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Impulse oscillometry compared with spirometry in detecting small airway dysfunction in children with uncontrolled asthma

Ercan Yilmaz¹, Erdem Topal¹, Hatice Turgut², Murat Semih Demir³¹*İnönü University, Faculty of Medicine, Department of Pediatric Allergy and Asthma, Malatya, Türkiye*²*İnönü University, Faculty of Medicine, Department of Neonatology, Malatya, Türkiye*³*İnönü University, Faculty of Medicine, Department of Pediatrics, Malatya, Türkiye*

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Abstract

Small airway dysfunction is closely related to asthma control and may not always be adequately detected by spirometry. This study aimed to compare spirometry and impulse oscillometry (IOS) parameters between well-controlled and uncontrolled asthma groups in children with moderate-to-severe persistent asthma and to evaluate small airway involvement. Sixty-one pediatric patients aged 6–17 years who had been diagnosed with asthma according to GINA criteria were included in the study. Asthma control was assessed using the Childhood Asthma Control Test (cACT), and patients were divided into two groups: well-controlled ($n = 27$) and uncontrolled ($n = 34$). Spirometry and IOS measurements were performed on all patients according to ATS/ERS standards. Demographic, clinical, and laboratory data were recorded. No significant differences were found between the groups in terms of age, gender, smoking exposure, and atopic sensitization ($p > 0.05$). The cACT score was lower ($p = 0.001$) and total IgE level was higher ($p = 0.016$) in the uncontrolled group. In spirometric evaluation, FEV_1 , FEV_1/FVC , and MEF_{25-75} values were significantly lower in the uncontrolled group ($p = 0.005$, $p = 0.01$, $p = 0.028$, respectively); however, most values were not below pathological thresholds. Among the IOS parameters, $R5-R20$ (kPa·s/L), $R5-R20$ (%), and AX values were significantly higher in the uncontrolled group ($p < 0.05$). Although spirometry can demonstrate differences between groups in children with moderate-to-severe persistent asthma, it may be limited in identifying small airway dysfunction. IOS, particularly with the $R5-R20$ parameter, reveals small airway involvement more sensitively. The use of IOS as a complementary method in the evaluation of small airways in uncontrolled asthma may be clinically beneficial.

Keywords: Airway resistance; asthma; oscillometry; spirometry

Introduction

Asthma is one of the most common chronic inflammatory airway diseases in childhood, characterized by variable airway obstruction and bronchial hyperresponsiveness [1]. Current guidelines consider symptom frequency, exacerbations, rescue medication requirements, and pulmonary function tests as key determinants in assessing asthma control [1]. However, it has been reported that persistent inflammation and functional impairment, particularly in the small airways, may continue even in patients who appear clinically controlled or who receive regular inhaled corticosteroid (ICS) therapy [2,3]. This highlights the heterogeneous nature of asthma and the limitations of routine assessment methods.

Small airways (bronchioles with a diameter < 2 mm) are anatomical regions that are affected early in the pathophysiology of asthma and are significantly involved in the processes of inflammation and remodeling [2]. In contrast, spirometry, the most commonly used method in clinical practice, primarily reflects changes in flow in the central and medium-sized airways [3]. Although Forced expiratory volume in one second (FEV_1) and the Ratio of forced expiratory volume in one second to forced vital capacity (FEV_1/FVC) are valuable in demonstrating large airway obstruction, they may not always adequately reveal small airway dysfunction. Although the mid-expiratory flow rate (MEF_{25-75}) parameter provides information about the peripheral airways, it is not considered a reliable small

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Corresponding Author: Ercan Yilmaz, İnönü University, Faculty of Medicine, Department of Pediatric Allergy and Asthma, Malatya, Türkiye
Email: ercanyilmaz44@gmail.com

airway marker on its own due to high variability and limited reproducibility [3,4]. Indeed, there are studies showing the presence of small airway dysfunction despite normal or near-normal spirometry values [5].

Impulse oscillometry (IOS) is a method that evaluates airway mechanics by measuring airway resistance and reactance at different frequencies during tidal breathing; it is particularly applicable in the pediatric age group [4,6]. The R5–R20 difference is considered a parameter reflecting the contribution of small airways to total resistance; reactance measurements such as AX and Fres provide information about peripheral airway elastic properties and airway closure tendency [4,6]. Recent studies have reported that IOS parameters show a significant correlation with asthma control levels and can detect small airway dysfunction more sensitively than spirometry [5–7].

A significant proportion of children with moderate-to-severe persistent asthma may have clinically uncontrolled disease despite receiving regular ICS treatment. Evidence suggesting that small airway dysfunction may be associated with symptom control, risk of exacerbation, and quality of life necessitates a more detailed assessment of peripheral airways in this patient group [2,7]. In this context, it is thought that IOS may contribute to clinical assessment as a complementary method to spirometry, particularly in uncontrolled asthmatic patients.

The aim of this study is to compare well-controlled and uncontrolled asthma groups in children with moderate-to-severe persistent asthma in terms of demographic characteristics, laboratory findings, spirometric parameters, and IOS measurements; specifically, to highlight the relative contributions of spirometry and IOS in the assessment of small airway dysfunction. This aims to highlight the role of small airways in assessing asthma control and to demonstrate the potential value of IOS in clinical practice.

Material and Methods

Study Design and Patient Selection

This study is a cross-sectional, observational study conducted in children with asthma diagnosed and followed at a tertiary pediatric allergy center. A total of 61 patients aged 6–17 years who had been diagnosed with asthma according to the Global Initiative for Asthma (GINA) criteria [1] were included in the study. All patients had been under regular follow-up for at least 6 months and were receiving inhaled corticosteroid (ICS) therapy as part of standard stepwise treatment.

Patients experiencing an acute asthma exacerbation, those who had used systemic corticosteroids within the last 4 weeks, and those with additional chronic lung disease (e.g., cystic fibrosis, bronchopulmonary dysplasia), congenital heart disease, or neuromuscular disease were excluded from the study.

Assessment of Asthma Control

Asthma control classification in this study was based on the Childhood Asthma Control Test (cACT) in combination with

clinical evaluation, reflecting a real-world, pragmatic approach commonly used in pediatric practice. The level of asthma control was assessed using the Childhood Asthma Control Test (cACT). Based on the cACT score and clinical assessment, patients were divided into two groups: “well-controlled asthma” and “uncontrolled asthma.” The clinical status, symptom frequency, and medication use at the time of the study were recorded.

Demographic and Clinical Data

The patients’ age, gender, age at asthma diagnosis, passive smoking exposure, and personal and family history of atopy were recorded. Skin prick test results and sensitization profiles (pollen, house dust mite, mold, cat dander, etc.) were obtained from the files. Laboratory evaluation included analysis of total IgE levels and the percentage of eosinophils in peripheral blood.

Spirometric Assessment

Spirometry was performed on all patients according to American Thoracic Society/European Respiratory Society (ATS/ERS) criteria [8]. Forced vital capacity (FVC), forced expiratory volume in one second (FEV₁), FEV₁/FVC ratio, and mid-expiratory flow rate (MEF_{25–75}) were measured and recorded as percent predicted values for age, height, and gender. A reduced MEF_{25–75} (< 70% predicted), indicating impaired mid-expiratory flow and possible small airway obstruction [8].

Impulse Oscillometry (IOS)

Impulse oscillometry testing was performed on all patients during tidal breathing to assess airway mechanics. Measurements were performed according to ATS/ERS recommendations [8,9]. Total airway resistance (R5), central airway resistance (R20), the R5–R20 difference indicating small airway contribution (kPa·s/L and %), reactance (X5, X20), area reactance (AX), and resonance frequency (Fres) parameters were recorded. An increase in the R5–R20 difference was considered an indicator of small airway dysfunction. Small airway dysfunction was defined based on previously reported criteria, including an elevated R5–R20 value (> 30%), reflecting increased frequency-dependent resistance suggestive of peripheral airway [9].

Statistical Analysis

Statistical analysis of the data was performed using the SPSS program (IBM SPSS Statistics for Windows, Version 21.0, IBM Corp., Armonk, NY, USA). The distribution of continuous variables was assessed using the Kolmogorov–Smirnov and Shapiro–Wilk tests. Data following a normal distribution were expressed as mean ± standard deviation (SD), while data not following a normal distribution were expressed as median (minimum–maximum). Categorical variables were presented as counts and percentages. For comparisons between well-controlled and uncontrolled asthma groups, the Mann–Whitney U test was used for variables not showing a normal distribution. The chi-square test or Fisher’s exact chi-square test was applied when expected cell frequencies were below 5 for the comparison of categorical variables. All statistical tests were performed bilaterally, and $p < 0.05$ was considered statistically significant.

Impulse oscillometry (IOS) and spirometric parameters were analyzed separately between the two groups. R5–R20 (kPa·s/L), R5–R20 (%), and AX parameters were considered in the evaluation of small airway dysfunction. In Spirometry, MEF25–75 values below 70% and, in impulse oscillometry (IOS), R5–R20 values exceeding 30% were considered indicators of small airway dysfunction.

Local ethics committee approval was obtained from the İnönü University Scientific Research and Publication Ethics Board on 24 February 2026 (decision no. 2026/9321) for the study, and written informed consent was obtained from parents and informed consent from participants.

Results

A total of 61 patients were included in the study. Forty-eight (78.7%) of the participants were male, and their median age was 12 years (range 6–17). The median age at asthma diagnosis was 7 years (range 2–13). Passive smoking exposure was present

in 18 (29.5%) of the cases. Based on asthma control status, 27 (44.3%) of the patients were considered well-controlled, and the median score on the Childhood Asthma Control Test (cACT) was 19 (9–25).

When personal atopic history was examined, the most common accompanying condition was allergic rhinitis (91.8%), followed by food allergy (19.7%), eczema (14.8%), and drug allergy (6.6%). In the family history, allergic rhinitis was the most common condition (59%) (Table 1). Regarding treatment characteristics, 45 (73.8%) of patients used inhaled corticosteroids (ICS), 28 (45.9%) used long-acting β 2-agonists (LABA), and 26 (42.6%) received montelukast treatment. Laboratory evaluation revealed a median total IgE level of 254 IU/mL (2.42 – 1646) and an eosinophil percentage of 2.6% (0.2 – 13.7). When the sensitization profile was examined, pollen sensitization was the most common (77.0%), followed by house dust mite (13.1%), mold (8.2%), and cat dander (8.2%) sensitization (Table 1).

Table 1. Demographic, medical, and laboratory characteristics of participants (n = 61)

Category	Variable	n (%)
Demographics	Male sex	48 (78.7)
	Age, years, median (min-max)	12 (6 – 17)
	Age of diagnosis	7 (2 – 13)
	Passive smoking exposure	18 (29.5)
	Controlled asthma	27 (44.3)
	cACT score	19 (9 – 25)
Personal history of atopy	Allergic rhinitis	56 (91.8)
	Eczema	9 (14.8)
	Drug allergy	4 (6.6)
	Food allergy	12 (19.7)
Family history of atopy	Allergic rhinitis	36 (59)
	Asthma	23 (37.7)
	Eczema	7 (11.5)
Medical history	Inhaled corticosteroids	45 (73.8)
	Long-acting β 2-agonist + ICS	28 (45.9)
	Montelukast	26 (42.6)
Laboratory	Total IgE, IU/mL	254 (2.42 – 1646)
	Eosinophils, %	2.6 (0.2 – 13.7)
	Pollen sensitization	47 (77)
	House dust mite sensitization	8 (13.1)
	Mold sensitization	5 (8.2)
	Cat dander sensitization	5 (8.2)

Abbreviations: cACT, Childhood Asthma Control Test; ICS, inhaled corticosteroid; IgE, immunoglobulin E; IU/mL, international units per milliliter; min–max, minimum–maximum; n, number of participants.

The study compared the well-controlled asthma group with the uncontrolled asthma group in terms of demographic, laboratory, and pulmonary function test parameters. Twenty-one (77.8%) patients in the well-controlled group and 27 (79.4%) patients in the uncontrolled group were male ($p = 1.000$). Cigarette exposure was detected in 5 (18.5%) and 13 (38.2%) patients, respectively

(p = 0.163). Skin prick test positivity was present in 23 (85.2%) patients in the well-controlled group and 27 (79.4%) patients in the uncontrolled group (p = 0.740). The groups were similar in terms of age distribution and eosinophil percentage (p > 0.05). However, the cACT score was significantly lower in the uncontrolled group (p = 0.001), while the total IgE level was higher (p = 0.016).

While the R5 and R20 values were similar in impulse oscillometry parameters (p = 0.159), the R5–R20 (kPa·s/L) and R5–R20

(%) values were significantly higher in the uncontrolled group (p = 0.02 and p = 0.005, respectively). The AX value was also increased in the uncontrolled group (p = 0.027), but there was no difference in terms of X5, X20 and Fres (p > 0.05).

In spirometric evaluation, FEV1, FEV1/FVC, and MEF25–75 values were significantly lower in the uncontrolled asthma group (p = 0.005, p = 0.01, p = 0.028, respectively) but were not pathological values indicating airway obstruction. FVC and PEF values were similar between groups (p > 0.05) (Table 2).

Table 2. Differences in clinical, laboratory, IOS, and spirometric parameters between well-controlled and uncontrolled asthma patients

IOS parameters	Well controlled asthma group (n = 27)	Uncontrolled asthma group (n = 34)	p value
Gender, male, n (%)	21 (77.8)	27 (79.4)	1.0
Age, median (min-max), years	12 (6 – 16)	13 (6 – 17)	0.714
Exposure to cigarettes, n (%)	5 (18.5)	13 (38.2)	0.163
Skin prick test positivity, n (%)	23 (85.2)	27 (79.4)	0.740
cACT score	23.5 (10 – 25)	17 (9 – 27)	0.001
Total IgE	215 (2.42 – 1646)	328.5 (17.8 – 1587)	0.016
Eosinophil percent (%)	2.6 (0.4 – 13.2)	2.95 (0.2 – 13.7)	0.15
R5 (kPa·s/L) mean ± SD	0.417 ± 0.251	0.508 ± 0.245	0.159
R20 (kPa·s/L) mean ± SD	0.288 ± 0.147	0.277 ± 0.146	0.159
R5–R20 (kPa·s/L) mean ± SD	0.128 ± 0.137	0.231 ± 0.190	0.02
R5–R20 (%), mean ± SD	30.769 ± 24.476	38.353 ± 39.916	0.005
X5 (kPa·s/L) mean ± SD	-0.120 ± 0.112	-0.138 ± 0.086	0.354
X20 (kPa·s/L) mean ± SD	-0.024 ± 0.075	-0.037 ± 0.087	0.636
AX (kPa/L) mean ± SD	1.152 ± 1.492	1.820 ± 1.549	0.027
Fres (Hz) mean ± SD	18.469 ± 6.477	20.607 ± 7.191	0.805
FVC (% predicted), mean ± SD	101 ± 17.6	90.5 ± 22.4	0.673
PEF (% predicted), mean ± SD	69.5 ± 20	64.7 ± 19	0.441
FEV1 (% predicted), mean ± SD	105 ± 19.5	89.9 ± 22.6	0.005
FEV1/FVC (%), mean ± SD	87.2 ± 9.3	83 ± 8.6	0.01
MEF25–75 (% predicted), mean ± SD	93.1 ± 23.7	79.1 ± 27.7	0.028

Data are presented as mean ± standard deviation for normally distributed variables and median (minimum–maximum) for non-normally distributed variables. Abbreviations: AX, area of reactance; cACT, Childhood Asthma Control Test; FEV1, forced expiratory volume in one second; FEV1/FVC, ratio of forced expiratory volume in one second to forced vital capacity; Fres, resonance frequency; FVC, forced vital capacity; IgE, immunoglobulin E; IOS, impulse oscillometry; MEF25–75, mid-expiratory flow rate; min–max, minimum–maximum; n, number of participants; PEF, peak expiratory flow; R5, resistance at 5 Hz; R5–R20, difference between resistance at 5 Hz and 20 Hz; R20, resistance at 20 Hz; SD, standard deviation; X5, reactance at 5 Hz; X20, reactance at 20 Hz.

Discussion

In this study, spirometry and impulse oscillometry (IOS) parameters were compared according to asthma control levels in children with moderate-to-severe persistent asthma, the vast majority of whom used regular inhaled corticosteroids (ICS). Although FEV₁, FEV₁/FVC, and MEF25-75 values were shown to be statistically significantly lower in the uncontrolled asthma group, it is noteworthy that these values were mostly not below

the classic thresholds used to define small airway disease (e.g., FEV₁ < 80%, MEF25-75 < 70%). This suggests that although spirometry can demonstrate differences between groups, it may be limited in revealing small airway dysfunction. Indeed, it is known that small airways are affected early and significantly in the pathophysiology of asthma, but spirometry mainly reflects central airways [2,3]. When IOS parameters were evaluated, the significantly higher values of R5–R20 (kPa·s/L), R5–R20 (%),

and AX in the uncontrolled asthma group indicate that peripheral airway dysfunction is more pronounced. The R5–R20 difference reflects the difference between total airway resistance at low frequencies and central airway resistance at high frequencies, revealing the contribution of small airways. Recent studies have reported that IOS, particularly through the R5–R20 parameter, can detect small airway dysfunction even in symptomatic patients with normal spirometry [5-7,10]. These findings are consistent with our study, which showed increased R5–R20 values and percentages in the uncontrolled group.

Studies examining the relationship between asthma control and IOS parameters have shown that small airway dysfunction is significantly associated with poor asthma control [7,10]. Studies conducted in the pediatric population, in particular, have reported that IOS measurements correlate with asthma control tests and reveal small airway involvement more sensitively than spirometry [7]. In our study, the high R5–R20 and AX values in the uncontrolled group with low cACT scores support the relationship between small airway dysfunction and clinical control level.

Studies comparing the performance of spirometry and IOS in detecting small airway disease emphasize that while MEF25-75 provides insight into peripheral airways, it has high variability and is not a reliable marker on its own [4]. In our study, although MEF25-75 was found to be statistically low in the uncontrolled group, the fact that the mean values were not below 70% indicates that it has limited value in defining small airway disease. In contrast, the increase in R5–R20 obtained with IOS more clearly revealed small airway dysfunction.

The fact that approximately three-quarters of our patients were using ICS therapy is also an important finding. Nevertheless, the persistence of small airway dysfunction demonstrated by IOS in the uncontrolled group suggests that inflammation in the peripheral airways cannot be completely suppressed. The literature also indicates that small airway dysfunction can persist even in clinically treated asthmatic patients and that it is associated with symptom control [6,7]. This situation highlights the importance of treatment strategies targeting small airways (e.g., extra-fine particulate inhaler preparations), especially in patients with moderate-to-severe persistent or uncontrolled asthma.

Impulse oscillometry (IOS) may offer additional clinical value in routine practice as a complementary tool to conventional spirometry, particularly in patient groups where spirometric assessment is limited or insensitive. IOS may be especially useful in children with suboptimal cooperation, in patients presenting with persistent respiratory symptoms despite normal spirometric values, and in those suspected of having early small airway involvement. By providing information on peripheral airway resistance and reactance, IOS may help to detect subtle functional abnormalities that are not captured by standard

spirometric indices, thereby supporting earlier recognition and more individualized management of airway disease.

One important limitation of our study is the relatively small sample size ($n = 61$), which may have limited the statistical power of the analyses and may affect the generalizability of our findings. In addition, a considerable proportion of our patients were receiving inhaled corticosteroid (ICS) and/or long-acting beta-agonist (LABA) therapy at the time of evaluation. Although these treatments reflect real-world clinical management, variations in treatment intensity and adherence may have influenced IOS and spirometric parameters by modifying airway inflammation and bronchial tone, potentially introducing variability in lung function measurements. Future studies with larger sample sizes, standardized treatment protocols, and detailed assessment of medication adherence are warranted to further clarify these associations.

Conclusion

In conclusion, our findings indicate that spirometry can demonstrate differences between groups based on asthma control levels but may be limited in establishing threshold values that define small airway disease. In contrast, IOS parameters both reflect group differences more clearly and reveal small airway dysfunction more sensitively. Therefore, IOS is considered an important complementary method to spirometry in the assessment of small airway involvement, particularly in children with uncontrolled or moderate-to-severe persistent asthma.

Ethical Approval

Ethical approval was obtained from the İnönü University Scientific Research and Publication Ethics Board on 24 February 2026 (decision no. 2026/9321).

Patient Consent

Written informed consent for participation in the study was obtained from the participants' parents. Informed consent was also obtained from the participants.

Conflict of Interest

The authors confirm the absence of any conflicts associated with this work.

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References

1. Global Initiative for Asthma (GINA). Global Strategy for Asthma Management and Prevention. 2024 Update.
2. Siora A, Vontetsianos A, Chynkiamis N, et al. Small airways in asthma: from inflammation and pathophysiology to treatment response. *Respir Med*. 2024;222:107532.
3. Shi Y, Aledia AS, Tatavoosian AV, et al. Relating small airways to asthma control by using impulse oscillometry in children. *J Allergy Clin Immunol*. 2012;129:671-8.
4. Toumpanakis D, Usmani OS. Small airways in asthma: pathophysiology, identification and management. *Chin Med J Pulm Crit Care Med*. 2023;1:171-80.

5. Cottini M, Bondi B, Bagnasco D, et al. Impulse oscillometry defined small airway dysfunction in asthmatic patients with normal spirometry: Prevalence, clinical associations, and impact on asthma control. *Respir Med*. 2023;218:107391.
6. Galant SP, Komarow HD, Shin HW, et al. The case for impulse oscillometry in the management of asthma in children and adults. *Ann Allergy Asthma Immunol*. 2017;118:664-71.
7. Lin LM, Chang YJ, Yang KD, et al. Small airway dysfunction measured by impulse oscillometry and fractional exhaled nitric oxide is associated with asthma control in children. *Front Pediatr*. 2022;10:877681.
8. Graham BL, Steenbruggen I, Miller MR, et al. Standardization of Spirometry 2019 Update. An Official American Thoracic Society and European Respiratory Society Technical Statement. *Am J Respir Crit Care Med*. 2019;200:e70-88.
9. King GG, Bates J, Berger KI, et al. Technical standards for respiratory oscillometry. *Eur Respir J*. 2020;55:1900753.
10. Yun HJ, Eom SY, Hahn YS. Assessing asthma control by impulse oscillometry and fractional expiratory nitric oxide in children with normal spirometry. *J Allergy Clin Immunol Pract*. 2023;11:2822-9.e1.