderate chronic obstructive pulmonary disease using spirometry and IOS at baseline, after bronchodilators, and after 3 months follow up. IOS measurements showed immediate improvements in terms of reactance area (AX P 0.043) while FEV1 measurements were unaffected after bronchodilator at baseline and after 30 months follow up. However, there was a decrease in AX (P 0.0008) and decrease in R5 (P 0.0011)

DISCUSSION

The diagnosis of COPD is based on symptoms, risk factors and spirometry data. Spirometry includes a forced expiratory maneuver to measure expiratory flow limitation and dynamic lung volumes. It does not simulate normal breathing and hence is artificial. Some patients find it difficult to perform spirometry either due to coughing or severe breathlessness after trials hence no objective measure (spirometry) can be used to assess and monitor the patient.

Impulse Oscillometry (IOS), the most used forced oscillation technique, is performed using normal tidal breathing and so is effort independent and more physiological than spirometry. The resistance at 20 Hz (R20) is unrelated to COPD severity and does not change with bronchodilation which indicates that COPD is mainly a disease of small airways, not large airways. The peripheral airway resistance (R5-R20) and peripheral airway compliance (AX) are both related to COPD severity and exacerbation.

Table 1: Summary of studies assessing the use of IOS and Spirometry in the diagnosis of COPD

Study ID	Publication Author/ Year	Sample size	Age (mean ±SD Years)	Measured outcome	Outcome
1	Wei, X 2017[6]	215	67.69 (±9.95)	Correlation between spirometry and IOS measurements for the assessment of COPD airflow limitation.	• A moderate negative correlation observed between % pred FEV1 and % pred Z5, R5-20, (R5-R20)/R5%, Fres, Ax (spearman correlation coefficient r = -0.474, -0.5 and -0.521 respectively, P< 0.01) • % pred FEV1showed a moderately positive correlation with X5 (r = 0.54, P<0.01). • There was a weak negative correlation with R5 and % pred R5(r= -0.35 and -0.292 respectively, P<0.01) • R20 and % pred R20 showed no correlation with % pred FEV1 (P>0.05) • FEV1/FVC which reflects airflow limitation, was consistent with IOS parameter but the correlation was weaker with than that with % pred FEV1.
2	Anderson., WJ 2012[4]	57	66.4 (±1.28)	Correlation between spirometry and IOS variables in COPD patients	• Strong correlation was found between R5 with FEV1, FVC and FEF 25-75%. • Correlation between R5-R20 and FEV1 r = -0.499 P<0.001) • Correlation between R5-R20 and FVC (r = 0.521 P<0.001) • Significant Correlation between R5-R20 and FEF 25-75 (r = -0.397 P=0.002) • No correlation between R20 and any spirometry variable.
3	Nikkhah., M 2011[8]	143(87 healthy,87 Asthmatics & 56 COPD patients)	45(±19) three groups 64.1 (±15.8) COPD	Correlation between spirometry and IOS variables in COPD patients	• R5 was significantly correlated with FVC (r = -0.285 P<0.05) • R5 was significantly correlated with FEV1 (r = -0.292 P<0.05) • R20 was significantly correlated with FVC (r = -0.289 P>0.05) • R20 was significantly correlated with FEV1/FVC (r= 0.263 P>0.05) • X5 is significantly correlated with FEV1/FVC (r = 0.349 P>0.05)
4	Saadah., C 2015[5]	30	63.8 (±8.22)	Correlation between IOS and spirometry parameters at baseline and 3 months after inhaled bronchodilator to monitor pulmonary responses to bronchodilators.	• IOS was able to detect improvement in lung function after inhaled bronchodilator while FEV1 values had no significant change in terms of AX (p=0.064) but not R5 (p=0.148). • After 3-18 months of inhaled corticosteroids, beta-2 agonists and/ or anticholinergic therapy, FEV1 didn't show any significant improvement in comparison to baseline. However, all IOS parameters had significantly improved compared to baseline at time of follow up with a 37% decrease in impedance AX (p = 0.0008) and 20% decrease in R5 (p= 0.0011).

Lipworth et al[9] proposed the IOS cutoff points for R5>0.5 kPa/L/s (> 5.1 cmH2O/L/s) R5-20 > 0.10 kPa/L/s (1.02 cmH2O/L/s), AX> 1.0 kPa/L (> 10.2 cmH2O/L) indicating pathological levels to establish the diagnosis of COPD[6,9,10]. In the Eclipse study cohort of 2054 COPD patients ,R20 values were similar across the groups but higher than the controls whereas R5-R20 were higher when compared with the controls[10]. In a screening study to detect COPD in patients with positive spirometry criteria, spirometry data correlated well with higher values of R5-R20, X5, and AX[11]. The reported reduction in AX values (improved lung compliance) in COPD post bronchodilator may reflect the lung deflation due to the medications effect.

Wei et al[6] included 215 patients with COPD with a mean age of 67.69 years. They correlate the IOS parameters with spirometric values. The reactance parameters had a better correlation than the resistance parameters. There was a clear correlation with the FEV1 predicted, FEV1/FVC and R5-R20, R5-R20%R5, and AX thus the IOS parameters correlated with the airflow. They showed no correlation with the R20 (proximal airway resistance). These findings are promising to have IOS to support and or perhaps replace spirometry in the assessment of COPD.

Anderson et al[7] studied 57 patients with COPD with a mean age of 66.4 years and showed a correlation with R% and R5-R20 with FEV1, FVC, and FEF 25-27% and no correlation with R20 Thus, their study shows correlation with the parameters of airflow limitation. The study didn't show a correlation between the FEV1/FVC ratio and the IOS parameters. This differs from what Wei et al[6] reported may be due to the number of subjects studied. Nikkah[8] compared a group of healthy individuals with asthmatic and COPD patients. In the 56 COPD patients, the mean age was 64.1 years where the mean age for the whole study population was 45. Again, the study showed a correlation with the FEV1/FVC, FEV1, and R5, and X5. Nikkah[8] postulated cutoff points to diagnose COPD using IOS parameters of R5 >0.53 (sensitivity 58.93, Specificity 89.53), R20 >0.39 (sensitivity 41.07, specificity 82.35) and X5 < -0.16 (sensitivity 79.79, specificity 81.61). Muscarinic and beta-2 receptors are in small airways and more important in mediating the bronchodilator response in COPD and hence R5-R20, X5 and AX correlated better with bronchodilator response[9]. Saadeh et al[5] studied 30 patients with COPD and followed them up to 18 months. The mean age was 63.80 years and used R15 instead of R20. He showed at baseline spirometry failed to show change with bronchodilator but AX demonstrated that while R5 and R15 didn't. He didn't correlate the IOS parameters to the spirometry and inferred that the IOS parameters, especially AX, were more sensitive to detect bronchodilator responsiveness and monitor response to therapy over time. He used reference ranges for IOS reported by Komarow and Goldman[12,13] to establish the diagnosis of COPD rather than the spirometric measures.

This systematic review shows that IOS is a useful diagnostic tool in the diagnosis of COPD.

Implications of this systematic review are that the concomitant use of IOS with spirometry may improve the diagnostic accuracy in patients suspected to have COPD.

CONCLUSION

The current systematic review confirms the presence of reliable correlation between IOS and spirometry in the diagnosis of COPD. Future larger studies are required to establish the relationship of IOS with spirometry across different grades of airflow limitation due to the limited heterogeneous data available in the published articles.

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Potential Conflict of Interest: None

Competing Interest: None

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