Open Access

Original Article

Comparison of Nebulized Versus Systemic Corticosteroids for Management of Children Presenting with Acute Exacerbation of Asthma

Silwana Taroni, Shakeel Ahmed, Wahid Nawaz, Andleeb Tariq, Fatima Raza, Abdullah

Department of Pediatrics, Combined Military Hospital/National University of Medical Sciences (NUMS), Rawalpindi Pakistan

ABSTRACT

Objective: To compare the efficacy of Nebulized versus Systemic Corticosteroids in the management of children presenting with acute exacerbation of asthma.

Study Design: Quasi-experimental study.

Place and Duration of Study: Department of Pediatrics, Combined Military Hospital, Rawalpindi Pakistan, from Feb to May 2024.

Methodology: A total of 60 pediatric patients with acute asthma exacerbations were enrolled using non-probability consecutive sampling. Group-I (Nebulized Corticosteroids) and Group-II (Systemic Corticosteroids). Group-I received Nebulized Budesonide, while Group-II received Oral or Intravenous Corticosteroids (Prednisolone or Hydrocortisone). The primary outcome was the change in oscillometric airway resistance at 20 Hz (R20), measured at baseline and on Day 14 using the Impulse Oscillometry System (IOS). Data were analyzed using SPSS version 26, with statistical significance set at $p<0.05$.

Results: The R20 baseline values ($p=0.02$) and symptom scores ($p=0.01$) were significantly different. The Nebulized-Group had a greater severity. After 14 days, all groups improved in R20 and symptom score, and the systemic Corticosteroid-Group had a greater reduction in airway resistance and symptom severity ($p=0.001$) than the Nebulized-Group. Both treatments produced clinically significant improvements, although the systemic corticosteroid resulted in a greater effect on airway resistance and symptom severity.

Conclusion: Both Nebulized and Systemic Corticosteroids produce clinically significant improvements in acute exacerbation of asthma in children. The Systemic Corticosteroids produced a greater reduction in R20, and the Nebulized Corticosteroids produced better symptom control.

Keywords: Acute Asthma Exacerbation, Airway Resistance, Nebulized Corticosteroids, Systemic Corticosteroids.

How to Cite This Article: *Taroni S, Ahmed S, Nawaz W, Tariq A, Raza F, Abdullah. Comparison of Nebulized Versus Systemic Corticosteroids for Management of Children Presenting with Acute Exacerbation of Asthma. Pak Armed Forces Med J 2026; 76(3): 429-434.*

DOI: https://doi.org/10.51253/pafmj.v76i3.13458

INTRODUCTION

Asthma is a major global public health issue that affects over 260 million people and results in over 450,000 fatalities each year.[1] Approximately 9.1% of children in WHO region 1 had current asthma symptoms, 11.0% of teenagers in WHO region 2, and 6.6% of adults in WHO region 3, according to the Global Asthma Network, which suggests that asthma symptoms are frequent in individuals of all ages worldwide.[2] Approximately 7.5 million adults and 15 million children in Pakistan suffer from asthma, with a 4.3% prevalence rate.[3] In Pakistan, the prevalence of asthma has also been on the rise, rising by about 5% annually.[4]

An acute exacerbation of asthma is an episode of symptoms that are progressively worsening, to the point of experiencing some complications, and that usually requires acute intervention by a physician.[5] Due to smaller airway diameters and heightened inflammatory responses, pediatric patients are especially vulnerable to severe complications.[6] Corticosteroids remain the cornerstone of treatment during such exacerbations, with two main routes of administration: Systemic (oral/IV) and inhaled (Nebulized).[7] Systemic Corticosteroids have been in existence for decades and have been shown to effectively reduce inflammation in hours. While Intravenous and Oral Corticosteroids deliver medication systemically, Nebulized Corticosteroids deliver it directly into the lungs, the site of inflammation, but provide minimal systemic side effects.[8]

Asthma is a common and growing concern among children in Pakistan, yet local data comparing treatment options remain limited. While Systemic Corticosteroids are effective, they may cause more side effects than nebulized forms. This study will provide additional evidence to support future decision-making in the management of pediatric asthma and consider

Correspondence: Dr Silwana Taroni, Department of Pediatrics, Combined Military Hospital, Rawalpindi Pakistan

Received: 06 May 2025; revision received: 21 Aug 2025; accepted: 22 Aug 2025

the ideal route of corticosteroid administration in the acute care setting. The present study aimed to examine the effectiveness of Nebulized versus Systemic Corticosteroids for the treatment of children with acute exacerbation of asthma.

METHODOLOGY

The purpose of this quasi-experimental study was to compare the efficacy of Systemic and Nebulized Corticosteroids in treating children who arrive at the Pediatric Emergency Department (PED) with acute asthma flare-ups.

The study was conducted at the Combined Military Hospital (CMH), Rawalpindi, for four months starting from February 2024, and ending in May, 2024. The study was approved by the Institutional Ethical Review Board (IRB Number: 865).

Using OpenEpi software, sample size estimates were carried out with a 95% confidence level, 80% power, and assuming prior evidence of 10% hospitalization in the systemic corticosteroid group vs 31% in the nebulized corticosteroid group (absolute difference ≈21%).[7] These presumptions led to the conclusion that a minimum of 30 patients per group was needed to identify a difference between the two therapies that was clinically significant.

Using non-probability consecutive sampling, 60 patients in all were recruited from children who presented to pediatric emergency rooms or outpatient clinics with an acute exacerbation of their asthma. Acute exacerbation was defined as increased wheezing, cough, shortness of breath, or respiratory distress not relieved by home-based therapy and requiring medical attention.

Inclusion Criteria: Children aged 2 to 12 years with a clinical diagnosis of bronchial asthma and presenting with an acute exacerbation, and those who had not received corticosteroid therapy in the previous 7 days were included to eliminate the confounding effect of recent corticosteroid use.

Exclusion Criteria: Patients with chronic respiratory illnesses other than asthma (such as cystic fibrosis or bronchopulmonary dysplasia), congenital heart defects, active lower respiratory tract infections requiring antibiotics, or a history of corticosteroid hypersensitivity or those who required mechanical ventilation at the time of presentation or those admitted to the intensive care unit (ICU) were excluded to maintain homogeneity of the study population and reduce severity bias.

After confirming eligibility and obtaining written informed consent from parents or guardians, participants were randomly assigned to one of two treatment groups: Group-I (Nebulized Corticosteroids) and Group-II (Systemic Corticosteroids). (Figure) Participants in Group-I received Nebulized Corticosteroids in the form of Budesonide 0.5mg twice daily, administered using a jet nebulizer with a mouthpiece or mask, depending on the child's age. The therapy was initiated in the emergency department and continued during hospitalization or at home if discharged early.

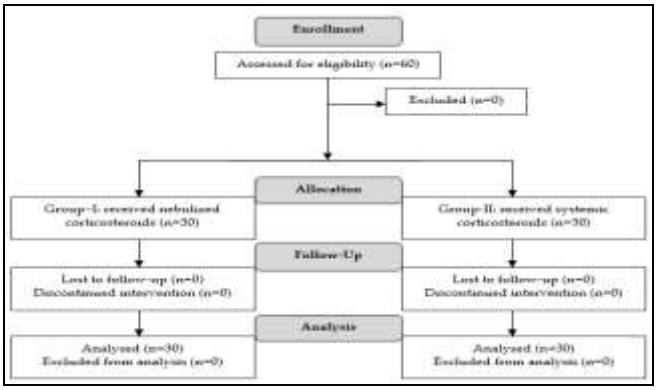

Figure: The flow chart showing a step-by-step visual representation of patient selection, group allocation, treatment given/ intervention, follow-up up and analysis

Patients in Group-II received Systemic Corticosteroids. For children able to take oral medication, oral Prednisolone was administered at a dose of 1–2 mg/kg/day, divided into two doses. For those unable to tolerate oral intake due to the severity of symptoms, intravenous Hydrocortisone was given at a dose of 4 mg/kg every 6 hours, later transitioned to oral Prednisolone as their condition stabilized. The duration of corticosteroid treatment in both groups ranged from 7 to 14 days, based on clinical improvement, and was closely monitored by the treating physician. All patients, irrespective of group allocation, received standard asthma care, including inhaled short-acting beta-agonists (Salbutamol), oxygen supplementation if required, antipyretics, and supportive care such as hydration and rest. Clinical monitoring was done throughout the hospital stay and during a follow-up visit on Day 14.

The main outcome was the change in oscillometric airway resistance at 20 Hz (R20), measured at baseline (Day 0) and follow-up (Day 14) with portable oscillometry. Impulse Oscillometry System (IOS) measures oscillometric resistance

following the guidelines of the European Respiratory Society (ERS).[9] During the test, the child was positioned to mouth breathe normally during the superimposed pressure oscillations over tidal breathing. Because R20 reflects central airway resistance, R20 values were recorded at baseline and then 14 days later to assess improvement in airway obstruction.

A pulse oximeter was utilized to obtain the most recent ongoing SpO2 at baseline (Day 0) and Day 14 while the participant was stabilized while resting, and breathing room air. The pulse oximeter was placed on a finger or toe of the participant to record the SpO2 levels, which were able to provide accurate readings to monitor respiratory status during the acute exacerbation of asthma. The total symptom score was obtained with a standardized measurement tool that holistically assessed the level of asthma symptom severity. Each assessed asthma symptom (wheezing, cough, shortness of breath, chest tightness) was assigned a numeric score based on the intensity of these symptoms.[10] The total score was measured at baseline (Day 0), which reflected the severity of symptoms. The score would also be measured on Day 14 during follow-up to document symptom severity improvement or decline after the prescribed treatment. The total symptom score ranged from 0 to 12, with higher scores indicating more severe symptoms. Changes in symptom scores were used as an important measure of treatment outcome.

The collected data were entered and analyzed using Statistical Package for the Social Sciences SPSS version 26. Continuous variables such as age, weight, duration of asthma, airway resistance at 20 Hz (R20), symptom scores, and oxygen saturation (SpO_2) were summarized using mean and standard deviation (Mean±SD). Categorical variables, including gender, treatment outcome status, and presence or absence of adverse effects, were presented as frequencies and percentages. To assess the suitability of parametric tests, the normality of continuous variables was evaluated using the Shapiro-Wilk test along with visual inspection of histograms and Q-Q plots. The results indicated that the variables, age, weight, duration of asthma, R20, symptom score, and SpO_2, were approximately normally distributed.

Therefore, parametric tests were deemed appropriate for further analysis. For between-group comparisons at baseline and at Day 14, the independent samples t-test was applied to continuous variables, while the Chi-square test was used for categorical variables. For within-group comparisons (baseline vs. Day 14), the paired t-test was used to assess changes in clinical and oscillometry outcomes within each treatment group. A *p*-value of less than 0.05 was considered statistically significant.

RESULTS

The study included 60 participants divided equally into two treatment groups (Group-I and Group-II, each n=30). The overall mean age of the participants was 7.7±1.9 years, with 33(55%) males and 27(45%) females. The mean weight across the cohort was 22.4±3.6 kg. The mean duration of asthma prior to treatment was 2.29±0.65 years in Group-I and 2.27±0.62 years in Group-II, indicating comparable baseline characteristics. The average hospital stay was 4.7±1.9 days. Regarding safety, adverse effects were reported in 12 participants (20%), while 48(80%) remained unaffected during the treatment period (Table-I).

Table-I: Descriptive Statistics of Participants (n=60)

Variable(s)	Mean±SD / n(%)
Age (years)	7.70±1.90
Gender	
Male	33(55.0%)
Female	27(45.0%)
Weight (kg)	22.4±3.6
Treatment Group	
Group-I	30(50.0%)
Group-II	30(50.0%)
Duration of Asthma	
Group-I	2.29±0.65
Group-II	2.27±0.62
Hospital Stay (days)	4.70±1.90
Adverse Effects	
Present	12(20.0%)
Absent	48(80.0%)

Table-II: Baseline Characteristics of Participants (n=60)

Variable	Group-I (n=30)	Group-II (n=30)	*p*-value
Age (years)	7.70±1.90	7.80±1.90	0.89
Gender (M/F)	25(83.3) / 5(16.7)	28(93.4) / 2(6.6%)	0.22
Weight (kg)	22.40±9.40	22.30±3.80	0.96
Baseline R20	7.10±0.39	7.30±0.310	0.02*
Symptom Score (0–12)	10.90±1.80	9.40±2.10	0.01
SpO_2 (%)	90.50±1.40	89.90±1.31	0.13

R20: Airway Resistance at 20 Hz
Independent t-test and Chi-square test are used for statistical analysis
**P< 0.05 is considered significant*

Both treatment groups were comparable at baseline in terms of age, gender distribution, and weight, with no statistically significant differences

observed (p>0.05). However, a significant difference was noted in the baseline R20 values between the Nebulized and Systemic Corticosteroid Groups (p=0.02), indicating potential variation in initial airway resistance. Symptom scores also differed significantly at baseline, with the Nebulized-Group presenting higher severity (p=0.01). Oxygen saturation levels were slightly lower in the Systemic-Group, though the difference was not statistically significant (p=0.13). These findings underscore the importance of adjusting for baseline characteristics in the comparative analysis (Table-II).

At the end of 14 days, a significant improvement was noted in both R20 values and symptom scores in favor of the Systemic Corticosteroid-Group (p=0.001 for both comparisons), indicating a more pronounced reduction in airway resistance and symptom severity compared to the Nebulized-Group. Although oxygen saturation showed a slight increase in both groups, the difference between them was not statistically significant (p=0.18). Clinical improvement, defined by outcome status, was observed in 63.3% of participants in the Nebulized-Group and 70.0% in the Systemic-Group, with no significant difference between them (p=0.57). Adverse effects were more frequent in the Nebulized-Group (26.7%) compared to the Systemic-Group (13.3%), though this difference was also statistically non-significant (p=0.20) (Table-III).

Table-III: Comparison of Clinical and Oscillometry Outcomes at Day 14

Variable	Group I (Nebulized) n=30	Group-II (Systemic) n=30	*p*-value
R20 at Day 14	5.2±0.38	4.6±0.30	0.001*
Symptom Score at Day 14	1.70±0.4	5.4±1.4	0.001*
O_2 Saturation at Day 14 (%)	93.1±2.1	92.2±2.0	0.18
Outcome Status (Improved)	19(63.3%)	21(70.0%)	0.57
Adverse Effects	8(26.7%)	4(13.3%)	0.20

R20: Airway Resistance at 20 Hz
Independent t-test and Chi-square test are used for statistical analysis
**P< 0.05 is considered significant.*

Significant improvements were observed within both treatment groups across all clinical and oscillometric parameters from baseline to Day 14. In Group-I (Nebulized Corticosteroids) as well as Group-II (Systemic Corticosteroids), R20 values decreased substantially, reflecting reduced airway resistance (p=0.001 for both groups). Symptom scores also dropped markedly within both groups, highlighting notable clinical improvement over the treatment period (p=0.001). Similarly, oxygen saturation showed a statistically significant rise in both groups by Day 14 (p=0.001), indicating better oxygenation status post-treatment (Table-IV).

Table-IV: Within-Group Comparison of Clinical and Oscillometry Outcomes (Baseline vs. Day 14)

Variable	Group	Baseline (Mean±SD)	Day 14 (Mean±SD)	*p*-value
R20	I	7.10±0.39	5.20±0.38	0.001*
	II	7.30±0.31	4.60±0.30	0.001*
Symptom Score	I	10.90±1.80	1.70±0.40	0.001*
	II	9.40±2.10	5.40±1.40	0.001*
O_2 Saturation (%)	I	90.50±1.40	93.10±2.10	0.001*
	II	89.90±1.31	92.20±2.00	0.001*

R20: Airway Resistance at 20 Hz
Paired t-test used for statistical analysis
**p< 0.05 is considered significant.*

DISCUSSION

This study evaluated the efficacy and safety of Nebulized versus Systemic Corticosteroids in children with acute asthma exacerbation, with an emphasis on clinical improvement, oscillometric measures (especially R20), and oxygen saturation over 14 days. We found significant improvement within all groups in all measure outcomes, and that the Systemic Corticosteroid provided better airway resistance (R20) and symptom severity control than Nebulized Corticosteroids, but both groups were effective, and there was no significant overall clinical improvement or difference in adverse effects between the groups.

The improvement in airway resistance (R20) in both groups is based on the anti-inflammatory effects of corticosteroids in the management of asthma. But in our study, the Systemic-Group had a larger improvement (p=0.001), indicating the systemic anti-inflammation may be quicker or stronger. This is in agreement with Gurnell *et al.,* and Imtiaz *et al.,* who reported that Systemic Corticosteroids led to faster resolution of asthma symptoms in children presenting to emergency departments when compared to Inhaled Corticosteroids.[11,12] Likewise, empirical evidence from Hasegawa *et al.,* and Baqdunes *et al.,* has established that Systemic Corticosteroids are the best agents in the early treatment of acute exacerbations, because they have complete bioavailability and an immediate onset of action.[13,14]

Although our results equally support Nebulized Corticosteroids as a viable alternative, especially in cases where the systemic route is inappropriate or not preferred. The positive and clinically significant change in R20, symptom scores, and oxygen saturation in the Nebulized- Group (p=0.001 for all), is similar to the work by Ahmadi *et al.,* and Direkwattanachai *et al.,*

who demonstrated that high-dose inhaled budesonide is similar in effectiveness to oral prednisolone in the management of moderate asthma exacerbations in children.[15,16] In addition, the localized action and minimal risk of systemic side effects of Nebulized Corticosteroids are generally preferred, especially in the mild to moderate range.

The obvious baseline discrepancy in R20 values and symptom scores among the groups showed that the Nebulized-Group had a higher severity rating at baseline, which likely influenced the lower magnitude of change in this cohort. This highlights the need for baseline adjustments in future trials, or at least when interpreting treatment results. The increase in oxygen saturation occurred in both groups, but the difference in change was not significant (p=0.18), demonstrating that the clinical effect of either treatment appears to improve gas exchange and oxygenation similarly. Similar findings were reported when comparing Inhaled vs. Systemic Corticosteroids by Papadopoulou *et al.*, and Zineldin *et al.*, who found comparable changes in oxygen saturation due to Inhaled vs. Systemic Corticosteroids.[17,18] Collections of adverse effects, although more frequent in the Nebulized-Group, were not different in both arms (p=0.20), contrary to typical expectations that Systemic Steroid usage entails more side effects. Presumably, the increased incidence of adverse events in the Nebulized-Group could in part be attributable to localized irritation and potentially higher doses to sufficiently address acute severe baseline symptomology.

The findings of the present research support the use of both corticosteroid treatment modalities of Systemic and Nebulized Corticosteroids in acute pediatric asthma exacerbations. In cases of moderate to severe exacerbations, Systemic Corticosteroids demonstrated quicker improvement in symptoms and functional outcomes, whereas Nebulized Corticosteroids are still a viable, effective option for patients with mild/moderate exacerbations or when systemic therapy cannot be used.

LIMITATION OF STUDY

The most significant limitation was the lack of randomization, which may have added selection bias and restricted the ability to control any possible confounding factors. Additionally, without blinding participants or care providers to the groups, performance and observer bias were possible, especially in subjective measures of outcomes like symptom scores. Additionally, the lack of either long-term follow-up or adverse effects after the intervention was completed prevents conclusions regarding lasting efficacy and safety. Lastly, we did not control for external factors such as environmental stimuli, compliance with medication at home, or variability in care from caregivers, which may limit the generalizability of the study.

CONCLUSION

Both Nebulized and Systemic Corticosteroids are effective in potentially improving clinical outcomes in pediatric patients with asthma. Systemic Corticosteroids had the most significant improvement in airway resistance (R20), while Nebulized Corticosteroids had better symptom reduction. The primary clinical improvements in both included treatment groups were very similar, with no statistically significant differences in the rate of overall improvement for either group. As such, both forms of treatment may have beneficial therapeutic effects related to asthma management, with selection dependent on the severity of the condition, the choice of the patient, and the clinical scenario. That said, caution should be exercised with both treatment types, especially if there is prolonged use due to the possibility of adverse effects.

Conflict of Interest: None.
Funding Source: None.

Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

ST & SA: Data acquisition, data analysis, critical review, approval of the final version to be published.

WN & AT: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

FR & A: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

REFERENCES

1. Garg R, Piplani M, Singh Y, Bhateja P, Rana R. An overview of integrated risk factors with prevention and prevalence of asthma at the global level. Curr Trad Med 2024; 10(4): 71-81. https://doi.org/10.2174/2215083810666230525153908
2. Song P, Adeloye D, Salim H, Dos Santos JP, Campbell H, Sheikh A, et al. Global, regional, and national prevalence of asthma in 2019: a systematic analysis and modelling study. J Glob Health 2022; 12: 04052. https://doi.org/10.7189/jogh.12.04052
3. Khan S, Iqbal S, Azam A, Qadeer S, Khanam S. Prevalence and determinants of Asthma in adults in Khyber Pakhtunkhwa, Pakistan. Abasyn J Life Sci 2022; 5(2): 26-32. https://doi.org/10.34091/AJLS.5.2.4
4. Iqbal MZ, Alqahtani SS, Shahid S, Mubarak N. Socio-demographic, environmental and clinical factors influencing asthma control in community pharmacies of Lahore Pakistan. Sci Rep 2025; 15(1): 10587. https://doi.org/10.1038/s41598-025-95373-4

5. Gershkovich D. Acute exacerbation of asthma. Masters Thesis. University of Zagreb, School of Medicine; 2023. https://urn.nsk.hr/urn:nbn:hr:105:749372
6. Leung JS. Paediatrics: how to manage acute asthma exacerbations. Drugs Context 2021; 10: 2020-12-7. https://doi.org/10.7573/dic.2020-12-7
7. Marghli S, Bouhamed C, Sghaier A, Chebbi N, Dlala I, Bettout S, et al. Nebulized budesonide combined with systemic corticosteroid vs systemic corticosteroid alone in acute severe asthma managed in the emergency department: a randomized controlled trial. BMC Emerg Med 2022; 22(1): 134. https://doi.org/10.1186/s12873-022-00691-9
8. Altube MJ, Perez N, Romero EL, Morilla MJ, Higa LH, Perez AP. Inhaled lipid nanocarriers for pulmonary delivery of glucocorticoids: Previous strategies, recent advances and key factors description. Int J Pharm 2023; 642: 123146. https://doi.org/10.1016/j.ijpharm.2023.123146
9. 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. https://doi.org/10.1183/23120541.00080-2022
10. Rao SK. Management of Asthma & Its Exacerbations in smaller settings, International J Clin Rep Stud 2023; 2(6): 2-8. https://doi.org/10.31579/2835-8295/041
11. Gurnell M, Heaney LG, Price D, Menzies-Gow A. Long-term corticosteroid use, adrenal insufficiency, and the need for steroid-sparing treatment in adult severe asthma. J Intern Med 2021; 290(2): 240-256. https://doi.org/10.1111/joim.13273
12. Imtiaz R, Yameen S, Hassan A, Ramzan H, Nizami S, Ayub Z. Clinical Efficacy Of Dexamethasone Versus Hydrocortisone In Acute Exacerbation Of Asthma In Children. Pak J Intensive Care Med 2025; 5(01): 35. https://doi.org/10.54112/pjicm.v4i02.35
13. Hasegawa K, Craig SS, Teach SJ, Camargo Jr CA. Management of asthma exacerbations in the emergency department. J Allergy Clin Immunol Pract 2021; 9(7): 2599-2610. https://doi.org/10.1016/j.jaip.2020.12.037
14. Baqdunes MW, Leap J, Young M, Kaura A, Cheema T. Acute exacerbation of chronic obstructive pulmonary disease. Crit Care Nurs Q 2021; 44(1): 74-90. https://doi.org/10.1097/cnq.0000000000000341
15. Ahmadi Afshar A, Rahmati M, Maleki A, Kamali K. The Effectiveness of Budesonide in the Treatment of Asthma Attacks in Children: A Systematic Review and Meta-Analysis. Prev Care Nurs Midwifery J 2023; 13(3): 9-18. http://doi.org/10.61186/pcnm.13.3.9
16. Direkwattanachai C, Aksilp C, Chatchatee P, Jirapongsananuruk O, Kamalaporn H, Kamchaisatian W, et al. Practical considerations of nebulized corticosteroid in children with acute asthmatic exacerbation: A consensus. Asian Pac J Allergy Immunol 2021; 39(3): 168-176. https://doi.org/10.12932/ap-170918-0407
17. Papadopoulou E, Safar SB, Khalil A, Hansel J, Wang R, Corlateanu A, et al. Inhaled versus systemic corticosteroids for acute exacerbations of COPD: a systematic review and meta-analysis. Eur Respir Rev 2024; 33(171): 230151. https://doi.org/10.1183/16000617.0151-2023
18. Zineldin MA. Systemic Corticosteroids with or without Nebulized Budesonide for Treatment of Acute Severe Asthma Exacerbations in the Emergency Room: A retrospective Study. Int J Med Arts 2024; 6(11): 5116-5121. https://doi.org/10.21608/ijma.2024.333093.2063

.....