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Postoperative pulmonary complications and associated risk factors in children with asthma undergoing surgery

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Abstract

Background Evidence regarding postoperative pulmonary complications (PPCs) in children with asthma is limited compared with adults. This study aimed to determine the frequency of PPCs and to identify preoperative risk factors in children with asthma undergoing surgery.

Methods This retrospective, cross-sectional observational study included children aged 5–18 years with asthma who underwent surgical procedures between January 2022 and January 2025 and were evaluated preoperatively at a tertiary pediatric allergy clinic. Demographic characteristics, clinical and laboratory findings, surgical and anesthetic features, and postoperative follow-up data were collected. Risk factors for PPCs were identified using univariable and multivariable logistic regression analyses.

Results A total of 84 children with asthma were included (male: 82.1%; median age: 8.5 [range: 5–17] years). PPCs occurred in 15 patients (17.9%). PPCs were more common in children undergoing open surgery and in those with uncontrolled asthma, who also had longer post-anesthesia care unit stays. A history of atopic dermatitis and a higher annual number of asthma exacerbations were also associated with PPC development. Multivariable analysis identified uncontrolled asthma, atopic dermatitis, frequent exacerbations, and open surgery as independent risk factors for PPCs (all $p < 0.05$).

Conclusions PPCs occur at a considerable frequency in children with asthma undergoing surgery. Preoperative asthma control, long-term disease activity, atopic background, and surgical approach appear to play a key role in postoperative respiratory risk. Careful preoperative assessment incorporating these factors may help reduce postoperative morbidity in pediatric patients with asthma.

Keywords Asthma, Asthma control test (ACT), Pediatrics, Postoperative pulmonary complications, Risk factors, Surgery

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Background

Asthma is a major public health problem worldwide, affecting approximately 300 million individuals and accounting for nearly 1,000 deaths per day [1]. Its prevalence ranges from 1% to 29% across countries, with an increasing burden particularly in developing regions and in the pediatric population [1–3].

Children with asthma may require surgical interventions for various indications.

In these patients, postoperative pulmonary complications (PPCs), including cough, laryngospasm, bronchospasm, aspiration, hypoxemia, prolonged need for mechanical ventilation, pneumonia, atelectasis, and pneumothorax, may occur as a result of surgery, anesthesia, and airway instrumentation [1, 4–7].

Major international and national asthma guidelines provide limited standardized recommendations for the perioperative management of children with asthma [1, 8–11]. Most evidence supporting perioperative recommendations in these guidelines is derived from adult studies published between 2006 and 2009 [1, 4, 12, 13]. Therefore, perioperative risk in clinical practice is often managed using individualized approaches that consider patient-related factors (e.g., asthma control and recent infection or exacerbation), anesthetic characteristics, and surgical factors.

According to the Global Initiative for Asthma (GINA) 2025 report [1], no clear increase in perioperative risk is observed in the general asthma population; however, risk may be higher in the presence of chronic obstructive pulmonary disease (COPD) or reduced FEV_1 values. Potentially life-threatening PPCs, including bronchospasm and laryngospasm, have been reported at variable frequencies in patients with asthma [4, 7, 14], particularly in those with advanced age, COPD, or uncontrolled disease [1, 4, 5, 7, 14]. Accordingly, careful preoperative evaluation, appropriate intraoperative management, and close postoperative monitoring are essential to reduce perioperative morbidity and mortality.

Most studies evaluating the perioperative course in asthma have focused on adult populations [4, 6, 14, 15]. Although an increased risk of PPCs has been theoretically suggested in pediatric asthma [7], data on surgical procedures in this population remain limited, with most studies focusing on specific surgical interventions or children with uncontrolled asthma [5, 7, 16–18]. Therefore, this study aimed to examine preoperative assessment characteristics of children with asthma undergoing surgery, determine the frequency of PPCs, and identify associated risk factors, while also providing a broader and more up-to-date perspective across different surgical procedures and anesthetic practices.

Methods

Study design and population

This retrospective, cross-sectional, observational study was conducted at the Department of Pediatric Allergy and Immunology, Dokuz Eylul University Faculty of Medicine Hospital. Children aged 5–18 years with asthma who underwent surgical procedures between January 2022 and January 2025 and were evaluated preoperatively in our clinic were included.

Inclusion criteria were age 5–18 years, an asthma diagnosis according to GINA guidelines [1], preoperative consultation at the Pediatric Allergy and Immunology Clinic, and at least one week of postoperative follow-up.

Exclusion criteria included severe immunodeficiency, active lower respiratory tract infection in the preoperative period, severe cardiac disease or chronic lung disease other than asthma, congenital airway anomalies, malignancy, developmental delay, or incomplete medical records.

Data collection and definitions

Patients' demographic characteristics (age, sex, birth weight, gestational age, parental history of asthma, prior surgical procedures, and/or intensive care unit [ICU] admission) and asthma-related clinical data, including preoperative asthma severity and treatment step, pre- and postoperative Asthma Control Test (ACT) scores, inhaled corticosteroid (ICS) use within two weeks before surgery, annual asthma exacerbation frequency, and the interval between the most recent exacerbation and surgery, were recorded.

Data on comorbidities (allergic rhinitis [AR], atopic dermatitis [AD], food and drug allergy, and passive or active smoking exposure), laboratory parameters (absolute eosinophil count [AEC], serum total and specific IgE levels), surgical characteristics (type and duration of surgery), and postoperative outcomes (post-anesthesia care unit [PACU] length of stay, PPCs, emergency department visits, and ICU admission) were obtained from the hospital information system (Probel) and medical records. A PACU stay ≥ 6 h was used as a cutoff to capture both early and delayed postoperative respiratory complications (e.g., bronchospasm, atelectasis, hypoventilation, and secretion retention), as well as potential anesthesia- or drug-related effects (including hypersensitivity reactions).

The diagnosis of AR was made according to the Allergic Rhinitis and Its Impact on Asthma (ARIA) guidelines, and the diagnosis of AD was established based on the revised Hanifin and Rajka criteria [19, 20].

Asthma severity and control

Asthma diagnosis, severity, and treatment steps were defined according to GINA guidelines [1]. Asthma control was assessed using validated scales for the

Turkish population: the Childhood Asthma Control Test (C-ACT) for children aged 5–11 years [21, 22] and the ACT for those aged ≥ 12 years [23, 24]. Uncontrolled asthma was defined as an ACT or C-ACT score ≤ 19.

Laboratory assessments and allergen sensitization

Eosinophilia was defined as an AEC ≥ 450 cells/μL [25]. As total IgE levels vary with age, pediatric age–specific reference ranges were used [26].

Allergen sensitization was assessed using skin prick tests (SPT) with standard commercial extracts (LoFarma®, Milan, Italy), including pollens, house dust mites, animal epithelia and insects, and molds.

Antihistamines and systemic corticosteroids were discontinued at least 15 days before testing. Skin reactions were evaluated after 20 min, and a wheal diameter ≥ 3 mm compared with the negative control and positive histamine control was considered positive [27]. Allergen sensitization was defined as a specific IgE level ≥ 0.35 kU/L and/or a positive SPT to at least one allergen.

Outcomes and Postoperative Pulmonary Complications (PPC)

PPCs were defined as bronchospasm, pneumonia, atelectasis, respiratory failure requiring oxygen therapy, asthma exacerbation, prolonged intubation, or need for mechanical ventilation occurring within seven days after surgery [6].

Surgery-related variables, including type of surgery (open or laparoscopic), type of anesthesia (general or local), operation duration, and PACU length of stay (< 6 or ≥ 6 h), were recorded.

Statistical analysis

Data were analyzed using IBM SPSS Statistics version 29.0.2.0 (IBM Corp., Chicago, IL, USA). Continuous variables were expressed as mean ± standard deviation or median (minimum–maximum), and categorical variables as number and percentage. Data distribution was assessed using the Kolmogorov–Smirnov test.

Group comparisons were performed using the independent samples t-test or Mann–Whitney U test, as appropriate, while categorical variables were compared using the chi-square or Fisher's exact test.

Variables with $p < 0.10$ in univariable analyses and those considered clinically relevant were included in multivariable logistic regression models to identify independent risk factors for PPCs. Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs), and $p < 0.05$ was considered statistically significant. To reduce the risk of model overfitting given the limited number of events, the number of variables included in multivariable models was restricted, with an events-per-variable (EPV) ratio of approximately 5.

Ethical approval

The study was approved by the Ethics Committee of Dokuz Eylul University Faculty of Medicine (decision no. 2025/15 – 12) and conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines.

Results

A total of 84 children with asthma were included in the study. The median age was 8.5 years (range: 5–17), and 82.1% were male ($n = 69$). AR was present in 60.2% of patients. Passive smoking exposure was observed in more than half of the patients and was significantly more common among boys than girls ($p = 0.031$).

Peripheral eosinophilia was present in 32.1% of patients, and allergen sensitization in 58.1% of those tested (43/74), most commonly to pollen.

Preoperatively, 92.9% of patients had partially or fully controlled asthma, with no change postoperatively ($p = 1.000$). Most patients received step 1–2 therapy (72.6%). Treatment was escalated preoperatively in patients with uncontrolled asthma (7.1%).

Open surgery was performed in 57.1% of patients, and 80.7% received general anesthesia. The most common procedures were adenotonsillectomy (19.0%), orthopedic surgery (17.9%), and circumcision (11.9%). Figure 1 illustrates the distribution of surgical procedures in the study population. Demographic, clinical, and laboratory characteristics are summarized in Table 1.

The incidence of PPCs was 17.9% ($n = 15$). The most common complication was asthma exacerbation (46.7%, $n = 7$), followed by respiratory failure requiring oxygen therapy (20.0%, $n = 3$), prolonged intubation or need for mechanical ventilation (20.0%, $n = 3$), bronchospasm (13.3%, $n = 2$), and influenza-related pneumonia (6.7%, $n = 1$); multiple PPCs occurred in some patients. For improved clinical interpretability, PPC events were categorized as mild-to-moderate or severe. Of the 15 cases, 10 (66.7%) were mild-to-moderate (e.g., asthma exacerbation or bronchospasm), while 5 (33.3%) were severe (e.g., respiratory failure or prolonged intubation).

Among patients with PPCs, the most common treatment was a combination of ICS, short-acting beta-agonists (SABA), and systemic corticosteroids (SCS) (46.7%, $n = 7$). This was followed by ICS + SABA (20.0%, $n = 3$), ICS + SABA + SCS + magnesium (13.3%, $n = 2$), SCS alone (13.3%, $n = 2$), and ICS + SABA + SCS + ipratropium bromide (6.7%, $n = 1$). Five patients (6.0%) had a PACU stay longer than 6 h.

Compared with laparoscopic procedures, open surgery was associated with more frequent general anesthesia, longer operative duration, and a higher incidence of PPCs ($p < 0.001$, $p < 0.001$, and $p = 0.019$, respectively). Open surgery was also more common in patients with

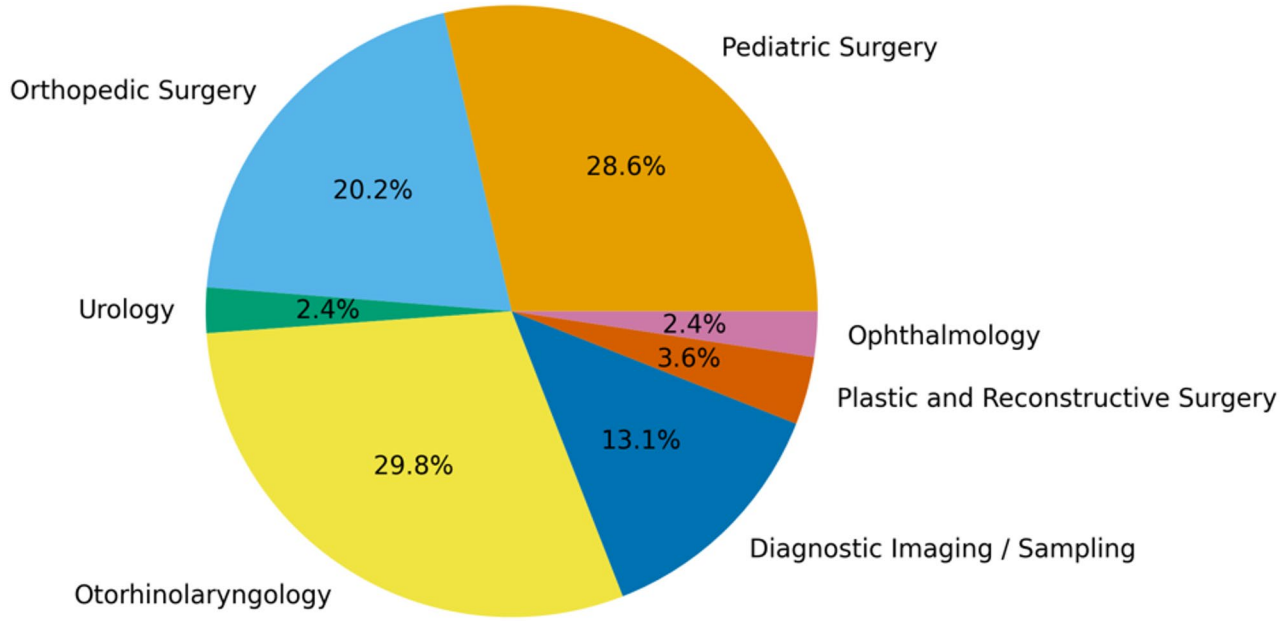


Fig. 1 Distribution of surgical procedures among the study population

uncontrolled preoperative asthma ($p = 0.035$) (Tables 2 and 3). Among children aged 5–11 years, open surgery was associated with lower pre- and postoperative ACT scores ($p = 0.016$ and $p = 0.015$, respectively).

Allergen sensitization was more common in the 12–18-year age group than in the 5–11-year group ($p < 0.001$). Sensitized patients more often had prior anesthesia exposure, a higher prevalence of AR, required higher-step asthma therapy, and showed higher annual exacerbation rates, as well as higher AEC values and serum total IgE levels ($p = 0.050$, $p = 0.004$, $p = 0.003$, $p = 0.045$, $p = 0.018$, and $p = 0.018$, respectively).

Polysensitized patients had higher preoperative asthma treatment steps and more frequent annual exacerbations than monosensitized patients ($p = 0.013$ and $p = 0.035$, respectively). Polysensitized patients aged 12–18 years also had lower preoperative ACT scores ($p = 0.026$). No significant association was observed between allergen sensitization or polysensitization and PPC development. By contrast, PPC incidence was higher in patients with a history of AD than in those without ($p = 0.028$) (Table 3).

In children with moderate-to-severe asthma, preoperative escalation of the treatment step was more common ($p = 0.045$). Compared with those with mild asthma, these patients were older ($p = 0.025$), had a shorter interval between the last exacerbation and surgery (median: 2 vs. 4 months; $p = 0.005$), and a higher annual exacerbation rate ($p < 0.001$). Regular ICS use within two weeks before surgery was also more frequent ($p < 0.001$). In addition, rates of AR, allergen sensitization, and polysensitization were higher in this group ($p = 0.022$, $p = 0.003$, and $p = 0.013$). By contrast, asthma severity was not associated with PPC development or PACU length of stay ($p = 1.000$ for both) (Tables 2 and 3).

Patients with uncontrolled asthma had higher rates of PPCs and PACU stays ≥ 6 h than those with controlled asthma ($p < 0.001$ and $p = 0.002$, respectively) (Tables 2 and 3). In subgroup analyses stratified by age, surgery type, preoperative asthma control, and recent ICS use, as well as in the overall cohort, no significant differences were observed between pre- and postoperative asthma control levels ($p > 0.05$).

No significant associations were observed between regular ICS use within the last two weeks before surgery and PPC development, PACU length of stay, or postoperative asthma control ($p > 0.05$).

Patients who developed PPCs had a higher annual asthma exacerbation rate than those without PPCs ($p = 0.028$). A comparison of patients with and without PPCs is presented in Table 3.

In multivariable logistic regression analysis, a history of AD (OR 5.92; 95% CI 1.45–24.39; $p = 0.013$), open surgery (OR 11.11; 95% CI 1.86–66.67; $p = 0.008$), and a higher annual number of asthma exacerbations before surgery (OR 1.95; 95% CI 1.10–3.45; $p = 0.022$) were independent risk factors for PPCs.

In a separate model including preoperative asthma control instead of annual exacerbation frequency, uncontrolled asthma was independently associated with PPCs (OR 18.18; 95% CI 1.68–200.00; $p = 0.017$), while associations with AD (OR 4.85; 95% CI 1.18–20.00; $p = 0.029$) and open surgery (OR 5.35; 95% CI 1.10–29.41; $p = 0.043$) remained significant (Table 4).

Table 1 Demographic, clinical, and laboratory characteristics of the study population

Variable	Total (*n* = 84)
Age, years, median (min–max)	8.5 (5–17)
Age group, *n* (%)	
• 5–11 years	58 (69.0)
• 12–18 years	26 (31.0)
Male sex, *n* (%)	69 (82.1)
Allergic rhinitis, *n* (%)	50/83 (60.2)
History of atopic dermatitis, *n* (%)	23/80 (28.7)
Passive smoking exposure, *n* (%)	52/82 (63.4)
Previous ICU admission, *n* (%)	16 (19.0)
Previous anesthesia exposure, *n* (%)	28 (33.3)
AEC ($\times 10^3/\mu L$), median (min-max)	300 (0-1200)
Total IgE (IU/mL), median (min–max)	160 (1-2000)
Allergen sensitization (Among tested patients, *n* = 74), *n* (%)	43 (58.1)
• Pollen sensitization	26 (35.1)
• House dust mite sensitization	23 (31.1)
• Mold sensitization	15 (20.3)
• Animal dander sensitization	18 (24.3)
• Food sensitization	1 (1.4)
Polysensitization (among sensitized patients), *n* (%)	26 (60.5)
Asthma control status (preoperative), *n* (%)	
• Controlled / partially controlled	78 (92.9)
• Uncontrolled	6 (7.1)
Asthma treatment step (preoperative), *n* (%)	
• Step 1–2	61 (72.6)
• Step 3–5	23 (27.4)
Regular ICS use within 2 weeks preoperatively, *n* (%)	40 (47.6)
Type of surgery, *n* (%)	
• Open surgery	48 (57.1)
• Laparoscopic surgery	36 (42.9)
Type of anesthesia, *n* (%)	
• General anesthesia	67/83 (80.7)
• Local anesthesia	16/83 (19.3)

Data are presented as *n* (%) or median (min–max). *AEC* absolute eosinophil count, *ICU* intensive care unit, *ICS* inhaled corticosteroid, *IgE* immunoglobulin E

Discussion

In this study, the frequency of PPC and associated risk factors were comprehensively evaluated in children with asthma undergoing surgery. Our findings indicate that perioperative risk for PPC development in pediatric asthma cannot be explained solely by the presence of asthma or treatment step, but should be interpreted in the context of atopic background, surgical factors, and long-term clinical characteristics.

Current guidelines do not indicate a clear overall increase in perioperative risk in the general asthma population; however, risk may be higher in the presence of comorbidities such as COPD or reduced FEV_1 values [1]. While several studies have reported increased perioperative complications in adults with asthma [4, 6, 14, 28], pediatric data remain limited [5, 16]. Existing pediatric studies suggest a possible association between asthma and postoperative complications or prolonged hospital stay, although findings vary by surgical type and patient characteristics [16, 29]. Accordingly, this study aimed to contribute to the literature by evaluating PPCs in children with asthma undergoing diverse surgical procedures.

Risk factors for PPCs can be classified as patient- and procedure-related, including anesthetic technique and surgical duration [12]. Asthma is a heterogeneous disease with variable airway inflammation, hyperreactivity, and airflow obstruction, which may explain why perioperative respiratory risk cannot be reliably predicted by a single parameter in all children with asthma [7, 28]. Consistent with this, uncontrolled preoperative asthma, a higher annual exacerbation frequency, open surgery, and a history of AD were the variables most strongly associated with PPCs in our study.

Poor asthma control is a well-established risk factor for intraoperative bronchospasm and PPCs [7, 30, 31]. Consistent with our findings, previous studies have emphasized the importance of preoperative asthma control as a key determinant of perioperative respiratory risk. Accordingly, careful assessment and optimization of asthma control are recommended, particularly in elective surgery patients with severe disease, recent exacerbations, or persistent airflow limitation [4, 7, 32]. In emergency settings, the risk of inadequate asthma control should be balanced against surgical urgency [31].

The approximately fivefold increased risk associated with AD suggests that a systemic atopic inflammatory background, reflecting both airway involvement and skin barrier dysfunction, may contribute to perioperative respiratory risk. AD is a major criterion of the Asthma Predictive Index and an early marker of chronic airway reactivity, and previous studies reporting an association between AD and PPCs support our findings [32, 33].

Although the presence of rhinitis has been reported to increase PPC risk and eosinophilia has been suggested to reduce PPC risk in relation to steroid responsiveness [5, 6], no significant associations were observed in our study between PPCs and allergen sensitization, eosinophilia, or AR, despite its higher prevalence in our cohort. This discrepancy may be attributable to pediatric-specific clinical characteristics and phenotypic heterogeneity. In younger children, AD tends to be more prominent, whereas AR becomes more prevalent in later childhood and adolescence. The stronger association of AD in our cohort may therefore reflect the atopic march, in which early skin barrier dysfunction represents a key feature of systemic

Table 2 Comparison of patient groups according to surgical type, asthma severity, and preoperative asthma control

Variable	According to surgical type			According to asthma severity			According to preoperative asthma control		
	Open surgery (*n* = 48)	Laparoscopic surgery (*n* = 36)	*p* value	Mild asthma (*n* = 61)	Moderate-severe asthma (*n* = 23)	*p* value	Uncontrolled (*n* = 6)	Controlled / partially controlled (*n* = 78)	*p* value
Age (years), median (min–max)	7.5 (5–17)	9 (5–17)	0.312	7 (5–17)	10 (5–17)	**0.025**	8 (5–17)	8.5 (5–17)	0.993
Sex, *n* (%)									
Female	6 (12.5)	9 (25.0)	0.160	10 (16.4)	5 (21.7)	0.542	0 (0)	15 (19.2)	0.585
Male	42 (87.5)	27 (75.0)		51 (83.6)	18 (78.3)		6 (100)	63 (80.8)	
Allergic rhinitis, *n* (%)	27 (56.3)	23 (65.7)	0.496	32 (52.5)	18 (81.8)	**0.022**	5 (83.3)	45 (58.4)	0.395
Atopic dermatitis, *n* (%)	12 (26.1)	11 (32.4)	0.620	18 (31.6)	5 (21.7)	0.428	3 (50.0)	20 (27.0)	0.347
Preoperative Asthma Control, *n* (%)									
Uncontrolled	6 (12.5)	0 (0)	**0.035**	5 (8.2)	1 (4.3)	1.000	—	—	—
Controlled / Partiallycontrolled	42 (87.5)	36 (100)		56 (91.8)	22 (95.7)		—	—	—
Treatment Step, *n* (%)									
Step 1–2	37 (77.1)	24 (66.7)	0.329	—	—	—	5 (83.3)	56 (71.8)	1.000
Step 3–5	11 (22.9)	12 (33.3)		—	—	—	1 (16.7)	22 (28.2)	
ICS use (2 wks), *n* (%)	21 (43.8)	19 (52.8)	0.509	17 (27.9)	23 (100)	**< 0.001**	2 (33.3)	38 (48.7)	0.678
Anesthesia, *n* (%)									
General anesthesia	45 (93.8)	22 (62.9)	**< 0.001**	48 (80.0)	19 (82.6)	1.000	5 (83.3)	62 (80.5)	1.000
Local anesthesia	3 (6.2)	13 (37.1)		12 (20.0)	4 (17.4)		1 (16.7)	15 (19.5)	
Duration of surgery, minutes, median (min–max)	85 (20–165)	45 (20–300)	**< 0.001**	85 (20–425)	74 (20–270)	0.273	72.5 (20–210)	85 (20–425)	0.761
PACU stay ≥ 6 h, *n* (%)	4 (8.3)	1 (2.8)	0.386	4 (6.6)	1 (4.3)	1.000	3 (50.0)	2 (2.6)	**0.002**
Eosinophilia, *n* (%)	14 (29.2)	13 (36.1)	0.637	17 (27.9)	10 (43.5)	0.197	2 (33.3)	25 (32.1)	1.000
Total IgE (IU/mL), median (min–max)	200 (1-2000)	146 (1-1700)	0.721	151 (1-2000)	201 (32-1700)	0.121	204 (24-2000)	160 (1-1700)	0.681

Data are presented as *n* (%) or median (min–max). *ICS* inhaled corticosteroid, *PACU* post-anesthesia care unit. *p* values < 0.05 were considered statistically significant
Bold values indicate statistical significance ($p < 0.05$)

atopic predisposition. Additionally, differences in sample size, population characteristics, and disease severity may have contributed to the inconsistency with previous reports.

Extensive airway manipulation during open surgery has been reported to increase bronchospasm risk through vagal stimulation and airway irritation [34]. Although adult studies suggest that laparoscopic surgery does not always reduce respiratory risk [6], our findings indicate a safer respiratory profile for laparoscopic procedures in children with asthma. The association between open surgery and PPCs may be explained by greater surgical trauma, longer operative duration, and more frequent endotracheal intubation.

Previous studies have shown that frequent exacerbations, increased bronchodilator use, and asthma-related emergency visits are key indicators of perioperative bronchospasm risk [5, 34]. Consistent with this, patients with frequent exacerbations in our study developed PPCs more often, even when asymptomatic preoperatively. Beyond point-in-time asthma control assessments, these findings suggest that annual exacerbation frequency reflects dynamic disease activity and may be a valuable marker of postoperative respiratory risk.

Previous studies report a higher incidence of postoperative airway complications in children younger than 6 years [32]; however, no significant association between age and PPC development was observed in our study.

General anesthesia may precipitate bronchospasm and asthma exacerbations through diaphragmatic dysfunction, vagal stimulation from airway instrumentation, reduced mucociliary clearance, and cough suppression [4, 5, 7, 28]. In our study, all PPCs occurred in patients receiving general anesthesia, which limited meaningful statistical comparison and precluded reliable assessment of its independent effect. In addition, the strong association between surgical type and anesthesia modality, together with the limited number of events, made it difficult to disentangle their individual contributions. Although open surgery was identified as an independent predictor of PPCs, this finding should be interpreted with caution, as it may partly reflect anesthesia-related factors, particularly given the strong association between surgical type and anesthesia modality and the fact that all PPC cases occurred under general anesthesia. Nevertheless, open surgery may still contribute to PPC risk through mechanisms such as greater surgical trauma, longer operative duration, and increased airway manipulation.

Table 3 Comparison of patients with and without postoperative pulmonary complications (PPCs)

Variable	PPC (–) (*n* = 69)	PPC (+) (*n* = 15)	*p* value
Age, years, median (min–max)	8 (5–17)	9 (5–17)	0.869
Age group, *n* (%)			
– 5–11 years	48 (69.6)	10 (66.7)	1.000
– 12–18 years	21 (30.4)	5 (33.3)	
Sex, *n* (%)			
- Female	14 (20.3)	1 (6.7)	0.287
- Male	55 (79.7)	14 (93.3)	
Allergic rhinitis, *n* (%)	39 (57.4)	11 (73.3)	0.383
History of atopic dermatitis, *n* (%)	15/65 (23.1)	8 (53.3)	**0.028**
Passive smoking exposure, *n* (%)	40 (59.7)	12 (80.0)	0.235
Previous ICU admission, *n* (%)	15 (21.7)	1 (6.7)	0.282
Previous anesthesia exposure, *n* (%)	21(30.4)	7 (46.7)	0.242
Allergen sensitization, *n* (%)	35 (57.4)	8 (53.3)	1.000
Polysensitization, *n* (%)	21 (60.0)	5 (62.5)	1.000
Eosinophilia, *n* (%)	22 (31.9)	5 (33.3)	1.000
AEC ($\times 10^3$/μL), median (min–max)	200 (0–1200)	300 (100–900)	0.524
Total IgE (IU/mL), median (min–max)	151 (1–1700)	215 (25–2000)	0.520
Asthma treatment step 3–5, *n* (%)	19 (27.5)	4 (26.7)	1.000
Increase in asthma treatment step, *n* (%)	4 (5.8)	2 (13.3)	0.290
Uncontrolled asthma (preoperative), *n* (%)	1 (1.4)	5 (33.3)	**< 0.001**
Preoperative annual asthma exacerbations, median (min–max)	2 (1–6)	3 (1–6)	**0.028**
Time from last asthma exacerbation to surgery, months, median (min–max)	3.0 (0.25–24.0)	2.0 (0.5–12.0)	0.058
General anesthesia, *n* (%)	52 (76.5)	15 (100.0)	0.064
Open surgery, *n* (%)	35 (50.7)	13 (86.7)	**0.019**
Duration of surgery, minutes, median (min–max)	80 (20–425)	99 (20–425)	0.277
Regular ICS use within 2 weeks preoperatively, *n* (%)	35 (50.7)	5 (33.3)	0.264
PACU stay ≥ 6 h, *n* (%)	0 (0)	5 (33.3)	**< 0.001**

Data are presented as *n* (%) or median (min–max). *AEC* absolute eosinophil count, *ICU* intensive care unit, *ICS* inhaled corticosteroid, *IgE* immunoglobulin E, *PACU* post-anesthesia care unit

Bold values indicate statistical significance ($p < 0.05$).

Table 4 Risk factors for PPCs in children with asthma

Variable	Model 1[a] OR (95% CI)	*p* value	Model 2[b] OR (95% CI)	*p* value
Open surgery	11.11 (1.86–66.67)	**0.008**	5.35 (1.10–29.41)	**0.043**
Atopic dermatitis	5.92 (1.45–24.39)	**0.013**	4.85 (1.18–20.00)	**0.029**
Annual asthma exacerbations	1.95 (1.10–3.45)	**0.022**	—	—
Uncontrolled asthma	—	—	18.18 (1.68–200.00)	**0.017**

These data were analyzed by multivariable logistic regression analysis

[a]Model 1: annual asthma exacerbation–based model

[b]Model 2: preoperative asthma control–based model

Bold values indicate statistical significance ($p < 0.05$)

Furthermore, detailed evaluation of anesthesia-related variables (e.g., specific anesthetic agents and airway management techniques) was not feasible due to limitations inherent to the retrospective data structure. Therefore, prospective studies with detailed perioperative anesthesia data are needed to better clarify these relationships.

In our study, no significant association was observed between ICS use within the two weeks before surgery and PPC development. However, this finding should be interpreted with caution, as ICS use was assessed only as a binary variable. Suboptimal adherence or insufficient dosing may have masked the potential protective effects of ICS therapy. Therefore, the potential effect of ICS therapy on perioperative respiratory outcomes cannot be fully excluded, and the absence of a significant association in our study should not be interpreted as evidence of a lack of benefit of ICS therapy in the perioperative setting. Evidence on this issue remains conflicting. While the GINA guideline recommends uninterrupted continuation of prescribed ICS therapy during the perioperative period [1], the benefit of short-term preoperative ICS use in reducing complications is unclear [5]. Our findings suggest that postoperative respiratory risk may be more closely related to asthma control, symptom burden, and surgery-related factors than to medication use alone. Further prospective studies with standardized assessment of treatment adherence and dosing are needed to clarify the impact of preoperative ICS optimization on respiratory outcomes.

Evaluation of all patients in a pediatric allergy clinic enabled identification of uncontrolled asthma in the preoperative period and optimization of stepwise treatment when indicated; however, PPCs still occurred in 17.9% of patients. Current literature recommends preoperative assessment by physicians experienced in respiratory diseases, ideally at least one week before elective surgery [5, 28]. Nevertheless, evidence-based guidance on optimal timing of preoperative evaluation, required duration of asthma control, and management in emergency settings remains limited. Given the importance of a multidisciplinary approach, clearer recommendations for anesthesiologists and pediatric allergists are needed, and prospective studies addressing risk factors, preventive strategies, and perioperative management are warranted.

Strengths and limitations

This study has several strengths. First, it addresses a clinically important and timely topic—postoperative pulmonary complications in children with asthma—for which

pediatric data remain limited. Second, the study was conducted with a clear research objective in a well-defined patient population, allowing a comprehensive evaluation of demographic, clinical, and perioperative factors. All patients were assessed in a pediatric allergy clinic using standardized clinical evaluations, enabling detailed characterization of asthma control, atopic comorbidities, and perioperative risk factors. In addition, the inclusion of children undergoing a wide range of surgical procedures contributes to the clinical generalizability of our findings. Finally, the use of multivariable logistic regression analysis allowed the identification of independent risk factors while accounting for potential confounders. Our findings provide meaningful contributions to the limited pediatric literature in this field.

The main limitation of this study is its retrospective, single-center design and relatively small sample size. Although all patients were evaluated preoperatively in a tertiary pediatric allergy clinic, our cohort does not exclusively represent a highly selected group of complex cases. Due to the regional role of our center, a substantial proportion of patients are referred from secondary care settings or are routinely consulted by surgical departments for preoperative assessment. As a result, the study population encompasses a heterogeneous spectrum of disease severity and clinical risk profiles, including children with mild to moderate asthma. Nevertheless, referral bias cannot be entirely excluded, as patients requiring specialist evaluation may still differ from the broader pediatric surgical population in terms of perceived perioperative risk and comorbidity burden. Therefore, our findings should be interpreted within the context of this mixed referral structure, and their generalizability to all children undergoing surgery should be considered with caution.

Another limitation was the inability to comprehensively assess perioperative anesthesia-related variables, such as specific anesthetic agents and airway management techniques, due to the retrospective nature of the data. PPC identification based on retrospective medical records may have resulted in underreporting or misclassification, particularly for mild or transient events.

Due to the limited number of PPC events, stratified analyses according to severity were not statistically feasible, and the heterogeneity of the composite outcome should be considered when interpreting the results. While our study identifies risk factors for a composite outcome of PPCs, it is important to acknowledge that the determinants for mild-to-moderate events may differ from those leading to severe complications—a distinction that warrants further investigation in larger samples. Given the relatively small number of events, the events-per-variable ratio in our multivariable models was limited (approximately 5), and the risk of model overfitting cannot be fully excluded. To address this, we adopted a parsimonious modeling strategy by restricting the number of variables included in each model and constructing two separate models based on clinically distinct but related predictors (annual exacerbation frequency and preoperative asthma control). This approach also avoided potential multicollinearity between these variables. The consistency of key risk factors across both models supports the robustness of our findings; however, given the limited number of events and the single-center design, these results should be interpreted with caution, considered exploratory, and require validation in larger, prospective multicenter cohorts.

Another limitation was that respiratory function tests and blood gas analyses could not be performed in all patients preoperatively, mainly due to surgical urgency, time constraints, and limited cooperation in younger children. We agree that spirometric parameters, particularly FEV_1, are important indicators of asthma severity; therefore, the absence of objective pulmonary function data may have limited comprehensive assessment of disease severity and may have led to underestimation of subclinical airway obstruction. In this study, asthma severity and control were evaluated using age-appropriate validated tools (ACT and C-ACT) in accordance with GINA recommendations [1]. However, these tools primarily reflect symptom-based control and may not fully capture objective lung function. Although spirometry is recommended in elective pediatric assessments, it is often not feasible or prioritized in the preoperative setting. Current evidence suggests that perioperative risk in children with asthma is more closely related to clinical stability, absence of recent exacerbations, and normal physical examination findings rather than specific spirometric thresholds [7]. Moreover, routine preoperative investigations, including spirometry, have not consistently been shown to reduce the incidence of PPCs [12, 32]. Nevertheless, the lack of objective pulmonary function measures remains an important limitation, and future prospective studies incorporating spirometric parameters are warranted to improve risk assessment.

Conclusions

In this study, PPCs occurred at a considerable frequency in children with asthma undergoing surgery, and a history of AD, higher annual asthma exacerbation rates before surgery, uncontrolled preoperative asthma, and open surgical procedures were identified as key determinants of PPC development. Our findings indicate that postoperative respiratory risk cannot be reliably predicted based solely on the diagnosis of asthma or treatment step; instead, parameters reflecting clinical activity and systemic atopic background should be evaluated together with surgical factors. Routine consideration of these

risk factors during preoperative assessment, supported by multidisciplinary and individualized perioperative approaches, may contribute to reducing surgery-related morbidity. Nevertheless, prospective multicenter studies are needed to establish clearer and evidence-based recommendations for the perioperative management of children with asthma.

Abbreviations

ACT	Asthma control test
AD	Atopic dermatitis
AEC	Absolute eosinophil count
AR	Allergic rhinitis
ARIA	Allergic rhinitis and its impact on asthma
C-ACT	Childhood asthma control test
COPD	Chronic obstructive pulmonary disease
GINA	Global Initiative for Asthma
ICS	Inhaled corticosteroid
ICU	Intensive care unit
PACU	Post-anesthesia care unit
PPC	Postoperative pulmonary complication
SABA	Short-acting beta-agonist
SCS	Systemic corticosteroid
SPT	Skin prick test

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Authors' contributions
G.K. and O.A. contributed to the study conception and design. Material preparation and data collection were performed by G.K., D.B.B., and H.Y. Statistical analysis was performed by G.K. and O.A. The first draft of the manuscript was written by G.K. and O.A., S.A. and N.U. commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability
The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee of Dokuz Eylul University Faculty of Medicine (decision no. 2025/15 – 12). All procedures were conducted in accordance with the principles of the Declaration of Helsinki and Good Clinical Practice guidelines.Due to the retrospective design of the study, the requirement for informed consent was waived by the ethics committee.

Competing interests
The authors declare no competing interests.

Consent for publication
Not applicable.

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