

# Predictors for intraoperative heart failure in children undergoing foreign-body removal

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## Abstract

This study aimed to determine the predictors for intraoperative heart failure (HF) in children undergoing foreign-body removal. The clinical data of all children with tracheobronchial foreign-body aspiration admitted to the First, Second, and Fourth Affiliated Hospitals of Harbin Medical University between January 1996 and September 2018 were analyzed. The variables with significant difference in univariate analysis were involved into the multivariate Logistic model to determine the predictors for intraoperative tachycardia. In total, 300 tracheobronchial foreign-body aspiration children were eligible for the study, among whom 60 cases (20%) suffered from HF during the operation. Between the children HF and those without HF, the differences were pronounced in history of allergy, history of asthma, congenital heart disease, preoperative respiratory infection, retention time of foreign bodies, duration of operation, and poor anesthesia effect ( $P < .05$ ). Multivariate analysis results showed that history of allergy (odds ratio [OR]: 1.395, 95% confidence interval [95% CI]: 1.202–1.620,  $P < .001$ ), congenital heart disease [OR: 3.071, 95% CI: 1.141–8.264,  $P < .001$ ], preoperative respiratory infection [OR: 2.345, 95% CI: 1.027–5.355,  $P = .043$ ], retention time of foreign bodies [OR: 1.013, 95% CI: 1.010–1.016,  $P < .001$ ], duration of operation [OR: 1.030, 95% CI: 1.027–1.033,  $P < .001$ ], and poor anesthesia effect [OR: 1.125, 95% CI: 1.117–1.134,  $P < .001$ ] were identified as the influencing factors for intraoperative HF. In conclusions, for children undergoing foreign-body removal, history of allergy, congenital heart disease, preoperative respiratory infection, retention time of foreign bodies, duration of operation, and poor anesthesia effect are associated with an increased risk of intraoperative HF.

**Abbreviations:** CI = confidence interval, FBA = foreign-body aspiration, HF = heart failure, OR = odds ratio, TFBA = tracheobronchial foreign-body aspiration.

**Keywords:** heart failure, multivariate logistic model, risk factor, tracheobronchial foreign-body aspiration

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All children's parents were informed consent, and the study was approved by the Institutional Review Board of The Fourth Affiliated Hospital of Harbin Medical University (approval number: 2020-SCILLSC-03).

The data used to support the findings of this study are included within the article.

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## 1. Introduction

Foreign-body aspiration (FBA) is one of the most common emergencies in the pediatric population, particularly in those aged 1 to 3 years.<sup>[1]</sup> It usually manifests as persistent cough followed by the symptoms such as tachypnea, fever, chest infection, and noisy breathing.<sup>[2]</sup> FBA is the significant cause of morbidity and even mortality, which can cause dyspnea and severe complications including pneumothorax, cardiac arrest, pneumomediastinum, and anoxic brain injury.<sup>[3–5]</sup> According to the statistics, the death caused by asphyxia following FBA is the leading cause of unintentional injury mortality in children aged less than 1 year and the fifth common cause of unintentional injury mortality in the United States.<sup>[6]</sup> The combined rate of death or anoxic brain injury related to pediatric FBA is reported to be approximately 4%, and each year the overall inpatient cost reaches up to \$12.8 million.<sup>[7]</sup>

Early diagnosis and timely removal of foreign bodies are very crucial for decreasing the incidence of complications and mortality.<sup>[8,9]</sup> Currently, the removal by surgery is the best treatment modality for foreign bodies in the respiratory tract, but the results can be affected by various factors, including operating conditions, patient's condition before surgery, surgical approaches, and the medication habits of clinicians.<sup>[10,11]</sup> In addition, the changes of heart rate and oxygen saturation of patients during the operation can also affect the process of operation.<sup>[12]</sup> The heart rate  $\geq 160$  bpm is usually considered the beginning of the heart failure (HF), which is the manifestation of sympathetic nerve activation and cardiac dysfunction. To achieve the goal of early intervention, anesthesiologists often depend on

the heart rate changes and preliminary physical tests to use anti-tachycardia drugs because timely monitoring of the heart function is difficult to perform during the operation.

In this study, we investigated the influencing factors for intraoperative tachycardia in children undergoing foreign-body removal, aiming at providing more evidences for decreasing the risk of intraoperative tachycardia.

## 2. Methods

### 2.1. Study population

In this retrospective study, the clinical data of children with tracheobronchial foreign-body aspiration (TFBA) admitted to the First, Second, and Fourth Affiliated Hospitals of Harbin Medical University between January 1996 and September 2018 were collected. The diagnosis of TFBA was confirmed by the surgery. Children aged 15 years or below who had complete, accurate clinical information were included, and those with wrong or incomplete clinical information were excluded. All children's parents were informed consent, and the study was approved by the Institutional Review Board of The Fourth Affiliated Hospital of Harbin Medical University (approval number: 2020-SCILLSC-03).

### 2.2. Collection of clinical data

The clinical data of all children with TFBA were assessed from medical records, including the age, gender, foreign-body property (plant and animal, and other), foreign-body location (trachea, right mainstem bronchus, and left mainstem bronchus), history of allergy, history of and asthma, congenital heart disease, preoperative respiratory infection, foreign-body retention time, anesthesia effect (good and poor), mechanism ventilation, duration of operation.

Foreign-body property is divided into 3 types, plant, and animal, and other. The main species of foreign bodies were plants, including peanuts, melon seeds (shells), broad beans, peas, and walnut kernels. Animal foreign body mainly refers to broken bones and minced meat. Diagnostic criteria for respiratory infections were as follows: patients with symptoms including fever and cough; elevated inflammatory marker (leukocyte count and C-reactive protein) remaindered by laboratory examinations; and pneumonia or tracheobronchitis evidenced through chest X-ray or chest computed tomography (essential item). Any one of the following conditions is considered as a poor anesthetic effect: the surgical operation was affected by severe cough due to body movement or significant breath-holding (10seconds), which required propofol for deeper anesthesia or additional airway surface anesthesia.

The diagnosis of HF was based on medical history and physical examination.<sup>[13]</sup> Patients with the following symptoms examined by physical examination during surgery could be diagnosed with intraoperative HR: hypotension, dyspnea, elevated heart failure, distention of jugular vein, tachycardia, and decreased SpO<sub>2</sub>.

### 2.3. Statistical analysis

The data were analyzed using SAS software (version 9.4, SAS Institute Inc, NC). Shapiro–Wilk test was used to test the data normality. The normally distributed data were compared using *t* test and described as the mean ± standard deviation ( $\bar{x} \pm s$ ); the

**Table 1**

**Baseline information of study population [n (%)/M (Q<sub>1</sub>, Q<sub>3</sub>)].**

Variables	Description (n = 300)
Age	2.1 (1.6, 2.7)
Gender, male/female	162 (54.00)/138 (46.00)
Foreign-body property	
Plant	112 (37.33)
Animal	103 (34.33)
Other	85 (28.33)
Foreign-body location	
Trachea	112 (37.33)
Right mainstem bronchus	100 (33.33)
Left mainstem bronchus	88 (29.33)
History of allergy	
Yes	148 (49.33)
No	152 (50.67)
History of and asthma	
Yes	144 (48.00)
No	156 (52.00)
Congenital heart disease	
Yes	4 (1.33)
No	296 (98.67)
Preoperative respiratory infection	
Yes	165 (66.67)
No	135 (45.00)
Foreign-body retention time	8.0 (3.0, 15.0)

abnormally distributed data were compared by Mann–Whitney *U* test and manifested as the median and quartile [M (Q<sub>1</sub>, Q<sub>3</sub>)]. Categorical data were compared using  $\chi^2$  test or Mann–Whitney *U* test, with the number of cases and its constituent ratio [n (%)] as the manifestation. The variables that showed statistically significant difference in univariate analysis were involved into the multivariate Logistic model to determine the influencing factors for intraoperative tachycardia in children undergoing foreign-body removal. Significant difference was presented at  $P < .05$ .

## 3. Results

### 3.1. Baseline information of study population

Between January 1996 and September 2018, a total of 300 children with TFBA were included in this study, with the average age of 2.1 (1.6, 2.7) years old, including 162 (54.00%) males and 138 (46.00%) females. Of the 300 patients, there were 112 (37.33%) patients with plant foreign body, 103 (34.33%) patients with animal foreign body, and 85 (28.33%) patients with others. Regarding the past medical history, 148 (49.33%) individuals had history of allergy, 144 (48.00%) patients with history of asthma, and 4 (1.33%) with congenital heart disease. There 165 (66.67%) participants experienced preoperative respiratory infection, and 135 (45.00%) did not. The median of foreign-body retention time was 8.0 (3.0,15.0) hours. The baseline information of study population was indicated in Table 1.

### 3.2. Univariate analysis of intraoperative HF

In terms of the history of allergy ( $\chi^2 = 11.215$ ,  $P < .001$ ), history of asthma ( $\chi^2 = 4.327$ ,  $P = .038$ ), and congenital heart disease ( $P = .026$ ), preoperative respiratory infection ( $\chi^2 = 4.125$ ,  $P$

**Table 2**  
Results of univariate analysis.

Variables	Total	Groups		Statistics	P
		HF (n=60)	Non-HF (n=240)		
Age	2.1 (1.6, 2.7)	2.2 (1.8,3.0)	2.1 (1.5, 2.5)	Z=1.40	.161
Gender, male/female	162 (54.00)/138 (46.00)	32 (53.33)/28 (46.67)	130 (54.17)/110 (45.83)	$\chi^2=0.013$	.908
Foreign-body property				$\chi^2=2.267$	.322
Plant	112 (37.33)	18 (30.00)	94 (39.17)		
Animal	103 (34.33)	21 (35.00)	82 (34.17)		
Other	85 (28.33)	21 (35.00)	64 (26.67)		
Foreign-body location				$\chi^2=0.264$	.876
Trachea	112 (37.33)	23 (38.33)	89 (37.08)		
Right mainstem bronchus	100 (33.33)	21 (35.00)	79 (32.92)		
Left mainstem bronchus	88 (29.33)	16 (26.67)	72 (30.00)		
History of allergy				$\chi^2=11.215$	<.001
Yes	148 (49.33)	42 (70.00)	110 (45.83)		
No	152 (50.67)	18 (30.00)	130 (54.17)		
History of and asthma				$\chi^2=4.327$	.038
Yes	144 (48.00)	36 (60.00)	108 (45.00)		
No	156 (52.00)	24 (40.00)	132 (55.00)		
Congenital heart disease				Fisher	.026
History of allergy	4 (1.33)	3 (5.00)	1 (0.42)		
Yes	296 (98.67)	57 (95.00)	239 (99.58)		
Preoperative respiratory infection				$\chi^2=4.125$	.042
Yes	165 (66.67)	40 (66.67)	125 (52.08)		
No	135 (45.00)	20 (33.33)	115 (47.92)		
Foreign-body retention time, hour	8.0 (3.0,15.0)	10.0 (5.0, 20.0)	7.0 (2.0, 9.0)	Z=6.54	<.001
Anesthesia effect				$\chi^2=27.273$	<.001
Good	165 (55.00)	15 (25.00)	150 (62.50)		
Poor	135 (45.00)	45 (75.00)	90 (37.50)		
Mechanism ventilation				$\chi^2=0.057$	.812
Retaining spontaneous breathing	186 (62.00)	38 (63.33)	148 (61.67)		
Mechanism ventilation	114 (38.00)	22 (36.67)	92 (38.33)		
Duration of operation, minute	22 (16,40)	30 (15, 50)	20 (16,32)	Z=2.96	.015

HF = heart failure.

=.042) differences were pronounced between the children with HF and those without HF. The retention time of foreign bodies ( $Z=6.54, P<.001$ ) and duration of operation ( $Z=2.96, P=.015$ ) in the children with HF was longer significantly compared with those without HF. Additionally, the children with HF had a higher constituent ratio of poor anesthesia effect than those without HF ( $\chi^2=27.273, P<.001$ ) (Table 2).

**3.3. Multivariate analysis of intraoperative HF**

As shown in Table 3, multivariate analysis results showed that the risk of intraoperative HF in children with allergy history was 1.395-fold than those without [odds ratio (OR):

1.395, 95% confidence interval (95% CI): 1.202–1.620,  $P<.001$ ]. The children with congenital heart disease had an increased risk of intraoperative HF than those without (OR: 3.071, 95% CI: 1.141–8.264,  $P<.001$ ). Per unit increase in retention time of foreign bodies (OR: 1.013, 95% CI: 1.010–1.016,  $P<.001$ ) and duration of operation (OR: 1.030, 95% CI: 1.027–1.033,  $P<.001$ ) was associated with decreased risk of intraoperative HF. In addition, preoperative respiratory infection (OR: 2.345, 95% CI: 1.027–5.355,  $P=.043$ ) and poor anesthesia effect (OR: 1.125, 95% CI: 1.117–1.134,  $P<.001$ ) were identified as independent risk factors for intraoperative HF in children undergoing foreign-body removal.

**Table 3**  
Results of multivariate logistic analysis.

Variables	$\beta$	S. E.	Wald	P	OR	95% CI	
						Lower	Upper
History of allergy	0.333	0.076	19.195	<.001	1.395	1.202	1.620
Congenital heart disease	1.122	0.505	4.933	<.001	3.071	1.141	8.264
Preoperative respiratory infection	0.852	0.421	4.096	.043	2.345	1.027	5.355
Foreign-body retention time	0.013	0.001	80.210	<.001	1.013	1.010	1.016
Poor anesthesia effect	0.118	0.004	854.417	<.001	1.125	1.117	1.134
Duration of operation	0.030	0.001	419.454	<.001	1.030	1.027	1.033

CI = confidence interval, OR = odds ratio.

#### 4. Discussion

According to inclusion and exclusion criteria, in total 300 TFBA children were eligible for the study, among whom 60 cases suffered from HF during the operation, while 240 did not. Multivariate Logistic analysis results exhibited that allergy history, congenital heart disease, longer retention time of foreign bodies, longer duration of operation, preoperative respiratory infection, and poor anesthesia effect were the independent risk factors for intraoperative HF. These all suggested that allergy history, congenital heart disease, longer retention time of foreign bodies, longer duration of operation, preoperative respiratory infection, and poor anesthesia effect were associated with an increased risk of intraoperative HF in children undergoing foreign-body removal.

The diagnosis of TFBA in children is often deferred by the following several factors: caregivers may be unwilling to accurately state the incident because they are afraid of being blamed; a clear history cannot be provided due to absence of parents; TFBA is initially misdiagnosed as upper respiratory infection, pneumonia, or bronchitis; the serious condition is neglected due to lack of medical knowledge.<sup>[14]</sup> The former evidences indicated that delayed treatment can make the retention time of foreign bodies in the respiratory tract prolonged, consequently leading to multiple complications such as emphysema and pneumonia,<sup>[15]</sup> which would increase the difficulty and risk of surgery. Our finding exhibited that the longer foreign-body retention time was associated with increased risk of intraoperative HF, highlighting a risk effect of longer foreign-body retention time on the intraoperative HF. Besides, our results that preoperative respiratory infection was a risk factor of intraoperative HF. Patients with respiratory infection are prone to hypoxia and CO<sub>2</sub> retention, which might cause myocardial damage due to myocardial overload, and the toxin produced by pathogen also causes myocardial damage, eventually inducing HF.<sup>[16,17]</sup> Reducing preoperative respiratory infection might be a vital measure to protect patients undergoing foreign-body removal from intraoperative HF. Therefore, once the foreign-body obstruction occurs in children, the cause should be clarified immediately and the operation should be carried out timely to control the preoperative respiratory infection, thereby decrease risk of intraoperative HF. In the future studies about the risk effect of foreign-body retention time on intraoperative HF, the critical value will be investigated in detail. In addition, our findings indicated that patients with congenital heart disease are more likely to suffer intraoperative HF when undergoing foreign-body removal. Congenital heart disease is often accompanied by abnormal hemodynamics, which is a pathological basis of increasing the heart burden to induce HF,<sup>[18]</sup> especially during surgery. Prophylactic useless of anti-HF drugs or other measures might be taken into accounted for patients with congenital heart disease before foreign-body removal.

Due to the obstruction of foreign bodies in the airway and reflexive bronchospasms, children with FBA are often accompanied by different degrees of anoxia and carbon dioxide retention, even respiratory muscle weakness or respiratory failure.<sup>[19]</sup> Vagus nerves are abundant in the laryngopharyngeal region, but the respiratory and circulatory capabilities of children are poor, leading to a poor tolerance to anoxia. Accordingly, children are likely to suffer from laryngospasms, bronchospasms, and apnea even cardiac arrest. The airway of foreign-body removal is in common with the anesthesia ventilation, and the operations of

foreign-body removal require to open the airway, thus the anesthesia has a high risk.<sup>[20]</sup> How to ensure good anesthesia effect plays an important role in foreign-body removal. In this study, poor anesthesia effect was identified as a risk factor for intraoperative HF. Adequate anesthesia could provide a reversible state of unconsciousness, allowing the patients to experience surgical procedures in a stable and safe way.<sup>[21]</sup> It can prevent airway spasms, decrease airway resistance, improve airway maintenance, and reduce the operation difficulty.<sup>[22]</sup> When a poor anesthesia effect occurred, the patients would cough or hold breath, which can lead to an increase of heart rate, resistance to surgery, increased oxygen consumption, and cessation of ventilation or hypoventilation due to throat or tracheal spasms. And meanwhile, the stimulation from surgical procedures can also increase the heart rate and induce HF. In this study, we found the longer duration of operation, the greater the risk of intraoperative HF. Therefore, when performing foreign-body removal, it is necessary not only to ensure appropriate anesthetic depth, but also to control the duration of operation to decrease the risk of intraoperative HF.

The strength of this study was that it was the first study to identify the predictors for intraoperative HF in children undergoing foreign-body removal. However, there are several limitations that cannot be ignored. First, the study populations were obtained from only one hospital in China. Our results needed to be validated through a great deal of additional work based on multicenters. Additionally, specific types of congenital heart disease cannot be collected, which hindered us from further analyses to investigate the associations of different congenital heart diseases and the risk of intraoperative HF in children undergoing foreign body. Future researches could focus on the exploration the relationships between intraoperative HF and different congenital heart diseases.

#### 5. Conclusions

For children undergoing foreign-body removal, allergy history, congenital heart disease, longer retention time of foreign bodies, longer duration of operation, preoperative respiratory infection, and poor anesthesia effect are associated with an increased risk of intraoperative HF. Paying close attention to these factors may contribute to evaluating the disease status and improving the prognosis of children with TFBA.

#### Author contributions

XYY designed the study, wrote, and drafted the manuscript. LZ and GYZ contributed to data collection. HFP and TTL contributed to data analysis. XH contributed to literature research. ML critically reviewed and edited the manuscript. All authors read and approved the final manuscript.

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