



OPEN ACCESS

EDITED BY

Paraskevi Xepapadaki,
National and Kapodistrian University of
Athens, Greece

REVIEWED BY

Yi-Luen Shen,
Asia University Hospital, Taiwan
Lifei Lu,
First Affiliated Hospital of Guangzhou Medical
University, China
Andreas M. Matthaiou,
University of Crete, Greece

*CORRESPONDENCE

Li Ping Chung

✉ liping.chung@health.wa.gov.au

RECEIVED 06 November 2025

REVISED 07 January 2026

ACCEPTED 19 January 2026

PUBLISHED 12 February 2026

CITATION

Chung LP, Beinart D, Goh ESY and King GG
(2026) Association between impulse
oscillometry Z-scores and asthma control and
exacerbation risk in a tertiary severe asthma
clinic.
Front. Allergy 7:1741154.
doi: 10.3389/falgy.2026.1741154

COPYRIGHT

© 2026 Chung, Beinart, Goh and King. This is
an open-access article distributed under the
terms of the [Creative Commons Attribution
License \(CC BY\)](#). The use, distribution or
reproduction in other forums is permitted,
provided the original author(s) and the
copyright owner(s) are credited and that the
original publication in this journal is cited, in
accordance with accepted academic practice.
No use, distribution or reproduction is
permitted which does not comply with these
terms.

Association between impulse oscillometry Z-scores and asthma control and exacerbation risk in a tertiary severe asthma clinic

Li Ping Chung^{1*}, Dylan Beinart¹, Emily S. Y. Goh¹ and Gregory G. King^{2,3}

¹Severe Airways Disease Clinic, Fiona Stanley Hospital, Perth, WA, Australia, ²Department of Respiratory Medicine, Royal North Shore Hospital, Sydney, NSW, Australia, ³Airway Physiology and Imaging Group, The Woolcock Institute of Medical Research, Sydney, NSW, Australia

Introduction: Respiratory oscillometry is a sensitive tool for assessing small airways dysfunction. However, limited evidence on cutoff values for interpretation remains a barrier to its clinical use. The aim of this study was to determine whether the presence and severity of abnormalities, defined by Z-scores for oscillometric parameters, are associated with asthma symptoms and exacerbation risk.

Methods: We retrospectively reviewed the medical records of all patients with asthma managed in a severe asthma clinic between 2019 and 2022 who underwent routine oscillometry. Z-scores for oscillometric parameters were analyzed as continuous and categorical variables to assess their associations with asthma control and exacerbation risk.

Results: When analyzed as categorical variables, Z-score-defined severity thresholds for resistance (R_5), reactance (X_5), and the area under the reactance curve (A_X) were associated with levels of asthma control (as measured by the ACQ5). When analyzed as continuous variables, Z-scores were also correlated with worst asthma control (as assessed by both ACQ5 and the asthma control test) ($P < 0.005$). These correlations remained significant after adjustment for spirometric indices, FeNO, and treatment changes. Elevated Z-scores (>1.64) for R_5 were associated with a higher risk of exacerbations (OR 2.70, 95% CI 1.27–5.17, $P = 0.009$). The risk of exacerbation increased with the severity of airway obstruction. Similar trends were observed for A_X and X_5 ; however, these associations did not reach statistical significance.

Discussion: The presence and severity of airway obstruction, as defined by R_5 Z-scores, predict poorer asthma control and an increased risk of exacerbations. Similar associations with asthma control were also observed for X_5 and A_X Z-scores. Clinicians should use Z-scores over other cutoffs to aid interpretation.

KEYWORDS

asthma, asthma control test, asthma exacerbation, impulse oscillometry, lung function test, respiratory oscillometry, small airways dysfunction

Introduction

Respiratory oscillometry is a simple, non-invasive, and effort-independent lung function test that overlays oscillatory pressure waves onto normal tidal breathing to measure the mechanical properties of the airways and lung parenchyma (1). Compared with spirometry, respiratory oscillometry is more sensitive for assessing the peripheral or small airways, especially in patients with chronic respiratory symptoms and preserved pulmonary function (2–4). Small airways dysfunction is highly prevalent in adults with asthma and is associated with the degree of airflow obstruction, symptom burden, and risk of exacerbations (5–7).

Introducing oscillometric assessment of small airways function into routine clinical practice provides clinicians with a more comprehensive understanding of airway physiology, enabling better assessment of disease activity and the risk of asthma exacerbations. Respiratory oscillometry therefore provides further information to spirometry when assessing current disease control and predicting clinical outcomes (4, 8). For example, patients with asthma who exhibit higher respiratory resistance, indicating worse small airways dysfunction, have been shown to achieve a better response to extra-fine particle inhaled therapy compared with non-extra-fine therapy (9, 10).

A recently published international Delphi study on the interpretation of respiratory oscillometry in adults with asthma or chronic obstructive pulmonary disease (COPD) reported that clinicians who routinely use oscillometry in clinical practice focus on a small number of metrics to guide interpretation, specifically resistance at 5 Hz (R_5), frequency dependence of resistance (R_5-R_{20} or R_5-R_{19}), reactance at 5 Hz (X_5), and area under the reactance curve (A_X) (11). This expert group agreed that respiratory oscillometry is clinically useful for identifying and grading the severity of lung function impairment, as well as for assessing clinically meaningful changes in lung function over time. The group recommended the use of Z-scores to define abnormal lung function, with cutoffs of >1.64 for R_5 and A_X and <-1.64 for X_5 . Because X_5 values are usually negative, more negative values indicate greater impairment in lung function. The severity of abnormal lung function was further defined according to the criteria outlined in Table 1.

Although Z-score cutoffs for impedance parameters provide a statistically robust framework for defining the severity of abnormality, empiric data are required to demonstrate their

clinical relevance and validity (11). This evidence gap represents a barrier to some clinicians using this lung function test in clinical practice.

We have previously demonstrated that, among patients with asthma attending our tertiary asthma clinic, R_5-R_{20} , X_5 , A_X , and resonant frequency (F_{res}) are correlated with asthma symptom burden, with the strongest association observed for R_5-R_{20} . Both A_X and R_5-R_{20} were associated with an increased risk of asthma exacerbations (5). However, this previous analysis was predominantly based on abnormal lung function defined by absolute value cutoffs commonly reported in published studies, rather than Z-scores. As the use of absolute values to define abnormal oscillometry findings was not endorsed by the Delphi study (11) and is subject to inherent limitations (12), the aim of this study was to determine whether the presence and severity of abnormal lung function, defined using Z-scores for oscillometric parameters, are associated with asthma symptoms and exacerbation risk.

Methods

This was a single-center, retrospective study of patients with asthma referred to a tertiary respiratory clinic who underwent oscillometry as part of their routine assessment between January 2019 and December 2022. The study was approved by the Human Research Ethics Committee and Research Governance Unit of Fiona Stanley Hospital (RGS5611).

The methods of this study have been previously published (5) and are briefly described here. Eligible patients had a respiratory specialist-confirmed diagnosis of asthma and had completed spirometry and oscillometry, specifically impulse oscillometry (IOS), as part of standard lung function testing. Patients were excluded if they did not have at least one documented IOS measurement performed at our tertiary clinic.

The relevant information was extracted from the medical records of all eligible patients corresponding to their clinic visit at which lung function testing was performed. Collected information included standard demographic data, asthma symptom scores [e.g., asthma control questionnaire (ACQ5) or asthma control test (ACT)], frequency of asthma exacerbations in the 12 months before and after the IOS test, asthma medications, asthma severity (based on GINA criteria), and IOS results. Asthma exacerbations were defined as any worsening of asthma symptoms that required treatment with antibiotics and/or oral corticosteroids or resulted in an unscheduled visit to an accident and emergency department, a hospital, or a general practitioner (13, 14). All exacerbations that occurred were included in the analysis.

Oscillometry was performed in accordance with the manufacturer's recommendations using an impulse oscillometry device (Masterscreen IOS, Jaeger, Germany). Typically, oscillometry was performed on the same day as the respiratory specialist review or within 48 h prior.

Prebronchodilator IOS parameters including R_5 , R_{20} , A_X , F_{res} , and X_5 were analyzed. Normative values for oscillometric

TABLE 1 Grading the severity of abnormal lung function.

Severity of abnormal lung function	Oscillometry parameter	
	R_5 , R_{20} , A_X , F_{res}	X_5
Normal (none)	Z-score ≤ 1.64	Z-score ≥ -1.64
Mild	Z-score > 1.64 and ≤ 2.5	Z-score < -1.64 and ≥ -2.5
Moderate	Z-score > 2.5 and ≤ 4	Z-score < -2.5 and ≥ -4
Severe	Z-score > 4	Z-score < -4

parameters were calculated based on data published by Oostveen (15). Z-scores for R_5 , R_{20} , X_5 , A_X , and F_{res} were evaluated as continuous and categorical variables to assess their associations with asthma control and exacerbation risk. Other IOS parameters, such as R_5-R_{20} , were not included in this analysis because normative data for these metrics are unavailable; hence, Z-scores could not be calculated. For categorical variables, abnormal lung function was defined as a Z-score > 1.64 for R_5 , R_{20} , A_X , and F_{res} and a Z-score < -1.64 for X_5 . The severity of dysfunction was defined a mild, moderate, or severe based on the Z-scores listed in Table 1.

Statistical analysis

Correlations between Z-scores of oscillometry parameters and asthma symptom scores (ACQ5 and ACT), evaluated as continuous variables using ANOVA regression analysis, are reported as Pearson correlation coefficients. The variables were confirmed to be normally distributed. For categorical analyses, mean ACQ5 and ACT scores for mild, moderate, and severe Z-score categories were compared with those of patients with normal Z-scores using multiple *t*-tests. Exacerbation risk across Z-score categories was compared using chi-square analysis. Multiple regression and logistic analyses were performed to adjust for potential confounders, including spirometric airflow obstruction ($FEV_1\%$ predicted, $FEV_1/FVC < 0.70$), FeNO, and treatment changes within 12 months after IOS testing.

No power calculations were performed, as this was a retrospective study that included all eligible patients. Statistical analyses were performed using Jamovi, version 2.2.5.

When relevant data were not documented in the patient record, patients were excluded from that analysis. For example, the absence of information about exacerbation history was not assumed to indicate that no exacerbation had occurred.

Results

A total of 149 patients were included in this retrospective study. Based on GINA criteria, 69% of patients were classified as having severe asthma (14). Nearly 90% of patients were receiving inhaled corticosteroid-based combination therapy, with equal proportions treated with inhaled corticosteroids (ICS) plus long-acting beta-2 agonists (LABA) and ICS/LABA plus long-acting muscarinic antagonists (LAMA). Based on the FEV_1/FVC ratio, 64% of patients had obstructive airflow. These clinical characteristics are consistent with the typical patient cohort referred to a tertiary asthma clinic. Demographic and clinical characteristics are summarized in Table 2.

Of the 149 patients, 101 (67.8%) had a change in treatment within 12 months after IOS testing. These changes include commencement or switching of a biologic agent ($N = 39$), ICS dose escalation and/or change to a fine or extra-fine particle ICS formulation ($N = 26$), or commencement of a LAMA or montelukast ($N = 12$). In addition, 16 patients underwent

TABLE 2 Patient demographics and clinical characteristics, including the prevalence of abnormal lung function as assessed by oscillometry.

Demographics (N = 149)	N (%) *Median (IQR)
Age (years)*	49.33 (34.81–62.19)
Male/female (%)	55/94 (37.2/63.0)
Ethnicity—Caucasian/other (%)	122/27 (81.9/18.2)
BMI (kg/m ²)*	30.09 (24.77–35.36)
Smoking status (%)	
Current	7 (4.7)
Former	57 (38.2)
Never	85 (57.4)
Exacerbation in the preceding or proceeding 12 months (%)	
Yes	81 (54.4)
No	56 (37.8)
Not documented (unknown)	12 (8.1)
Inhaled therapy	N (%)
None	8 (5.4)
ICS monotherapy	7 (4.7)
ICS/LABA	66 (44.6)
LAMA/LABA (no ICS)	1 (0.7)
Single-inhaler triple therapy (ICS/LABA/LAMA)	11 (6.8)
Triple therapy (ICS/LABA/LAMA) using multiple inhalers	67 (44.9)
Systemic therapy	N (%)
Montelukast	28 (18.9)
Oral corticosteroids (maintenance)	21 (14.2)
Biologic (monoclonal antibody)	25 (16.9)
Pulmonary function tests	Median (IQR)
$FEV_1\%$ predicted (%)	73.3 (57.1–85.0)
FVC % predicted (%)	92.9 (78.5–100.8)
FEV_1/FVC ratio (%)	62.5 (57.1–85.9)
FeNO (ppb)	31.5 (20.8–60.0)
R_{5Hz} [kPa/(L/s)]	0.54 (0.40–0.75)
R_{5Hz} % predicted (%)	173.15 (133.98–229.38)
R_{20Hz} [kPa/(L/s)]	0.38 (0.30–0.46)
R_{20Hz} % predicted (%)	136.40 (117.08–166.93)
R_5-R_{20} [kPa/(L/s)]	0.13 (0.08–0.28)
$\Delta R_5-R_{20}\%$ (%)	35.26 (22.99–59.68)
A_X (kPa/L)	0.66 (0.27–2.10)
BF (L/min)	12.98 (10.68–16.49)
F_{res} (Hz)	15.00 (10.75–20.92)
X_5 [kPa/(L/s)]	-0.17 (-0.28–-0.11)
$X_5\%$ predicted (%)	177.00 (115.45–248.20)
Prevalence of abnormal lung function (based on Z-scores, N = 149)	N (%)
R_5 (Z-score > 1.64)	105 (70.5)
R_{20} (Z-score > 1.64)	41 (27.5)
A_X (Z-score > 1.64)	44 (29.5)
X_5 (Z-score < -1.64)	67 (45.0)
F_{res} (Z-score > 1.64)	35 (23.4)

treatment “step-down” after optimization of inhaler technique and adherence to original treatments.

The prevalence of abnormal resistance (R_5), defined by Z-scores > 1.64 , was high at 70.4%. In contrast, the prevalence of small airways dysfunction was lower, occurring in 40.5% as defined by X_5 Z-score < -1.64 and in 29.5% as defined by A_X Z-scores > 1.64 . Abnormal lung function for R_5 , X_5 , and A_X was

associated with poorer symptom control, as assessed by ACQ5 and ACT, compared with patients who had normal oscillometric findings. No significant associations were observed between abnormal F_{res} and R_{20} and asthma control (Table 3).

When analyzed as categorical variables, Z-score-defined severity of lung function impairment for R_5 , X_5 , and A_X was significantly associated with the level of asthma control. Increasing severity of lung function impairment corresponded to poorer asthma control. This relationship was strongest when asthma control was measured using ACQ5 (Figure 1). The strength of these associations with ACT was similar for R_5 but weaker for X_5 and A_X compared with ACQ5 (Supplementary Table S1).

Z-scores for R_5 , X_5 , and A_X were all significantly correlated with asthma control scores (ACQ5: R_5 $r=0.38$, $P<0.001$, X_5 $r=0.26$, $P=0.001$, A_X $r=0.36$, $P<0.001$; ACT: R_5 $r=0.30$, $P<0.001$, X_5 $r=0.24$, $P=0.003$, A_X $r=0.34$, $P<0.001$). The worse the Z-score, the poorer the asthma control, as assessed by both ACQ5 and ACT (Figures 2A–F).

TABLE 3 Differences in asthma control between patients with normal vs. abnormal small airways function.

IOS parameter	N	Asthma control			
		Mean ACQ5	P	Mean ACT	P
R_5 normal (Z-score ≤ 1.64)	44	1.20	<0.0001	19.54	=0.001
R_5 abnormal (Z-score > 1.64)	105	2.15		16.59	
X_5 normal (Z-score ≥ -1.64)	82	1.20	<0.0001	18.39	=0.011
X_5 abnormal (Z-score < -1.64)	67	2.18		16.19	
A_X normal (Z-score ≤ 1.64)	105	1.64	=0.0002	17.84	=0.03
A_X abnormal (Z-score > 1.64)	44	2.40		13.67	
R_{20} normal (Z-score ≤ 1.64)	108	1.62	=0.241	16.88	=0.13
R_{20} abnormal (Z-score > 1.64)	41	1.98		18.76	
F_{res} normal (Z-score ≤ 1.64)	114	1.77	=0.059	19.44	=0.26
F_{res} abnormal (Z-score > 1.64)	35	2.26		16.51	

Statistical test: Multiple *t*-tests.

On multivariate analysis, spirometric indices (FEV₁% predicted) and FeNO were correlated with ACQ5 ($P=0.01$ and $P=0.009$, respectively), while FEV₁% predicted and FEV₁/FVC were correlated with ACT ($r=0.34$, $P=0.001$ and $r=0.28$, $P=0.02$, respectively). The associations between asthma symptom control and Z-scores for R_5 and A_X remained significant after adjusting for spirometry, FeNO, and treatment changes (ACQ5 R_5 $r=0.30$, $P=0.005$; ACT R_5 $r=0.26$, $P=0.05$; and ACT A_X $r=0.29$, $P=0.04$).

Eighty-one patients (54%) experienced at least one documented moderate-to-severe asthma exacerbation in the 12 months before or after the sentinel date. Impaired resistance (R_5) was associated with a significantly increased risk of exacerbation compared with patients with normal R_5 (OR 2.70, 95% CI 1.27–5.17, $P=0.009$). The risk of exacerbation increased with greater severity of airway obstruction (abnormal R_5) (Figure 3). Impaired reactance, as reflected by both X_5 and A_X , demonstrated trends toward an elevated risk of exacerbations compared with patients who had normal reactance parameters (X_5 : OR 1.24, 95% CI 0.63–2.47, $P=0.53$; A_X : OR 1.63, 95% CI 0.75–3.53, $P=0.21$). Similarly, there were non-significant trends suggesting that the risk of exacerbations increased with greater severity of impaired reactance. Similar to asthma control, exacerbation risk was not associated with abnormal R_{20} or F_{res} (Table 3). The association between R_5 and the risk of exacerbations was not significant on multivariate analysis.

Discussion

We have shown, in a retrospective study conducted within a tertiary referral clinic for severe asthma, that greater impairment in oscillometric parameters is associated with worse symptoms, i.e., asthma control, and with more frequent severe asthma exacerbations. The relationship between abnormal oscillometry

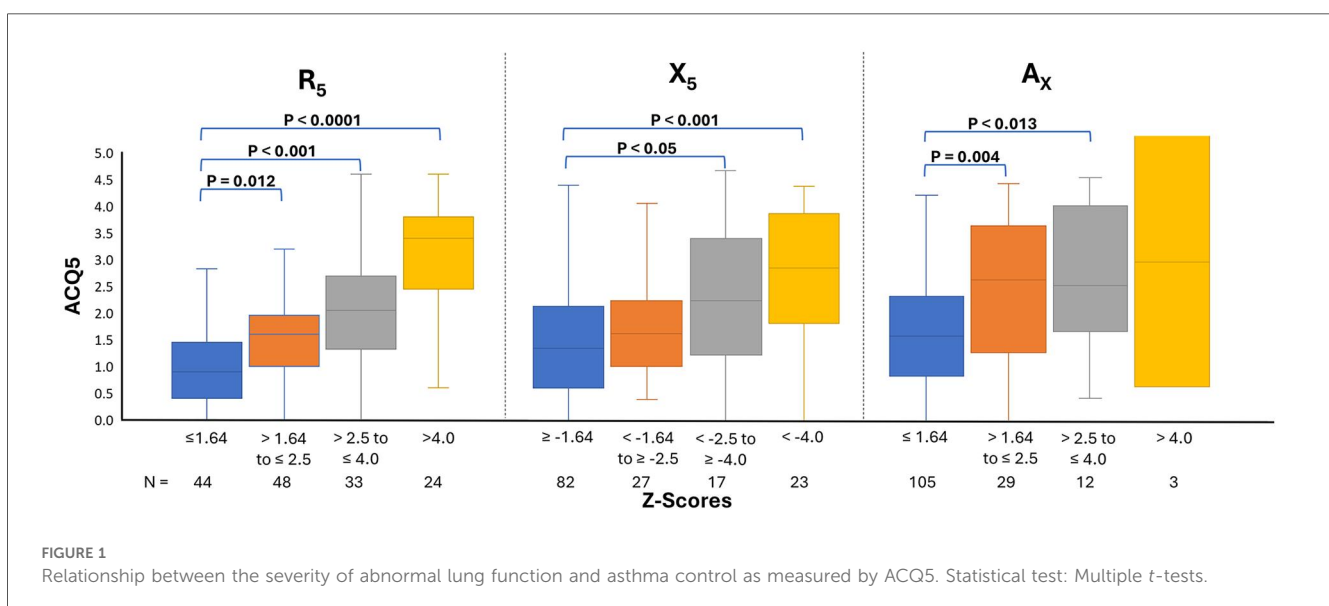


FIGURE 1 Relationship between the severity of abnormal lung function and asthma control as measured by ACQ5. Statistical test: Multiple *t*-tests.

For R_5 , the classifications of mild, moderate, and severe abnormality closely matched those used in clinical practice (11) and those applied in our study (Table 1). For X_5 , moderate impairment was calculated as Z-scores between <-4.5 and ≥-8.5 , which differs from the thresholds used in our study (<-2.5 to ≥-4), based on consensus recommendations (11). Liang acknowledged that a major limitation of their methodology was the limited consistency between oscillometry and spirometry and consequently proposed that cutoffs for oscillometry parameters should be guided by clinical practice, as was done in our study (11). However, these discrepancies highlight the need for additional research to further define the severity of abnormal oscillometry.

In our study, the associations between oscillometric parameters and exacerbation risk were strongest for R_5 , a measure of airway caliber across the entire airway tree (1). The associations between X_5 and A_X , indicators of small airways dysfunction, and exacerbation risk were weaker. This finding that resistance-based parameters are stronger predictors than reactance is also consistent with the *post-hoc* analysis of the ATLANTIS study, which focused on patients with mild asthma. In that study, the investigators also used IOS, although Z-scores were derived from 100 healthy individuals included in the study. Thus, our findings indicate that Z-scores for defining severity and abnormality are relatively robust, at least between the two reference equations used (7).

We found no statistically significant associations between X_5 and A_X and asthma exacerbations, whereas a previous analysis from the ATLANTIS study found that X_5 , A_X , and R_5-R_{20} were significantly correlated with asthma exacerbations and that a composite ordinal score based on these three parameters independently predicted the exacerbation risk (18). A retrospective study by Chan and Lipworth found that small airways dysfunction, defined by an $A_X \geq 1.0$ kPa/L and $R_5-R_{20} \geq 0.10$ kPa/L/s, was significantly associated with asthma exacerbations (19). Similarly, Gao et al. (20) demonstrated that small airways dysfunction was an important pathological feature among patients with asthma exacerbations and that X_5 , A_X , and R_5-R_{20} were significantly correlated with asthma exacerbations. Measures of reactance, X_5 and A_X , reflect physiologically severe airway narrowing and greater heterogeneity of ventilation. Failure to demonstrate significant relationships with exacerbation risk may be attributable to fewer patients exhibiting moderate to severe impairment when defined using the applied Z-score cutoffs. Greater airway closure and heterogeneity, as measured by single-breath nitrogen washout, has been shown to be associated with an increased risk of exacerbations (21, 22). Whether resistance or reactance parameters relate to exacerbations may differ across populations and may be expected given the marked heterogeneity in underlying pathophysiology among patients.

One of the challenges for clinicians who are less familiar with respiratory oscillometry is the large number of oscillometric parameters and the resulting uncertainty about which ones to use in clinical practice. Similar to spirometry, where interpretation is predominantly based on three core parameters,

namely, FEV₁, forced vital capacity (FVC), and FEV₁/FVC (12), the international Delphi study on the interpretation of respiratory oscillometry recommended using three oscillometry indices: R_5 , X_5 , and A_X (11). Hence, the findings of our study provide further insight and guidance to clinicians on the clinical significance of these parameters. Results from several studies suggest that respiratory oscillometry should be used in conjunction with spirometry (rather than as a replacement for it) (18, 23, 24), as their combination provides a more comprehensive assessment of lung physiology and clinical risks.

The main limitation of this study is its retrospective design and the exclusion of patients with inadequate data, including the presence or absence of exacerbations, as documented in their medical records. There are differences in measurements between oscillometry devices when tested in physical models or healthy participants (15, 25, 26). Differences in measurements between devices, as well as differences in normative values used to calculate Z-scores, may potentially affect the relationships between Z-scores and clinical outcomes (11). Therefore, our findings may not be generalizable to centers that use different oscillometry devices or prediction equations. Robust analysis differentiating the relationship between oscillometry measurements and previous or future exacerbations is limited by relatively few events and by the potential modifying effect of treatment escalations in two-thirds of the cohort in the year following IOS testing.

There are currently no well-established reference equations for the frequency dependence of resistance (R_5-R_{20}); hence, Z-score analysis of this measure of small airways dysfunction could not be performed. Normative data to derive Z-scores for R_5-R_{20} are needed, as R_5-R_{20} is a sensitive marker of small airways dysfunction (6), and impairment in R_5-R_{20} has been associated with an increased risk of asthma exacerbation and poor symptom control (7, 16, 20), including a previously published analysis of this data set, in which abnormality was defined as $R_5-R_{20} > 0.07$ kPa/(L/s) (5), as well as the ATLANTIS *post-hoc* analysis, where abnormal R_5-R_{20} was defined as a Z-score > 1.645 (7).

One of the strengths of this study is that it was conducted among patients referred to a tertiary severe asthma clinic, a population that matches the patient cohort most likely to have access to respiratory oscillometry in the current real-world clinical setting. As the routine use of oscillometry expands, similar research should be performed in broader adult asthma patient populations managed in primary care. This would help to confirm the clinical utility of this lung function test in this clinical setting.

Conclusion

The findings from our retrospective study provide real-world evidence supporting the use of R_5 Z-scores to define abnormality in preference to other cutoff values, such as absolute values or percentage predicted. In addition, the arbitrary thresholds used to define the severity of abnormality

appear to have some relevance in a severe asthma population managed at a tertiary referral clinic.

Data availability statement

The original contributions presented in the study are included in the article/[Supplementary Material](#), further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by the Human Research Ethics Committee and Research Governance Unit of Fiona Stanley Hospital (RGS5611). The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required from participants or their legal guardians/next of kin as this was a retrospective audit of medical records, and access to and analysis of patient data were performed by staff at Fiona Stanley Hospital who manage these patients, and no identifiable patient data were included in the analysis.

Author contributions

LC: Conceptualization, Writing – review & editing, Data curation, Supervision, Methodology, Formal analysis. DB: Formal analysis, Data curation, Writing – review & editing. EG: Data curation, Writing – review & editing. GK: Writing – review & editing, Data curation, Formal analysis.

Funding

The author(s) declared that financial support was received for this work and/or its publication. Chiesi Australia Pty Ltd supported this study by funding the time required for data acquisition and analysis, as well as involvement of a medical writer (George Krassas, Scius Healthcare Solutions Pty Ltd.). Chiesi Australia was not involved in the design, data acquisition, analysis, or interpretation.

Acknowledgments

The authors would like to acknowledge the contribution of George Krassas from Scius Healthcare Solutions Pty Ltd, who assisted with medical writing.

Conflict of interest

DB and LC received research funding from Chiesi Pharmaceuticals to account for the time required for data acquisition and analysis. The funder had no role in data acquisition, analysis, or interpretation. LC has also received honorarium for educational and/or advisory board meetings from Chiesi, AstraZeneca, Boehringer Ingelheim, Sanofi, and GlaxoSmithKline within the last 5 years. She has also received an investigator-initiated research grant from Chiesi for work unrelated to this publication. GK reports grants from the National Health & Medical Research Council and Asthma Foundation and has been a consultant/speaker for AstraZeneca, Boehringer Ingelheim, GlaxoSmithKline, Novartis, Menarini, and Mundipharma.

The remaining author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declared that generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence, and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/falgy.2026.1741154/full#supplementary-material>

References

- Kaminsky DA, Simpson SJ, Berger KI, Calverley P, de Melo PL, Dandurand R, et al. Clinical significance and applications of oscillometry. *Eur Respir Rev.* (2022) 31(163):210208. doi: 10.1183/16000617.0208-2021
- Li LY, Yan TS, Yang J, Li YQ, Fu LX, Lan L, et al. Impulse oscillometry for detection of small airway dysfunction in subjects with chronic respiratory symptoms and preserved pulmonary function. *Respir Res.* (2021) 22(1):68. doi: 10.1186/s12931-021-01662-7
- Mou T, Wang Y, Fu Y, Wang Y, Li G. Analysis of the correlations and inconsistencies between spirometry and impulse oscillometry in the diagnosis of small-airway dysfunction. *BMC Pulm Med.* (2024) 24(1):619. doi: 10.1186/s12890-024-03420-z
- King GG, Chung LP, Usmani OS, Nilsen K, Thompson BR. Improving asthma outcomes: clinicians' perspectives on peripheral airways. *J Allergy Clin Immunol Glob.* (2024) 3(2):100228. doi: 10.1016/j.jacig.2024.100228
- Beinart D, Goh ESY, Boardman G, Chung LP. Small airway dysfunction measured by impulse oscillometry is associated with exacerbations and poor symptom control in patients with asthma treated in a tertiary hospital subspecialist airways disease clinic. *Front Allergy.* (2024) 5:1403894. doi: 10.3389/falgy.2024.1403894
- Postma DS, Brightling C, Baldi S, Van den Berge M, Fabbri LM, Gagnatelli A, et al. Exploring the relevance and extent of small airways dysfunction in asthma (ATLANTIS): baseline data from a prospective cohort study. *Lancet Respir Med.* (2019) 7(5):402–16. doi: 10.1016/S2213-2600(19)30049-9
- Galant SP, Kuks PJM, Kole TM, Kraft M, Siddiqui S, Fabbri LM, et al. Assessment of the role of small airway dysfunction in relation to exacerbation risk in patients with well controlled asthma (ATLANTIS): an observational study. *Lancet Respir Med.* (2025) 13:990–1000. doi: 10.1016/S2213-2600(25)00283-8
- Cottini M, Bondi B, Bagnasco D, Braidò F, Passalacqua G, Licini A, 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. doi: 10.1016/j.rmed.2023.107391
- Sugawara H, Saito A, Yokoyama S, Tsunematsu K, Chiba H, Takahashi H. A retrospective analysis of usefulness of impulse oscillometry system in the treatment of asthma. *Respir Res.* (2020) 21(1):226. doi: 10.1186/s12931-020-01494-x
- Sugawara H, Saito A, Yokoyama S, Tsunematsu K, Takahashi H. Comparison of therapeutic effects of inhaled corticosteroids on three subtypes of cough variant asthma as classified by the impulse oscillometry system. *Respir Res.* (2019) 20(1):41. doi: 10.1186/s12931-019-1005-2
- Chung LP, Thompson B, King G, Usmani OS, Siddiqui S, Dandurand RJ, et al. Interpreting respiratory oscillometry in adults with asthma or COPD: findings of an international Delphi study. *ERJ Open Res.* (2025). doi: 10.1183/23120541.00398-2025
- Stanojevic S, Kaminsky DA, Miller MR, Thompson B, Aliverti A, Barjaktarevic I, et al. ERS/ATS technical standard on interpretive strategies for routine lung function tests. *Eur Respir J.* (2022) 60(1):2101499. doi: 10.1183/13993003.01499-2021
- National Asthma Council Australia. *Australian Asthma Handbook, Version 2.2.* Melbourne: National Asthma Council Australia (2022). Available online at: <https://www.astmahandbook.org.au/> (Accessed August 1, 2025).
- Global Initiative for Asthma: Global strategy for asthma management and prevention. (2025). Available online at: <https://ginasthma.org/2025-gina-strategy-report/> (Accessed August 1, 2025).
- Oostveen E, Boda K, van der Grinten CP, James AL, Young S, Nieland H, et al. Respiratory impedance in healthy subjects: baseline values and bronchodilator response. *Eur Respir J.* (2013) 42(6):1513–23. doi: 10.1183/09031936.00126212
- Abdo M, Kirsten AM, von Mutius E, Kopp M, Hansen G, Rabe KF, et al. Minimal clinically important difference for impulse oscillometry in adults with asthma. *Eur Respir J.* (2023) 61(5):2201793. doi: 10.1183/13993003.01793-2022
- Liang X, Zheng J, Gao Y, Zhang Z, Han W, Du J, et al. Clinical application of oscillometry in respiratory diseases: an impulse oscillometry registry. *ERJ Open Res.* (2022) 8(4):00080-2022. doi: 10.1183/23120541.00080-2022
- Kraft M, Richardson M, Hallmark B, Billheimer D, Van den Berge M, Fabbri LM, et al. The role of small airway dysfunction in asthma control and exacerbations: a longitudinal, observational analysis using data from the ATLANTIS study. *Lancet Respir Med.* (2022) 10(7):661–8. doi: 10.1016/S2213-2600(21)00536-1
- Chan R, Lipworth BJ. Determinants of asthma control and exacerbations in moderate to severe asthma. *J Allergy Clin Immunol Pract.* (2022) 10(10):2758–60.e1. doi: 10.1016/j.jaip.2022.06.042
- Gao F, Lei J, Zhu H, Zhao L. Small airway dysfunction links asthma exacerbations with asthma control and health-related quality of life. *Respir Res.* (2024) 25(1):306. doi: 10.1186/s12931-024-02937-5
- Veen JCIT, Beekman AJ, Bel EH, Sterk PJ. Recurrent exacerbations in severe asthma are associated with enhanced airway closure during stable episodes. *Am J Respir Crit Care Med.* (2000) 161(6):1902–6. doi: 10.1164/ajrccm.161.6.9906075
- Bourdin A, Paganin F, Préfaut C, Kieseler D, Godard P, Chanez P. Nitrogen washout slope in poorly controlled asthma. *Allergy.* (2006) 61(1):85–9. doi: 10.1111/j.1398-9995.2006.00970.x
- Cottee AM, Seccombe LM, Thamrin C, King GG, Peters MJ, Farah CS. Bronchodilator response assessed by the forced oscillation technique identifies poor asthma control with greater sensitivity than spirometry. *Chest.* (2020) 157(6):1435–41. doi: 10.1016/j.chest.2019.12.035
- Chiabai J, Friedrich FO, Fernandes MTC, Serpa FS, Antunes MOB, Neto FB, et al. Intra-breath oscillometry is a sensitive test for assessing disease control in adults with severe asthma. *Ann Allergy Asthma Immunol.* (2021) 127(3):372–7. doi: 10.1016/j.anai.2021.06.005
- Dandurand RJ, Lavoie JP, Lands LC, Hantos Z, Oscillometry Harmonisation Study Group. Comparison of oscillometry devices using active mechanical test loads. *ERJ Open Res.* (2019) 5(4):00160-2019. doi: 10.1183/23120541.00160-2019
- Brusaco V, Schiavi E, Basano L, Ottonello P. Comparative evaluation of devices used for measurement of respiratory input impedance in different centres. *Eur Respir Rev.* (1994) 19:118–20.