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Utility of Forced Oscillation Technique in Detecting Obstruction in Asthma and the Significance of 'Isolated Increase in R5-R20' (II R5-R20)

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ABSTRACT

Introduction & objective : The objective of this retrospective observational study was to investigate the role of forced oscillometry in detecting airway obstruction in asthma and to compare its sensitivity to that of spirometry in detecting airway obstruction.

Method: The retrospective observational study was conducted in the Pulmonary Medicine Department of a secondary hospital in South India. Data from diagnosed cases of asthma from October 1, 2024, to March 31, 2025, were collected and analyzed to determine the effectiveness of forced oscillometry in detecting airway obstruction in asthma compared to spirometry. Diagnosis of asthma was made by the treating pulmonologist based on history, examination, and investigations. The cohort included patients over eighteen years of age who underwent both oscillometry and spirometry. Patients who only had one of the tests done were excluded from the study. Asthma-COPD overlap syndromes were also excluded.

Results: The total number of patients in the cohort was 182 with a mean age of 48.5 years. Spirometry showed obstruction in 36.8% of diagnosed asthma cases, while forced oscillometry detected obstruction in 69.7% of cases ($p < 0.0001$, 95% CI 20%–46%, RR-1.89). When both spirometry and oscillometry were combined, the sensitivity for detecting underlying airway obstruction increased to 80.8% ($n = 147$). Isolated increase in R5-R20 (II R5-R20) was observed in 36.81% of the cohort, whit this phenomenon seen in 52.5% of cases where oscillometry was more successful than spirometry.

Conclusion: Oscillometry is more sensitive than spirometry in detecting airway obstruction in asthmatics. Using both methodsIt for evaluation increases sensitivity. 'II R5-R20' is defined as an increase in R5-R20 with a normal R5 and is the most sensitive parameter for detecting airway disease in asthmatics. It may detect the early changes in airway resistance, making it useful for identifying airway obstruction at an earlier stage.

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Introduction

Asthma is one of the most common non-communicable diseases among children, with a prevalence of 1 in 10 children. It is also common among adults, with a prevalence of 1 in 10 (1). Spirometry is a widely used investigation to demonstrate bronchial obstruction. However, many patients who suffer from symptoms related to asthma, such as wheezing, dyspnea, cough, and chest tightness, can have preserved spirometry values at presentation (2). Additionally, spirometry is a test that requires the patient to forcefully inhale and exhale, making the values highly dependent on patient effort. The values can also very based on the patient's understanding the effort of the spirometry technician, and any co-existing morbidities or lung diseases. Therefor, the ability of spirometry to detect bronchial obstruction among asthmatics is about 29% (3). According to Landman et al, only less than 2/3 of spirometry tests in specialized respiratory laboratories meet the ATS/ERS criteria (4). Tests conducted in other centers have even lower rates of meeting these criteria. The extremes of age and the presence of co-morbidities further add to the difficulty (5).

Impulse oscillometry detects variations in pressure and flow of waves passing through the airways, calculating resistance and airway narrowing by working within tidal volumes (6). Due to its lesser dependence on the patient's effort, it can be effectively applied in pediatric and elderly age groups. The aim of our study was to investigate the role of forced oscillometry in detecting airway obstruction in asthma and to compare the sensitivity of forced oscillometry to that of spirometry in detecting airway obstruction.

Methods

The retrospective observational study was conducted in the Pulmonary Medicine Department of a secondary hospital in South India. Spirometry using a pneumotach-based portable wireless spirometer, Spirofy, and forced oscillometry using the Tremoflo airway oscillatory system were performed on all suspected obstructive airway disease patients above the age of 18 who visited the outpatient department. Data from diagnosed cases of asthma from October 1, 2024, to March 31, 2025, were collected and analyzed to determine the efficiency of forced oscillometry in detecting airway obstruction in asthma compared to spirometry. Three months of data from cohort population were followed up in medical records for any changes in diagnosis and response to therapy.

The diagnosis of asthma was made by the treating pulmonologist based on history, examination, and investigations. Only individuals over eighteen years old were included in the study, with both spirometry and oscillometry performed at the time of diagnosis. Participants who only had one of the tests done or had missing data were excluded from the study. Asthma-COPD overlap syndromes were not considered in this study.

An FEV_1/FVC ratio less than 0.7, low Maximum Mid Expiratory Flow (MMEF 75/25), and a scooped-up appearance of the flow-volume loop were considered signs of airway obstruction in spirometry (7). In oscillometry, increased resistance at 5 Hz (R5), resistance at 20 Hz (R20), and the difference between the two values (R5-R20) were indicators of airway obstruction (6).

The values were presented as percentages. McNemar's test was used for paired binary comparison of discordant pairs, whit a p-value less than 0.05 considered statistically significant. The Chi-square test with Yates continuity correction was used to compare two independent proportions, and Relative Risk (RR) was also calculated.

Results

The cohort consisted of a total of 182 patients, with a mean age of 48.5 years. It was predominantly female, with 114 females (62.64%) and 68 males (37.36%). Sixty-four individuals (35.16%) had a body mass index of over 30.

Spirometry was able to demonstrate obstruction in 36.8% of the diagnosed cases of asthma, whereas forced oscillometry was able to detect obstruction in 69.7% of the cases ($p < 0.0001$, 95% CI 20%–46%). The difference in detection was 32.97%. RR was 1.89. When both spirometry and oscillometry were combined, the sensitivity of detecting an underlying airway obstruction increased to 80.8% (n = 147). Oscillometry was helpful in 43.96% (n = 80) of cases where spirometry failed to indicate an obstructed airway. However, in 10.9% (n = 20) of the cohort, oscillometry failed to indicate the presence of obstruction, whereas spirometry was successful in demonstrating the same.

Among the obese individuals, the sensitivity of spirometry was 21.88%, and that of oscillometry was 76.56% ($p < 0.0001$, 95% CI 38.5%–70.9%, RR-3.49). Among the non-obese individuals, oscillometry excelled with a 66.10% sensitivity compared to 44.92% sensitivity of spirometry ($p < 0.0006$, 95% CI 9.7%–32.7%, RR- 1.47) (Table 1).

'Isolated increase in R5-R20' (II R5-R20), where R5-R20 was increased despite normal R5 and R20 values, was identified as the most sensitive parameter in detecting an underlying obstruction. Isolated increase in R5-R20 was seen in 36.81% of the cohort. This phenomenon was seen in 52.5% of the cases where oscillometry was successful over spirometry. The correlation between 'II R5-R20' and MMEF was seen in only 59.7% of the cases. There was no significant difference in the presence of isolated increase in R5-R20 in obese and non-obese individuals (39.06% vs 35.59%, $p = 0.73$).

Table 1. Sensitivity of Oscillometry vs Spirometry in detecting airway obstruction.

COHORT	OSCILLOMETRY (SENSITIVITY)	SPIROMETRY (SENSITIVITY)	P_Value	Relative Risk
TOTAL	69.7	36.8	< 0.0001	1.89
OBESE	76.56	21.88	< 0.0001	3.49
NON OBESE	66.1	44.92	< 0.0006	1.47

Discussion

Spirometry is the most commonly used investigation to assess airway obstruction. The primary function of this tool is to calculate the volume or flow as a function of time. The most important calculated parameters are the total forced expiratory volume-forced vital capacity (FVC) and the volume exhaled in the first second (FEV_1) (8). There are clear guidelines regarding the standardization of the spirometry investigation and the test results from leading bodies in the field of respiratory medicine like the American Thoracic Society and the European Respiratory Society (9). However, since this is a forced technique where the patient has to exhale and inhale to his best effort according to the instructions from the technician, the values depend greatly on the effort from the patient as well as the technician.

In spirometry the FEV_1/FVC ratio will be less than 0.7 in cases of obstructive airway diseases. Normal FEV_1 and FVC need to be within 80% to 120% of the expected values. A low FEV_1 is seen in obstructive airway diseases and a low FVC is suggestive of a restrictive lung disease. A decreased Forced Expiratory Flow (FEF) 25-75%, the FEF in the middle half of the FVC is suggestive of an early small airway obstruction (7).

Only 31.9% of spirometry tests in primary care practices and only 60.3% of spirometry tests in specialized laboratories met the ATS/ERS criteria (4). It is a difficult tool to be applied in the elderly and children as the test efficiency depends on the effort, understanding, and coordination of the patient as well as the technician. Co-morbidities can also have a significant influence on the test and the result (10). Hence, spirometry reports need to be analyzed in detail regarding meeting the technical standards, the information provided by the report, and correlation with the clinical presentation. According to the international population-based BOLD study, spirometry demonstrated a restrictive pattern in those with diabetes mellitus, systemic hypertension, and cardiovascular diseases (11).

In 1956, Dubois et al. described the forced oscillometry technique for the first time using a sealed container (12). Grimby et al. in 1968 established the relationship between the oscillation frequency and the resistance it faced (13). The oscillation signals can be of mono or multi-frequency nature. They can be continuous multi-frequency sinusoidal waves, as also known as Pseudo Random Noise (PRN), or timed impulses, as also known as Impulse Oscillometry (IOS). The Forced Oscillation Technique (FOT) is an umbrella term used for all these modalities (14). Low-frequency waves have larger wavelengths and therefore travel longer distances, whereas high-frequency waves travel shorter distances. The technique of oscillometry is based on this principle (15). Higher frequencies will reach only the conducting airways, whereas smaller frequency waves can reach the lung periphery (6).

The various terminologies that we assess through oscillometry are:

Impedance (Z) – It is the total resistive, elastic, and inertial forces that a pressure wave needs to encounter on its travel through the airway. It can be expressed as a combination of real Resistance (R) and imaginary Reactance (X). Resistance is a measure of opposition to airflow, whereas Reactance is the rebound resistance from the distensible airways (16). Reactance is a balance between Inertance (I), a positive force from the conducting airways, and Capacitance (C), a negative force from the pulmonary parenchyma (17). It is represented as Xf, where 'f' is the frequency of that particular wave in Hertz.

Resonant frequency (Fres) is the frequency at which both the forces acting in Reactance are equal and the total forces become zero. Below the Fres, the elastic forces dominate, whereas above the Fres, inertance plays the major role (16). It is usually higher in children and decreases as age progresses.

Reactance area (Ax) is the triangular area bounded by Fres on the right side and the reactance at 5 Hz on the left side. It indicates the functioning of the peripheral airway and the pulmonary parenchyma.

Coherence is a parameter that indicates the reliability of the maneuver. A value less than 0.8 at 5 Hz and more than 0.9–1 at 20 Hz is considered acceptable (18,19).

The Coefficient of Variation (CoV%) is considered a better quality control parameter. A value less than or equal to 10% in adults and 15% in children for R5 is considered acceptable (20).

Any resistance in the central or peripheral airway will be indicated by a rise in R5, as the wave with a smaller frequency will travel to the peripheral airways. A rise in R20 suggests central airway resistance as the frequency with 20 Hz does not travel to the peripheral airways due to its shorter wavelength. An equal rise in R5 and R20 with a normal R5-R20 suggests of a central airway obstructive disease. An increased R5 with an increased R5-R20 and normal R20 suggests of a peripheral airway obstructive disease. If all three parameters are raised, it denotes an obstructive disease affecting both the central and peripheral airways (21).

A significant bronchodilator response in oscillometry is defined as a 40% improvement in resistance, a 50% improvement in reactance or an 80% improvement in the area of reactance. On a methacholine challenge test, a change of 50% to 80% in reactance is considered significant (22). R5-R20 is considered one of the most sensitive tools in assessing peripheral airway obstruction (23). R5-R20 is elevated due to an increase in R5 much more than an increase in R20.

The objective of our study was to assess the ability of oscillometry in suggesting an obstructive airway disease in asthmatics. The forced oscillometry technique was found to be far superior compared to spirometry (69.7% vs 36.8%). However, there were twenty patients (10.98%) in whom spirometry alone detected airway obstruction while the oscillometry findings were normal. Even though oscillometry was supposed to be more sensitive in detecting airway obstruction, this finding points to the imperfect technology behind oscillometry. Hence, combining both modalities improved the sensitivity to 80.8%. For these reasons, we should apply oscillometry and spirometry together for the evaluation of airway obstruction in asthmatics. If a single investigation needs to be chosen, oscillometry is preferred over spirometry.

Obese individuals can have extra-pulmonary restrictions in breathing that can affect spirometry values. Oscillometry was significantly superior in detecting airway obstruction in these individuals (76.56% vs 21.88%, $p < 0.0001$). This superiority was also maintained in non-obese individuals .

In our study, we have identified an II R5-R20 as the most sensitive parameter in detecting a raised airway resistance and suggesting airway obstruction. 'II R5-R20' is where R5-R20 is raised irrespective of a normal R5. Theoretically, R5-R20 will be raised only as a result of a much increased R5 compared to R20. But a raised 'isolated R5-R20' suggests that, even though both R5 and R20 are within the normal limits for a given individual, compared to 20 Hz frequency waves which remain in the central airways, 5 Hz frequency waves that travel to the peripheral airways are facing more resistance than the expected difference. Universally, adding relativity increases the sensitivity of a given parameter. It is another way of saying that 'it is good, but not good enough' (Figure 1).

'II R5-R20' was detected in 36.81% of the cohort and more importantly in 52.5% of people in whom only oscillometry detected a change and spirometry failed to do so. We also looked at any influence of obesity on the same, as obesity itself can increase peripheral airway resistance. But there was no significant difference in 'II R5-R20' between the obese and non-obese patients (39.06% vs 35.59%, p = 0.73). There was no significant correlation between this parameter and the MMEF from spirometry (p = 0.564). Based on our study, we would like to project 'II R5-R20' as the most sensitive oscillometry parameter to detect airway obstruction in asthmatics. It could be the earliest detectable change.

Limitation

There may be demographic-based physiological differences among people that can influence oscillometry values and references. A larger, multi-centered, multi-national study could add more value to our findings.

Conclusion

Oscillometry is more sensitive than spirometry in detecting airway obstruction in asthmatics. It is recommended to use both tests for evaluation to increase sensitivity. 'II R5-R20' is defined as an increase in R5-R20 with a normal R5. This parameter is found to be the most sensitive in detecting airway disease in asthmatics. It could be detect the earliest changes in airway resistance and can be used to identify airway obstruction at an earlier stage.

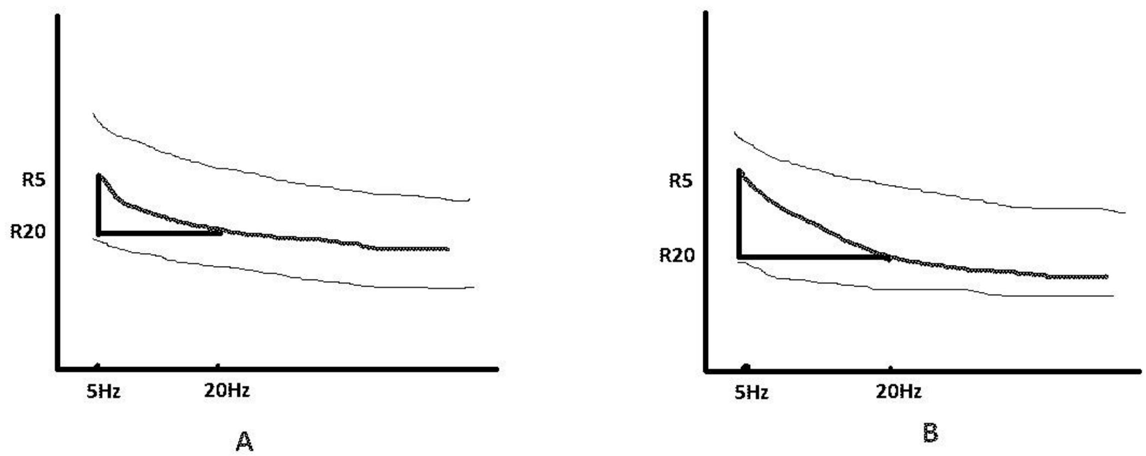

Figure 1. Isolated increase in R5-R20. **A)** R5, R20 and R5-R20 are within normal limits. **B)** Even though R5 and R20 are within normal limits, R5-R20 is elevated indicating a higher R5 than expected when compared to the R20.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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