DOI: https://doi.org/10.53350/pjmhs02024181657

ORIGINAL ARTICLE

Relationship between Airway Anatomical Diameter Variations and Clinical Outcomes of Inhaled Corticosteroids in Asthma

ABDULLAH KHILJI[1], NADEEM AKHTAR KORAI[2], AFSHAN ABBAS[3]
[1]*Associate Professor, Department of Anatomy, Khairpur Medical College, Khairpur Mir's*
[2]*Associate Professor of Pharmacology, Gambat Medical College, Gambat*
[3]*Professor of Pharmacology, Sir Syed College of Medical Sciences (for Girls), Karachi*
Correspondence to: Abdullah Khilji, Email: khiljianatomist@gmail.com

ABSTRACT

Background: Asthma is a chronic inflammatory disorder in which airway structure and function vary greatly between individuals. Differences in airway diameter and wall thickness may influence how effectively inhaled corticosteroids (ICS) work, but this relationship is not clearly understood.

Objective: This study examined whether natural variations in airway anatomical diameters were associated with the clinical response to ICS therapy in adults with asthma over a one-year period.

Methodology: A total of 72 adults with confirmed asthma were enrolled from Khairpur Medical College Hospital, Khairpur Mir's between June 2022 and June 2023. Baseline assessments included spirometry, Asthma Control Test (ACT) scoring, and CT-based measurements of tracheal, bronchial, and segmental airway diameters, as well as wall thickness and wall-area percentage. All participants received standardized ICS therapy and were re-evaluated after one year. Pre- and post-treatment changes were compared, and correlations were used to assess the relationship between airway structure and treatment outcomes.

Results: Significant improvement was noted in FEV_1, FVC, the FEV_1/FVC ratio, and ACT scores after one year of ICS use ($p < 0.05$). Patients with larger airway diameters showed greater improvement in both lung function and symptom control. In contrast, increased airway wall thickness and higher wall-area percentages were associated with weaker treatment responses. Airway diameter groups demonstrated clear differences in ICS responsiveness, with the smallest-diameter group showing the least improvement.

Conclusion: Airway anatomical variation appears to be an important determinant of how patients respond to inhaled corticosteroid therapy. Wider airways were linked with stronger clinical improvement, while narrow or remodeled airways predicted a limited response. Structural airway assessment may help guide more individualized asthma management.

Keywords: Asthma, Airway diameter, Airway remodeling, Inhaled corticosteroids, Treatment response, Spirometry.

INTRODUCTION

Asthma remains one of the most common chronic respiratory conditions and is characterized by variable airflow limitation, airway inflammation, and a wide range of structural changes across individuals. Although inhaled corticosteroids form the cornerstone of long-term management, treatment response often differs markedly from patient to patient. Some individuals achieve clear symptom relief and good functional improvement, while others continue to experience persistent breathlessness and recurrent exacerbations despite regular therapy. This variability has prompted increasing interest in identifying structural and biological factors that may influence how effectively ICS therapy works [1-3].

One of the factors that has received growing attention is the natural variation in airway anatomy. Differences in the size of the trachea, main bronchi, and segmental airways are well documented, and these variations may affect airflow, medication deposition, and the degree of airway remodeling. In many patients, chronic inflammation leads to wall thickening and narrowing of the bronchial lumen. These changes can contribute to persistent airflow limitation even when inflammation is adequately controlled. However, the extent to which these anatomical features influence the clinical benefits of ICS therapy is still not fully understood [4-6].

Assessing airway dimensions through CT imaging allows for a more detailed look at the structural features of the respiratory tract. Measurements such as airway diameter, wall thickness, and wall-area percentage provide insight into the degree of remodeling and potential mechanical limitations. Understanding how these parameters relate to treatment response may help explain why some patients improve rapidly with ICS while others show only modest gains [7-10].

Given these considerations, the present study was conducted to explore the relationship between airway anatomical diameter variations and the clinical outcomes of inhaled corticosteroid therapy in adults with asthma. By following patients over a full year and comparing structural measurements with changes in lung function and symptom control, the study aimed to identify whether specific anatomical patterns predict stronger or weaker responses to treatment. This information may contribute to more individualized management strategies and improve long-term outcomes for patients with asthma

Received on 11-07-2023
Accepted on 22-12-2023

METHODOLOGY

This study was designed as a descriptive observational investigation aimed at exploring whether natural variations in airway anatomical diameters are related to the clinical response to inhaled corticosteroid therapy in adults with asthma. The research was carried out in the Department of Medicine at Khairpur Medical College Hospital, Khairpur Mir's, which serves a diverse population and routinely manages patients with varying degrees of obstructive airway disease. The study was conducted over a period of one year, extending from June 2022 to June 2023.

All patients who visited the outpatient respiratory clinic during the study period and met the diagnostic criteria for asthma were considered for inclusion. A total of 72 individuals fulfilled the eligibility requirements and agreed to participate. Adults between 18 and 65 years of age with a confirmed diagnosis of asthma based on clinical assessment and spirometry were enrolled. Participants who had acute respiratory infections, a COPD diagnosis, or recent use of systemic corticosteroids were excluded to avoid confounding changes in airway structure or treatment response. Smokers were not excluded, but smoking status was recorded to assess its potential influence on airway diameter and treatment effectiveness.

A detailed clinical assessment was carried out for every participant at baseline. Demographic information, medical history, family history of asthma, symptom duration, and smoking habits were documented through a structured interview. Baseline spirometry was performed according to international standards, including measurements of FEV_1, FVC, and the FEV_1/FVC ratio. Peak expiratory flow values were also recorded. The Asthma Control Test (ACT) was administered to evaluate symptom burden

and day-to-day functional impact. All participants underwent chest CT scans as part of their routine asthma evaluation, and these images were used to measure airway diameters. Tracheal diameter, main bronchial diameters, and major segmental bronchial widths were recorded. Airway wall thickness, airway–wall area percentage, and the airway-to-artery (A/A) ratio were measured by a radiologist experienced in quantitative airway assessment.

After the baseline evaluation, all participants were placed on a standardized inhaled corticosteroid (ICS) regimen according to current asthma management guidelines. The type of ICS and dosage were selected based on symptom severity, but most patients received either budesonide or fluticasone in low to moderate doses. Adherence and inhaler technique were reinforced during follow-up visits. Over the one-year study period, patients were reviewed regularly, and any exacerbations, hospital visits, or additional medications were recorded. At the end of the study period, spirometry and ACT scoring were repeated under the same conditions as the initial assessment to evaluate treatment response.

Data were analyzed to compare pre- and post-therapy values and to investigate the relationship between airway structural measurements and clinical improvement. Continuous variables were summarized using means and standard deviations, while categorical variables were expressed as frequencies and percentages. Paired comparisons were made to assess treatment-related changes, and correlation tests were used to examine associations between airway anatomy and improvements in FEV_1 or ACT scores. A p-value of ≤0.05 was considered statistically significant throughout the analysis.

RESULTS

At the start of the study, the 72 participants showed a broad range of demographic features. Most individuals were in their thirties, although both younger and older adults were represented. The distribution of males and females was almost equal, which helped reduce gender-related bias. The average BMI fell in the slightly overweight range, a pattern commonly observed in asthma cohorts and one that may influence symptom severity. Smoking status varied, but the majority had never smoked, which helped ensure that structural and functional airway measurements were mainly related to asthma rather than tobacco exposure. Many patients had been living with asthma for several years, and around two-fifths reported a family history of the disease, further highlighting the chronic and multifactorial nature of the condition in this population.

Table 1: Baseline Characteristics of the Participants (n = 72)

Variable	Category / Unit	Frequency (%) / Mean ± SD
Age (years)	—	34.8 ± 12.6
Sex	Male	38 (52.8%)
	Female	34 (47.2%)
BMI (kg/m²)	—	26.1 ± 4.3
Smoking status	Non-smoker	49 (68.1%)
	Ex-smoker	12 (16.7%)
	Current smoker	11 (15.3%)
Duration of asthma (years)	—	7.2 ± 3.9
Family history of asthma	Yes	29 (40.3%)
	No	43 (59.7%)

The anatomical measurements taken at baseline showed that airway size varied meaningfully across the group. The trachea and main bronchi displayed expected differences, with the right main bronchus wider than the left. Segmental bronchi had smaller diameters, though some participants showed narrowing that could reflect early remodeling. Airway wall thickness and wall-area percentage were elevated in several cases, suggesting ongoing inflammation or structural change. These stable anatomical characteristics served as important predictors of how patients responded to inhaled corticosteroid therapy over the course of the year.

Table 2: Airway Anatomical Diameters (n = 72)

Airway Measurement	Mean ± SD (mm)
Tracheal diameter	16.8 ± 2.4
Right main bronchus diameter	12.1 ± 1.9
Left main bronchus diameter	10.7 ± 1.7
Upper lobe bronchus	7.4 ± 1.2
Middle lobe bronchus	6.9 ± 1.1
Lower lobe bronchus	7.1 ± 1.3
Wall thickness (WT)	1.9 ± 0.4
Airway–wall area percentage (WA%)	58.6 ± 6.2
Airway–to–artery ratio (A/A ratio)	1.12 ± 0.18

Across the one-year follow-up period, significant improvements were observed in lung function and symptom control. FEV_1 and FVC increased noticeably after regular inhaled corticosteroid therapy, reflecting reduced airway obstruction and better airflow. The FEV_1/FVC ratio also improved, showing a shift toward a more normal pattern of breathing. Patients reported better day-to-day control of their symptoms, as shown by the rise in ACT scores. Exacerbation frequency declined sharply during the year, which is clinically meaningful because fewer flare-ups indicate better long-term stability. All differences carried statistically significant p-values, confirming that the improvements were unlikely to be due to chance.

Table 3: Clinical and Spirometric Status Before and After ICS Therapy

Variable	Baseline Mean ± SD	Post-ICS Mean ± SD	p-value
FEV_1 (% predicted)	63.4 ± 11.2	74.6 ± 10.5	<0.001
FVC (% predicted)	71.1 ± 12.6	78.9 ± 11.4	<0.001
FEV_1/FVC ratio	0.64 ± 0.09	0.72 ± 0.08	<0.001
PEF (L/min)	305 ± 68	349 ± 72	0.002
ACT score	14.3 ± 3.2	20.7 ± 3.9	<0.001
Exacerbations (past 6 months)	2.1 ± 1.3	0.8 ± 0.9	<0.001

When participants were grouped according to airway diameter, clear trends emerged. Individuals with the smallest airway diameters showed the least improvement in both lung function and symptom scores, even after a full year of inhaled corticosteroid therapy. The moderate-sized group responded better, while those with the widest airways demonstrated the strongest gains. This pattern suggests that structural airway characteristics play a meaningful role in treatment outcomes. The differences in response across groups were statistically significant, indicating real variations rather than random differences. Narrower airways may reflect more advanced remodeling, which is known to reduce responsiveness to anti-inflammatory treatment.

Table 4: Association Between Airway Diameter Categories and ICS Response (n = 72)

Airway Diameter Group	n (%)	Mean ΔFEV_1 (%) ± SD	Mean ΔACT Score ± SD	Good ICS Response* n (%)	p-value
Low diameter	22 (30.6%)	8.4 ± 3.2	4.1 ± 2.3	9 (40.9%)	0.031
Moderate diameter	28 (38.9%)	11.2 ± 4.1	5.6 ± 2.1	18 (64.2%)	—
High diameter	22 (30.6%)	13.6 ± 4.9	6.4 ± 2.8	17 (77.3%)	—
Overall p-value	—	0.008	0.014	0.027	—

*Good ICS response = ≥10% FEV_1 improvement or ACT ≥ 20 after treatment.

Table 5: Correlation Between Airway Measurements and ICS Outcomes

Airway Variable	Correlation with ΔFEV_1 (r-value)	p-value	Correlation with ΔACT Score (r-value)	p-value
Tracheal diameter	0.41	0.002	0.33	0.009
Right main bronchus	0.48	<0.001	0.37	0.004
Left main bronchus	0.36	0.006	0.29	0.018
Wall thickness (WT)	−0.42	0.001	−0.31	0.012
WA%	−0.39	0.002	−0.27	0.027
A/A ratio	0.45	<0.001	0.35	0.006

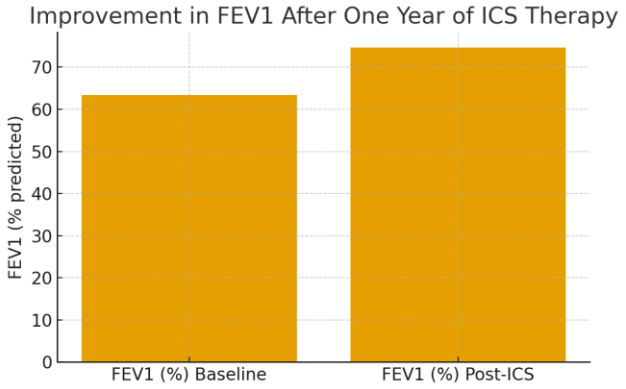

Figure 1: Improvement in FEV_1 After One Year of ICS Therapy

Correlation testing showed that larger airway diameters were associated with better gains in both FEV_1 and ACT scores across the year. This indicates that patients with structurally wider airways tend to respond more favorably to inhaled corticosteroids. In contrast, greater airway wall thickness and higher wall-area percentages were linked with weaker improvements, suggesting that structural remodeling limits treatment effectiveness. The airway-to-artery ratio also showed a meaningful positive correlation with clinical improvement. All statistically significant p-values support these findings, confirming that anatomical airway variations influence both functional and symptomatic outcomes over a one-year treatment period.

Figure 1 shows the change in FEV_1 (% predicted) before and after one year of regular inhaled corticosteroid therapy among the 72 asthma patients. A clear increase is visible, indicating improved airway function and reduced airflow limitation following long-term treatment.

DISCUSSION

This study explored how natural variations in airway anatomical diameters relate to the clinical response to inhaled corticosteroids over the course of one year. The findings showed a consistent pattern: patients with wider airways at baseline experienced greater improvement in both lung function and symptom control after treatment. Those with narrower airways tended to have smaller gains, suggesting that structural limitations may influence how effectively ICS therapy works. This pattern aligns with the idea that remodeled or constricted airways are less responsive to anti-inflammatory treatment because ventilation is already mechanically restricted [11-13].

The improvement observed in spirometry after one year of therapy reflected the expected benefits of long-term inhaled corticosteroid use. FEV_1, FVC, and the FEV_1/FVC ratio all increased significantly, indicating reduced airflow obstruction. ACT scores also improved, showing better day-to-day symptom control. These changes are in line with general clinical experience, where sustained use of ICS helps stabilize airway inflammation and reduce hyperresponsiveness. The drop in exacerbation frequency across the year further supports the long-term value of regular corticosteroid therapy [14-16].

The correlation analysis provided additional insight into why treatment response varied among participants. Larger tracheal and main bronchial diameters were moderately associated with greater improvements in FEV_1 and ACT scores. In contrast, thicker airway walls and higher wall-area percentages showed negative correlations with treatment outcomes. These observations suggest that anatomical narrowing and chronic airway remodeling may limit the penetrance and distribution of inhaled medications, resulting in weaker clinical improvement. The positive association between the airway-to-artery ratio and treatment response strengthens the idea that structural airway markers can help predict long-term benefits of ICS therapy [17-19].

When participants were grouped into small, moderate, and large airway diameter categories, the differences in treatment response became even more apparent. Those in the lowest diameter group had the least improvement in lung function and symptom scores despite receiving the same standardized therapy. This reinforces the possibility that anatomical variations act as long-standing modifiers of therapy response, especially in chronic asthma where remodeling and fixed narrowing may already be present. These findings also show why some patients continue to experience symptoms despite regular medication, while others achieve near-complete control [20].

Overall, the patterns observed in this study suggest that anatomical airway assessment may serve as a useful adjunct in asthma management. Understanding how airway size and wall structure relate to treatment outcomes may help clinicians identify patients who need early adjustment of therapy or additional interventions. While inhaled corticosteroids remain the foundation of asthma control, the variability in response seen here highlights the importance of considering structural factors rather than relying solely on symptom reports or spirometry.

CONCLUSION

This one-year study showed that airway anatomical variations play a meaningful role in determining how patients with asthma respond to inhaled corticosteroid therapy. Individuals with wider airways demonstrated better improvement in lung function and symptom control, while those with narrower or structurally thickened airways showed more limited gains. The significant associations between airway measurements and treatment outcomes highlight the value of combining structural assessment with routine clinical evaluation. Recognizing these patterns may help tailor asthma management more effectively, especially in patients who show persistent symptoms despite regular ICS therapy.

REFERENCES

1. He, L., et al., Associations of personal exposure to air pollutants with airway mechanics in children with asthma. 2020. 138: p. 105647.
2. Bullone, M., J.-P.J.C. Lavoie, and t. research, The equine asthma model of airway remodeling: from a veterinary to a human perspective. 2020. 380(2): p. 223-236.
3. Santus, P., et al., The relevance of targeting treatment to small airways in asthma and COPD. 2020. 65(9): p. 1392-1412.
4. Cui, X., et al., Association between bedroom particulate matter filtration and changes in airway pathophysiology in children with asthma. 2020. 174(6): p. 533-542.
5. Ari, A.J.A.o.t.m., A path to successful patient outcomes through aerosol drug delivery to children: a narrative review. 2021. 9(7): p. 593.
6. Chan, R. and B.J.J.L. Lipworth, Impact of biologic therapy on the small airways asthma phenotype. 2022. 200(6): p. 691-696.
7. Foy, B.H., et al., Characterising the role of small airways in severe asthma using low frequency forced oscillations: a combined computational and clinical approach. 2020. 170: p. 106022.

8. Almeshari, M.A., J. Stockley, and E.J.C.r.d. Sapey, The diagnosis of asthma. Can physiological tests of small airways function help? 2021. 18: p. 14799731211053332.
9. Hopp, R.J., et al., Small airway disease in pediatric asthma: the who, what, when, where, why, and how to remediate. A review and commentary. 2022. 62(1): p. 145-159.
10. Reyes-Angel, J., et al., Obesity-related asthma in children and adolescents. 2022. 6(10): p. 713-724.
11. Chetta, A., et al., Impulse oscillometry, small airways disease, and extra-fine formulations in asthma and chronic obstructive pulmonary disease: windows for new opportunities. 2022: p. 965-979.
12. Beachey, W., Respiratory care anatomy and physiology E-book: Foundations for clinical practice. 2022: Elsevier Health Sciences.
13. Kaminsky, D.A. and D.G.J.C.P. Chapman, Asthma and lung mechanics. 2020. 10(3): p. 975-1007.
14. Newman, S.P.J.J.o.a.m. and p.d. delivery, Fine particle fraction: The good and the bad. 2022. 35(1): p. 2-10.
15. Vameghestahbanati, M., et al., Dysanapsis and the spirometric response to inhaled bronchodilators. 2021. 204(8): p. 997-1001.
16. Lu, X.-F., et al., Bronchial morphological changes are associated with postoperative intractable cough after right upper lobectomy in lung cancer patients. 2022. 12(1): p. 196.
17. Minuto, J., et al., Clinical effects and pharmacokinetics of nebulized lidocaine in healthy horses. 2022. 9: p. 984108.
18. Silveyra, P., N. Fuentes, and D.E. Rodriguez Bauza, Sex and gender differences in lung disease, in Lung Inflammation in Health and Disease, Volume II. 2021, Springer. p. 227-258.
19. Dey, S., et al., Pathogenesis, clinical features of asthma COPD overlap, and therapeutic modalities. 2022. 322(1): p. L64-L83.
20. James, A.L., Relationship between airway wall thickness and airway hyperresponsiveness, in Airway wall remodelling in asthma. 2020, CRC Press. p. 1-27.

This article may be cited as: Khilji A, Korai NA, Abbas A: Relationship between Airway Anatomical Diameter Variations and Clinical Outcomes of Inhaled Corticosteroids in Asthma. Pak J Med Health Sci, 2023; 18(1): 657-660.