Original Article

Asthma and Medication Administration Practices in Children: An Exploratory Study on Bacterial Colonization of Inhaler Spacer Devices

Sai Geethika Malapati[1], Sai Nikhitha Malapati[2], Pushpalatha K[3], Basil Nduma[4], Chukwuyem Ekhator[5], Ravi GS[6]

From, [1]MBBS, MD, Senior Resident, Department of Pediatrics, ESIC Medical College & PGIMSR and Model Hospital, Rajaji Nagar, Bangalore, India, [2]MBBS, Research Intern, Department of Internal Medicine, Kamineni Academy of Medical Sciences & Research Center, Hyderabad, India, [3]MBBS, DCH, MD, Professor Department Of Pediatrics, ESIC & PGIMSR KK Nagar, Chennai, India, [4]MBBS, MD, MSHI, Chief Resident, Department of Internal Medicine, Medical City Arlington, Arlington, TX, USA, [5]MD,MPH,MS, Department of NIH/NINDS, Medstar Georgetown University Hospital, Washington, TX, USA, [6]MBBS, MD, Professor, Department of Microbiology, ESIC Medical College & PGIMSR and Model Hospital, Rajaji Nagar, Bangalore

ABSTRACT

Introduction: Asthma is one of the most common chronic respiratory diseases in children, and the use of metered dose inhalers (MDIs) with spacers is central to its management. However, these spacer devices, if not cleaned regularly, may become contaminated with bacteria that can worsen asthma symptoms or lead to respiratory infections. This study aimed to evaluate the level of bacterial contamination in MDI spacer devices used by children with asthma and to explore how cleaning habits influence this contamination and associated health outcomes. **Methods:** We conducted a hospital-based cross-sectional study involving 200 children with asthma who had been using MDI spacers for at least three months. Swabs were collected from the inner surfaces of their spacer devices and cultured on standard media. Bacterial colonies were identified using Gram staining and biochemical tests. Contamination levels were classified based on colony-forming unit (CFU) counts. Associations between contamination, cleaning methods, and hospital admissions were analyzed using appropriate statistical tools. **Results:** Out of 200 devices, 70 (35%) showed bacterial growth. While many cultures grew Micrococcus spp., potentially harmful bacteria such as *E. coli, Klebsiella pneumoniae, Pseudomonas aeruginosa,* and *Staphylococcus aureus* were also found. Children whose devices were cleaned after every use had significantly fewer hospital admissions than those whose devices were only cleaned occasionally or never. Despite receiving cleaning instructions, most caregivers did not follow proper cleaning routines. **Conclusion:** The study reveals that a substantial number of pediatric asthma spacer devices are contaminated with bacteria, including pathogenic strains, largely due to inconsistent cleaning practices. These findings emphasize the need for better caregiver education and standardized spacer hygiene protocols to reduce infection risk and enhance asthma control in children.

Key words: Asthma, MDI Spacer, Pediatric, Bacterial Contamination, Inhaler Hygiene, Exacerbations

Asthma is a major cause of chronic respiratory disease, and it currently affects about 300 million people worldwide [1]. Its incidence is increasing, and the prevalence is projected to be over 400 million by 2025. Asthma causes significant morbidity and mortality, especially in low and middle-income countries [2]. The standard of care for asthma treatment is inhaled medications. The most common delivery device for these inhaled asthma medications is the metered dose inhaler (MDI) with spacers, which facilitates the delivery of the inhaled drug to the lower airways [3, 4]. Microbial colonization of these devices when being used along with associated potential asthma exacerbation events have been reported [4].

Prior studies have documented various levels of contamination of these MDI spacer devices with various organisms including pathogenic bacteria such as *Pseudomonas aeruginosa, Staphylococcus aureus,* and *Klebsiella pneumoniae* [5]. The findings reflect the urgent need for regular maintenance and strict compliance with good hygienic practices. The goal of this current research is to

Access this article online

Received – 31st May 2025
Initial Review – 09th June 2025
Accepted – 10th June 2025

DOI: ***

Quick Response code

Correspondence to: DR. Sai Nikhitha Malapati, Department of Internal Medicine, Kamineni Academy of Medical Sciences & Research Center, Hyderabad, India.
Email: sainikhithamalapati@gmail.com

evaluate bacterial colonization in MDI spacer devices used in asthma-affected children and to determine variables associated with increased risk for contamination.

MATERIALS AND METHODS

The study is a hospital-based cross-sectional study carried out among children visiting the pediatric & Internal Medicine at ESIC Medical College & PGIMSR and Model Hospital, Rajaji Nagar, Bangalore, India. The study population includes children attending the Department of Internal Medicine & Pediatrics. Duration of the study was between August 2022 and January 2024. The study included children from ages 1 through 18 years of age and children who are already diagnosed with asthma and are on maintenance therapy for more than 3 months. Children with acute respiratory infections and cystic fibrosis were excluded. The sample was size calculated according to a study conducted by Navkiran N et al, [8] where the prevalence rate of microbial colonization was 28.8 percent with a 95 percent confidence interval and an allowable error of 7 percent.

The sample size for the present study is calculated using the formula below,

$$n = \frac{\left(z_{1-\frac{\alpha}{2}}\right)^2 p(1-p)}{d^2}$$

where ,

- n = Sample size
- p = Prevalence rate of microbial colonization
- Z 1-a/2=Standard table value at 95%
- d= Allowable error = 7%

Substituting these values,

$$n = \frac{(1.96)^2\,(28.8)(71.2)}{7^2}$$

$$n = \frac{7874}{49} = 161$$

Hence, the sample size is calculated as 161.

After obtaining ethical clearance from the Institutional Ethical Committee and collecting informed consent from their parents, 200 children fulfilling the inclusion criteria were enrolled in this study.

Sample Collection: Sterile cotton swabs were moistened in sterile normal saline and rotated 10 times in a concentric pattern around the inner surface of the spacer devices of MDI and the samples were immediately transferred to the microbiology laboratory for processing.

Microbiological Analysis and Identification: Samples were inoculated on Nutrient Agar, 5% Sheep Blood Agar, and MacConkey Agar at 37°C for 24 and 48 hours for colony growth. Direct Gram staining was done and examined microscopically. Bacterial isolates were identified using biochemical tests such as catalase, oxidase, and citrate utilization assays. Culture results were recorded as the mean number of colony-forming units (CFUs). Sites with less than 10 CFUs were defined as clean, those with 10–100 CFUs as mildly contaminated, and those with more than 100 CFUs as contaminated. The figures below show pictures from the laboratory cultures.

Figure 1: E. coli on Blood Agar

Figure 2: E. coli on MacConkey agar

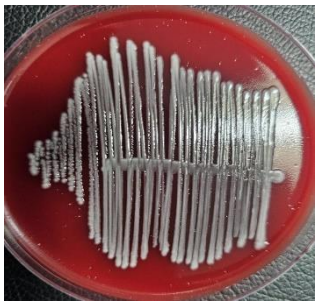

Figure 3: Klebsiella on blood agar

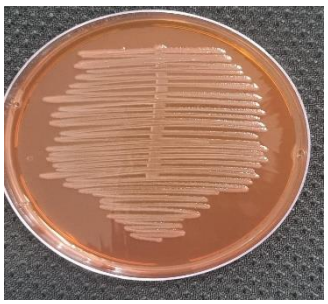

Figure 4: Pseudomonas on MacConkey agar

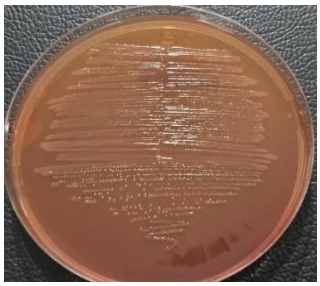

Figure 5: Proteus on MacConkey agar

Figure 6: Proteus on blood agar

Statistical method: The data collected was entered into Microsoft Excel and analyzed using SPSS version 20.0. Sociodemographic data was presented using descriptive statistics namely frequency (n), percentage (%), mean, standard deviation, median, inter quartile range wherever applicable. The normality of data was tested by the Kolmogorov–Smirnov test. Quantitative variables were compared using an unpaired t-test/Mann–Whitney test (for non-parametric data). Data was presented in the form of tables and bar diagrams wherever necessary.

RESULTS

Table 1: Tabular representation of demographic data of the study population

Variables	Number of patients	Percentage
Age		
1 – 5	35	17.5%
6 – 10	78	39%
11-15	56	28%
16 – 18	31	15.5%
Sex		
Female	87	43.5%
Male	113	56.5%
Total	200	100%

Table 2: Table showing usage of MDI and space devices in the study population

Received instruction and/or Complaint	Number of Patients who received and/or were compliant with instruction	Percentage	Number of Patients who did not receive and/or were not compliant with instructions	Percentage
Compliance to asthma treatment with PMDI with spacer	186	93%	14	7%
Proper technique of usage of PMDI with spacer for asthma medication delivery	144	72%	56	28%
Cleaning and maintenance instructions of spacer given by health care professionals previously	176	88%	4	2%

Table 3: Table showing the distribution of spacer device cleaning practices, method of cleaning of spacer devices among the study population

Variables	Number of patients	Percentage
Cleaning of spacer devices		
Occasionally	116	58%
Never	8	4%
After each use	76	38%
Method of cleaning		
Wipe using cloth	13	7%
Wash in running water	173	90%
Boiled	6	3%

It was also noted that 28% of patients (n=33) in the group that only cleaned their MDI space devices occasionally had at least 1 admission per year when compared to the group that cleaned their MDI spacer device after each use 7.1%, (n=5). Microbiology culture results showed positive culture growth of 35% (n=70) while 65% of the samples showed negative culture growth (n=130).

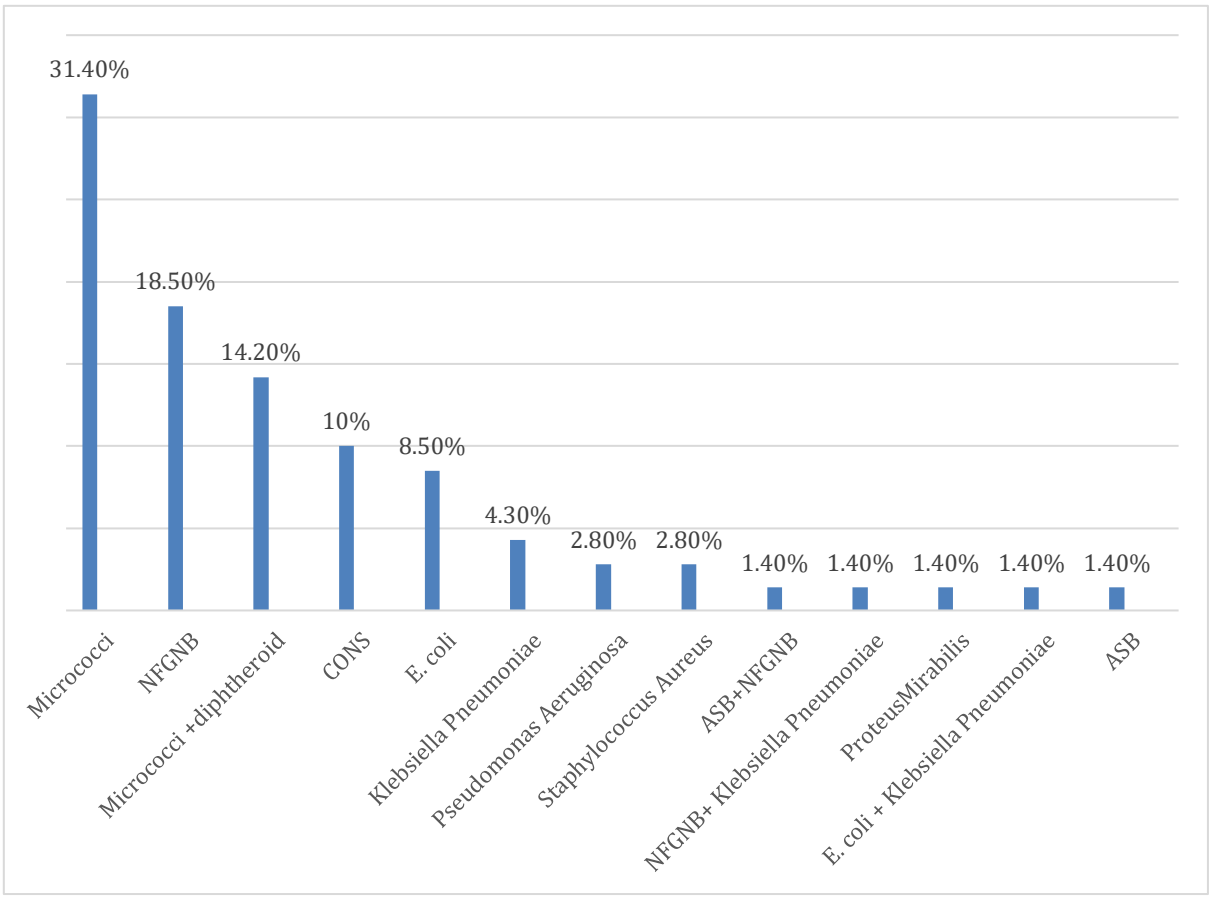

Figure 7: Bar Graph showing the microbial population of culture growth

NFGNB: Non-fermenting Gram-negative Bacilli; CoNS: coagulase-negative staphylococci; ASB: Aerobic spore bearer

DISCUSSION

This study sheds light on a clinically underexplored yet highly relevant aspect of Pediatric asthma management—the microbial contamination of MDI spacer devices and its correlation with hygiene practices and asthma-related hospitalizations. Among the 200 enrolled asthmatic children, 35% of the spacer devices demonstrated bacterial contamination, with both commensals and potentially pathogenic organisms being isolated. The predominant isolate was *Micrococcus spp*. (31.4%), a common skin commensal, but the detection of organisms such as *Escherichia coli* (8.5%), *Klebsiella pneumoniae* (4.3%), *Pseudomonas aeruginosa* (2.8%), *Staphylococcus aureus* (2.8%), and *Proteus mirabilis* (1.4%) raises significant concerns regarding the safety and maintenance of these commonly used devices. These findings are consistent with previous studies. Cohen et al. (2005) identified substantial microbial colonization in spacer devices used by asthmatic children, including *S. aureus* and Gram-negative bacilli [6].

Similarly, Borovina et al. (2012) demonstrated that community-used MDIs in Australia were contaminated with a wide spectrum of bacteria, raising concerns about community-acquired spacer-associated infections [7]. Another notable report by Shepherd et al. (2021) presented a case series linking microbial contamination of spacers to worsened asthma outcomes in pediatric patients, further reinforcing our conclusions [4]. These studies highlight that spacer devices, though designed to improve medication delivery and reduce oropharyngeal deposition may inadvertently act as reservoirs for pathogenic microorganisms if not cleaned properly.

What sets our study apart is its quantitative correlation between cleaning practices and clinical outcomes—specifically, hospital admission rates. Only 7.1% of children whose caregivers cleaned the spacer device after every use had at least one asthma-related hospital admission per year, compared to 28% of those who cleaned it only occasionally. This trend strongly suggests that regular cleaning reduces the risk of significant respiratory infections that may trigger exacerbations requiring hospitalization. While previous studies have addressed contamination qualitatively, few have examined its real-world clinical consequences in this fashion, especially in the Indian pediatric population. This makes our study both novel and clinically meaningful. Moreover, our findings expose an important behavioral and educational gap.

Despite 88% of participants reporting that they had received instructions on device maintenance from healthcare professionals, only 38% practiced cleaning after every use. This discrepancy indicates a critical need to understand barriers to adherence. Factors may include lack of perceived importance, forgetfulness, absence of reminders, or inadequate demonstrations during clinical consultations. This finding mirrors observations in a related study by Ranjan et al. (2022), who noted poor compliance with home nebulizer hygiene despite adequate caregiver education [9].

From a clinical standpoint, several differential diagnoses may explain frequent asthma exacerbations in children. These include viral respiratory tract infections (especially rhinovirus), allergen exposure, medication non-adherence, gastroesophageal reflux disease (GERD), and stress-related triggers. However, contamination of spacer devices remains a frequently overlooked factor. Given that multiple isolated organisms in our study are known to cause lower respiratory infections, their repeated reintroduction via contaminated spacers could exacerbate underlying inflammation in asthmatic children, potentially mimicking or amplifying other causes of flare-ups.

A few case reports from published literature further highlight the real-world significance of this issue. One case described a 9-year-old child with severe asthma who experienced repeated admissions despite adherence to medication. Eventually, cultures from her spacer revealed *Pseudomonas aeruginosa*, and resolution followed only after replacement and proper cleaning of her device [8]. Another case by Kameswaran et al. (2023) in India described *S. aureus pneumonia* in a 7-year-old child directly linked to a chronically uncleaned spacer [9]. These underscore that contaminated spacers are not merely academic concerns but can have tangible, harmful clinical consequences.

From a public health and preventive medicine standpoint, this study reinforces the importance of standardized cleaning protocols. Despite high rates of awareness, the gap in actual cleaning practices indicates that health education strategies need to be reevaluated. Visual demonstrations, the use of reminder cards, and caregiver-focused interventions might be necessary to bridge the knowledge-behavior gap. Furthermore, the study suggests exploring novel technological solutions—such as antimicrobial-coated spacers, UV-based cleaning devices, or smart spacers embedded with sensors that track hygiene compliance and provide alerts. Additionally, there is a need for policy-driven recommendations. Currently, there is no universally accepted guideline detailing how frequently or by what method spacer devices should be cleaned in the pediatric population. Our findings support the development of evidence-based national guidelines that are simple, feasible, and scalable across various healthcare settings in India.

CONCLUSION

This study highlights a critical but underrecognized risk in pediatric asthma care which is microbial contamination of MDI spacer devices due to inconsistent hygiene practices. By demonstrating a direct link between poor cleaning habits and increased hospital admissions for asthma exacerbations, our findings emphasize the urgent need for standardized cleaning protocols and enhanced caregiver education. Importantly, despite caregivers receiving prior instructions, adherence remained low, underscoring the gap between knowledge and practice. Future research should explore innovative solutions such as antimicrobial-coated or silver-ion embedded spacer devices, which may offer a passive, practical approach to reducing bacterial colonization and minimizing infection risks. Implementing such strategies could significantly improve asthma outcomes in children by addressing this often-overlooked contributor to exacerbations

REFERENCES

1. Hashmi MF, Cataletto ME. Asthma. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025.
2. Wang Z, Li Y, Gao Y, *et al*. Global burden of asthma from 1990 to 2019. Respir Res. 2023; 24:169. doi: 10.1186/s12931-023-02475-6.
3. Woo SD, Ye YM, Lee Y, *et al*. Metered-dose vs dry powder inhaler in older asthmatics: a 12-week trial. Allergy Asthma Immunol Res. 2020; 12(3):454-466. doi: 10.4168/aair.2020.12.3.454.
4. Shepherd MW, Hogan MB. Spacer microbial contamination and asthma outcomes: case series. J Asthma. 2021; 59(4):755-756. doi: 10.1080/02770903.2020.1870128.
5. Borovina LR, Tremellen KE, *et al*. Contamination of MDIs in community settings. Int J Pharm Pract. 2012; 20(2):129-133.
6. Cohen HA, Kahan E, Cohen Z, *et al*. Microbial colonization of nebulizers used by children. Pediatr Int. 2006; 48(5):454-458. doi: 10.1111/j.1442-200X.2006.02252.
7. Cohen Z, Czitron B, Wacks Y, *et al*. Bacterial contamination of spacer devices in asthmatic children. J Asthma. 2005; 42(3):169-172.
8. Ranjan N, Singla N, Ghosh S, *et al*. Bacterial colonization of home nebulizers. Indian Pediatr. 2022; 59(5):377-379.
9. Kameswaran M, Choudhury R, *et al*. Pediatric asthma and spacer contamination: a neglected risk. East J Med Sci. 2023; 7(1):40-44.

Funding: Nil; Conflicts of Interest: None Stated.

How to cite this article: Malapati SG, Malapati SN, Pushpalatha K, Nduma B, Ekhator C, Ravi GS. Asthma and Medication Administration Practices in Children: An Exploratory Study on Bacterial Colonization of Inhaler Spacer Devices. Eastern J Med Sci. 2025: Epub ahead of print.