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Foreign body aspiration into the respiratory tract in children

Aspiracja ciała obcego do dróg oddechowych u dzieci

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Abstract

Foreign body aspiration is a common occurrence in children, particularly preschoolers, and poses a high risk of airway blockage and death. Aspiration often occurs in the home environment, with only half of cases happening in the presence of a caregiver. Inhaled objects commonly include food fragments and inorganic substances, such as small toy parts. Foreign bodies in the respiratory tract typically lodge in the right bronchi, with symptoms varying depending on the aspirate's location and the time since the choking incident. The classic triad of symptoms is rare but highly sensitive in diagnosing foreign body aspiration. If not diagnosed, inflammatory complications can develop, leading to irreversible pulmonary fibrosis and bronchiectasis. Chest radiography is the most common examination for suspected foreign body aspiration, allowing visualisation of radiopaque foreign bodies and other signs of aspiration. Traditional bronchoscopy remains the gold standard diagnostic and therapeutic method for foreign body aspiration management, although the number of successful bronchial fibroscopy interventions in such cases has been increasing. The fact that foreign body aspiration into the respiratory tract in children is common and entails a significant risk of death makes it necessary to pay special attention to the primary prevention of choking, e.g. by educating parents and caregivers about selecting age-appropriate toys, practising proper feeding techniques, and understanding the principles of first aid for choking.

Keywords: foreign body, choking, bronchoscopy, aspiration, chronic cough

Streszczenie

Aspiracja ciała obcego jest częstym zjawiskiem u dzieci, zwłaszcza w wieku przedszkolnym, i wiąże się z wysokim ryzykiem niedrożności dróg oddechowych i zgonu. Do incydentów często dochodzi w środowisku domowym, a tylko połowa przypadków ma miejsce w obecności opiekuna. Aspirowanymi przedmiotami mogą być fragmenty pokarmów i substancje nieorganiczne, takie jak części zabawek. Ciała obce w drogach oddechowych częściej osadzają się w prawym oskrzelu, a objawy różnią się w zależności od lokalizacji i czasu, który upłynął od aspiracji. Klasyczna triada objawów jest rzadka, ale bardzo czuła w diagnostyce. Jeśli choroba nie zostanie zdiagnozowana, mogą rozwinąć się powikłania zapalne prowadzące do nieodwracalnego zwłóknienia płuc i rozstrzeni oskrzeli. W przypadku podejrzenia aspiracji ciała obcego najczęstszym badaniem jest rentgenogram klatki piersiowej, pozwalający na uwidocznienie nieprzepuszczalnych dla promieni rentgenowskich ciał obcych i objawów aspiracji. Tradycyjna bronchoskopia jest nadal złotym standardem w diagnostyce i leczeniu, chociaż liczba skutecznych zabiegów bronchofibroskopii wzrosła. Aspiracja ciała obcego do dróg oddechowych u dzieci jest częstym zjawiskiem i wiąże się ze znacznym ryzykiem zgonu, dlatego należy zwrócić szczególną uwagę na pierwotną profilaktykę zadławienia, m.in. poprzez edukację rodziców i opiekunów w zakresie doboru zabawek dostosowanych do wieku, prawidłowych technik karmienia oraz zasad udzielania pierwszej pomocy w przypadku zadławienia.

Słowa kluczowe: ciało obce, zadławienie, bronchoskopia, aspiracja, kaszel przewlekły

INTRODUCTION

Foreign body aspiration (FBA) is a potentially life-threatening condition that can obstruct the lumen of the respiratory tract, impairing ventilation and oxygenation. Larger foreign bodies that tightly block the airways are particularly dangerous and require immediate intervention. Most aspiration cases occur in children under three years old, and a classic triad of symptoms, including choking, coughing, and unilateral wheezing or decreased air entry, is observed in only a small group of patients⁽¹⁾.

EPIDEMIOLOGY

FBA is a common death cause in children under five years old, but its exact mortality rate is difficult to determine due to its classification within a broader category of injuries. It is ranked as the fourth leading cause of death in children under five in the USA⁽²⁾. In 2001–2016, nearly 306,000 incidents related to choking and not leading to death were reported in the US paediatric population, 73% of which involved children under five⁽³⁾. FBA to the respiratory tract has a mortality rate of 0–8.3%, according to Tuzla researchers⁽⁴⁾. Most cases occur in children under three years of age due to developmental characteristics in this period of life. The causes of the higher incidence of FBA in the population under 18 are summarised in Tab. 1⁽⁵⁾. The highest male-to-female sex ratio in the population of children with FBA was observed in Asian countries, such as India, China, and Pakistan, while in Sweden and Iran the ratio is approximately 1:1. This is likely due to more risky cognitive behaviours and culturally determined upbringing patterns⁽⁶⁾. Researchers from Israel investigated the impact of the COVID-19 pandemic on FBA frequency in children, but found no statistically significant differences between the lockdown period and the years 2016–2019. The male-to-female ratio and delayed aspiration diagnoses were similar⁽⁷⁾. The study based on a meta-analysis of 38,000 suspected FBA cases found that organic foreign bodies are more common than inorganic ones, with nuts, seeds, and unspecified organic materials being the most frequently aspirated, while magnets, sponges, and unspecified inorganic items being the most commonly aspirated inorganic foreign bodies^(8,9).

- Relatively narrow lumen of the respiratory tract
- Curiosity determined by development phases – high mobility and tendency to get easily distracted
- Oral exploration of the environment – tendency to put objects into the mouth
- Lack of molar teeth – inadequate chewing despite the ability to separate chunks (presence of incisors)
- Incomplete development of food-swallowing control
- Eating while playing, in motion
- Caregiver feeding the child when the child is crying/laughing
- Other aspiration-promoting factors such as neurological disorders, poisoning, and iatrogenic causes

Tab. 1. Causes of foreign body aspiration into the respiratory tract in children

Certain objects, such as latex balloons, spherical/oval/cylindrical objects, glass balls, beads, parts of toys, and items with sizes corresponding to the diameter of the upper airways, pose a particularly high risk of lethal consequences. In 2010, the American Academy of Pediatrics (AAP) Committee on Injury, Violence, and Poison Prevention determined that these foreign bodies posed a high risk of lethal consequences⁽¹⁰⁾. Most reports mention organic foreign bodies, such as nuts and their fragments. Their small size and aspiration-prone shapes, combined with their popularity as snacks in many countries, contribute to their prevalence. Aspiration of small plastic and metal items is a major issue in Brazil⁽⁶⁾. Most objects aspirated into the airways end up in the bronchi. In a study of 1,160 aspiration cases, foreign bodies were identified in various locations in the respiratory tract: right bronchus (59%), left bronchus (23%), trachea (13%), larynx (3%), and bilaterally (2%). In most countries, aspiration to the right main bronchus predominates due to anatomical conditions. However, in the population of children under three, the bronchi are symmetrical, so the lodging of aspired objects on the right and left can be expected with the same likelihood⁽¹¹⁾. Foreign bodies that are larger or have irregular shapes and sharp uneven edges often become stuck in the larynx and trachea. Obstructions in these location entail a higher mortality rate, as the entire bronchial tree is closed off⁽¹²⁾.

CLINICAL PICTURE

FBA should be suspected when a child or their caregivers report a choking episode in the history. However, children under three often cannot provide a reliable history, and caregivers witness choking in only half of the cases. It is important to consider FBA in differential diagnostics of respiratory tract diseases in children. The clinical manifestations of FBA depend on factors such as the level at which the airways obstruction occurred (Fig. 1).

Intensified paroxysmal coughing following aspiration is the most common symptom that can be alleviated or eliminated after some time or when the foreign body settles in the smaller bronchi. Respiratory failure, cyanosis, and

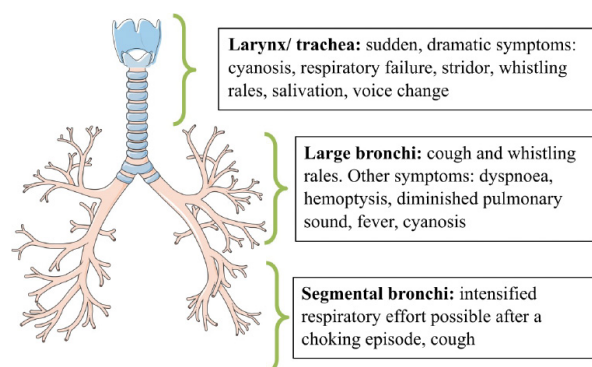


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Fig. 1. Symptoms depending on the foreign body's location

	Time	Clinical picture
Period of respiratory tract acute obstruction	Instantly after foreign body aspiration	Symptoms occur in 90% of cases: • violent expectorant reactions • dyspnoea • wheezing breath • apnoea • cyanosis Typically, the issue resolves within a few hours; auscultatory phenomena may last longer (a dozen or so hours). If a foreign body creates a one-way mechanism, an air trap is formed, leading to ventilation emphysema; then the symptoms recur, and urgent bronchoscopic intervention is required
Period with few symptoms	Several hours after aspiration; when the foreign body settles in the bronchus	Even when a foreign body blocks the main bronchus, it may reveal very few symptoms, only with minor dyspnoea; segmental bronchial blocking may be asymptomatic
Period of bronchial and pulmonary inflammatory complications	Several to a dozen or so days	Development of bacterial infection accompanied by fever and cough – bronchitis or pneumonia in the clinical picture
Period of irreversible bronchial and pulmonary failures	Days – weeks	Bronchi and pulmonary tissue damage in the course of inflammation: • bronchiectasia • chronic lung abscesses • inflammatory cysts • pulmonary fibrosis

Tab. 2. Stages of the disease caused by foreign body aspiration⁽¹⁴⁾

aggravated dyspnoea suggest obstruction of the large airway and require immediate intervention⁽¹³⁾. Typically, partial obstruction of the respiratory tract occurs during aspiration, resulting in coughing, rapid breathing, and focal monotone wheezing. A clinical triad including – wheezing, cough, and diminished pulmonary sound – occurs only in 57% of cases⁽¹²⁾. While the detection of these symptoms in a child has a high positive predictive value (92%), the negative predictive value is low (16%), which suggests that the presence of the classic triad is a strong indicator of aspiration⁽¹³⁾.

Foreign bodies in the larynx and trachea can cause respiratory failure, salivation, voice pitch changes or aphonia, stridor, inhalation and exhalation wheezes, and bilaterally diminished pulmonary sounds. The clinical presentation depends on the time elapsed since the choking episode. Symptoms such as haemoptysis, recurrent atelectasis in the same location, intractable asthma, laryngitis, or pneumonia warrant further diagnostic investigation. An intensified coughing episode lasting from several seconds to several minutes is typically observed immediately after FBA. After the subsidence of the acute phase, some patients may reveal no symptoms, which may delay seeking medical help and diagnosing the condition.

The acute phase symptoms arise from aspiration, respiratory tract mucous membrane irritation and bronchial obstruction, while an immediate removal of the aspirate leads to recovery. The natural progression of aspiration disease, encompassing four stages, is presented in Tab. 2.

The clinical course of FBA-related disease varies depending on the type, location, and degree of bronchial obstruction. Organic foreign bodies heavily contaminated with bacteria, such as cereal ears, are associated with a higher incidence of inflammatory granulation tissue formation, secondary changes of the bronchial structure, and bronchiectasis, with the risk increasing with prolonged deposition time^(15–17).

COMPLICATIONS

Early diagnosis and foreign body removal from the airways reduces the risk of inflammatory reactions and respiratory tract or parenchymal failure. Delayed diagnosis result in complications such as atelectasis, pneumonia, and bronchiectasis. The frequency of complications reported depends on the time between aspiration and diagnosis, with 64% when the diagnosis was 4–7 days late, 70% for delays of 15–30 days, and >95% when diagnosed over 30 days after aspiration⁽¹⁷⁾. Mantor et al. suggested that bronchoscopy should be performed in every suspected FBA case to reduce complications, with an acceptable rate of negative bronchoscopy procedures of 10–15%⁽¹⁸⁾.

Although foreign body obstruction of the airways can lead to respiratory and cardiac arrest, this rarely occurs in practice. Pneumonia is the most commonly reported FBA complication due to impaired secretion removal and bacterial growth. Bronchiectasis and fistula formation are less common^(19–21). Factors associated with a higher risk of lower respiratory tract infection in children with FBA include age, plant-based foreign bodies, irregular foreign body surfaces, and long-term incarceration⁽²²⁾.

ADDITIONAL EXAMINATIONS

A chest X-ray is the most often performed imaging test for children with suspected FBA. The examination is readily available and inexpensive. It is also highly sensitive to radiopaque foreign bodies, which account for approximately 10%^(23,24) of aspirations in children; radiolucent foreign bodies dominate. Radiograms often show pulmonary hyperlucency, atelectasis, mediastinal shift, and consolidation due to pneumonia⁽²⁵⁾. However, these symptoms are inconsistent, and according to literature reports, up to 30% of chest

radiograms in children with confirmed FBA were regular⁽²⁶⁾. Radiography during both inhalation and exhalation can be helpful in diagnosing a one-way mechanism caused by a foreign body. Low variability in lung volume and translucency during inhalation and exhalation can facilitate diagnosis by comparing the radiograms taken during the inhalation and exhalation phases. Confirming the presence of a foreign body in an imaging test enables a quick decision to perform bronchoscopy or transport the child to a medical centre.

The risk rate of a foreign body's secondary displacement in the respiratory tract during the patient's medical transport has not been determined so far. A distally lodged foreign body that does not cause respiratory insufficiency poses a significant hazard due to the possibility of its dislocation to the trachea and complete airway blockage. French authors performed a retrospective evaluation of 63 cases of children transported to a reference centre due to suspected FBA. In over 90% of these cases, no foreign body was discovered in the airways, and respiratory parameters did not deteriorate in any of the transported children. Based on these findings, it was concluded that non-medical transport could be considered for asymptomatic patients with suspected FBA⁽²⁷⁾. In symptomatic patients whose condition allows for medical transport to a reference centre, medical assistance should be provided during transport.

Bronchoscopy, which is both a diagnostic examination and therapeutic procedure, should be performed in every child with a high or medium risk of FBA. If aspiration likelihood is high, a rigid bronchoscope is recommended, as it enables simultaneous foreign body removal. Experienced bronchoscopists remove foreign bodies from air passages using tools such as bronchial fibroscopes^(28–30).

Chest tomography or magnetic resonance imaging can be used to diagnose children with low aspiration risk and stable general condition⁽⁵⁾. Ullal et al. found that both virtual bronchoscopy and rigid bronchoscopy were effective in identifying foreign bodies in FBA patients⁽³¹⁾. However, virtual bronchoscopy does not offer treatment opportunities. Chest CT can play a role in reducing unnecessary rigid bronchoscopies in patients with low clinical suspicion of aspiration⁽³²⁾. Physicians should avoid using it as the method of choice due to exposure to ionising radiation.

Lung ultrasound is typically not used in diagnostics due to technical limitations, but some cases of FBA suspected based on it have been reported, with symptoms such as missing A-line and consolidation, and absent or reduced lung sliding^(33,34).

PROCEDURE

If choking is witnessed in a paediatric patient, first aid should be provided. Fig. 2 shows the algorithm according to the European Resuscitation Council⁽³⁵⁾. The physiological cough reflex is the most effective and safest way to remove a foreign body, and this mechanism should be supported and actively encouraged in an effectively coughing child. When the

cough becomes ineffective, medical help should be called and rescue actions must be initiated. Abdominal thrusts, also known as the Heimlich manoeuvre, were introduced in 1974 by American physician Henry Heimlich as a rescue procedure for FBA into the respiratory tract. The procedure involves a rescuer standing behind the patient, placing one of their fists between the edge of the ribs and the navel, and pulling sharply inwards and upwards. The principle is based on compressing the air reserve in the chest by pressing the diaphragm, which is supposed to release and expel the foreign body from the airways^(36,37). There are several modified versions of the Heimlich manoeuvre, such as pressing the area above the navel with one hand and placing the other hand on the patient's back (typically used in younger children), or the patient performing the manoeuvre themselves by pressing the area above the belly button against an edge of a chair or table. If the patient is unconscious, chest pressing or rescue breathing should be performed (in an attempt to move the foreign body down to the main bronchus). One should remember that after a rescue action and successful foreign body expulsion, medical assessment and endoscopy of the respiratory tract shall be performed to exclude the possibility of foreign body residues remaining in the location⁽³⁸⁾.

Urgent interventions are needed if a foreign body is located in the larynx or trachea. Bronchoscopy is recommended for all children with a history of choking, even with no respiratory tract symptoms; for children with symptoms in the physical or imaging examination suggesting aspiration, a rigid bronchoscope is recommended as described above. In less suggestive cases, bronchial fibroscopy may be performed first to confirm or exclude FBA^(29,39).

Fig. 3 shows the method selecting algorithm – rigid versus flexible bronchoscopy (bronchial fibroscopy) according to the European Respiratory Society (ERS)⁽³⁹⁾. Researchers have suggested another clinical approach that involves calculating the score for symptoms and additional examination results in children with suspected FBA. Janahi et al. reported that, based on a retrospective analysis, the likelihood of confirming a foreign body's presence by bronchoscopy was 72% for a score of 5 or higher, 59% for the 4–5 score range, 29.8% for the 2–3 score, and 9.6% for the score of 1⁽⁴⁰⁾. Fasseeh et al. also proposed an algorithm based on a weighted risk score, showing that a score greater than 2 was linked to a high probability of a positive FBA, with 79.9% sensitivity and 84.9% specificity⁽⁴¹⁾.

The method of foreign body removal depends on the physician's and medical team's skills. Bronchial fibroscopy bronchoscopy enables assessment of the more distal branches of the bronchial tree, helping to locate the foreign body and plan how to remove it. Flexible bronchoscopy typically takes longer and has limitations in younger patients due to narrow air passages. In contrast, rigid bronchoscopy enables the patient's free ventilation through the instrument's tube, better control during foreign body removal, a bigger tool, a firmer grip, and improved ability to manage local complications. German researchers have highlighted the

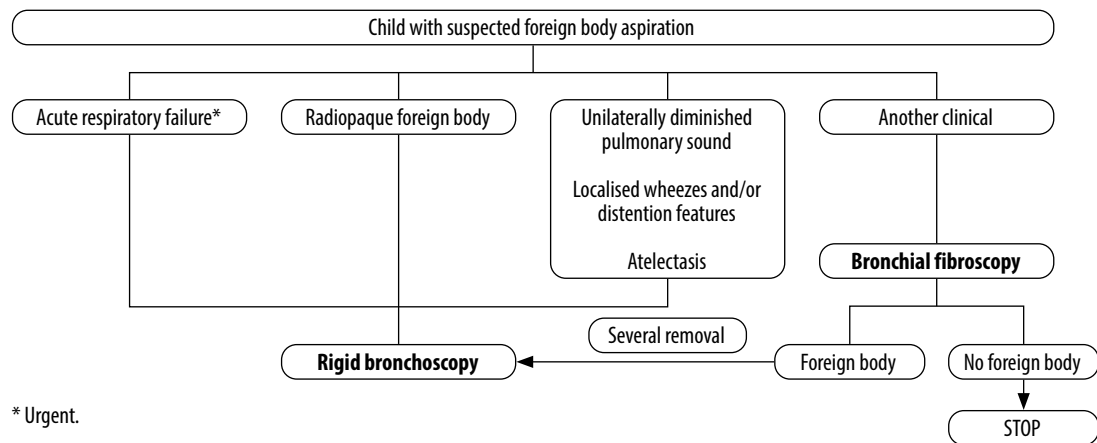


Fig. 2. Algorithm for selecting a foreign body removal method according to ERS

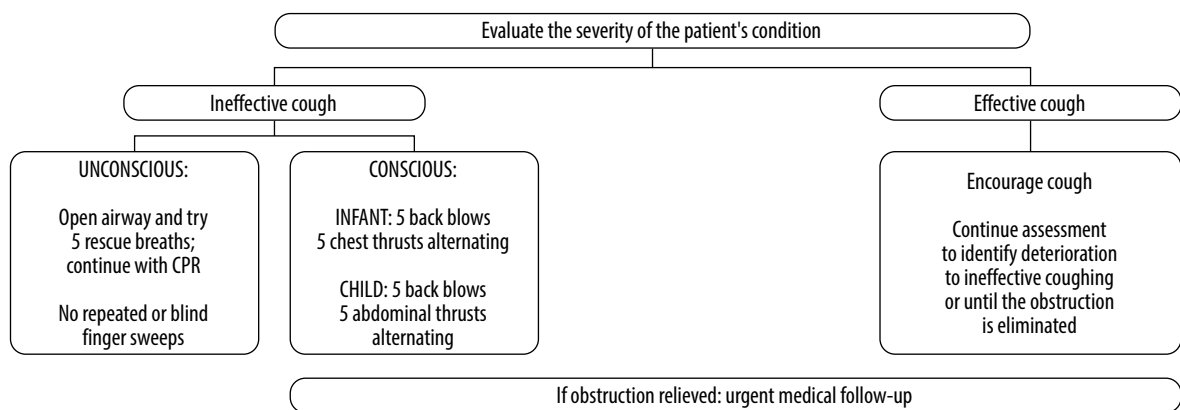


Fig. 3. First aid in choking – according to ERC's recommendations

discrepancy between ERS recommendations and the growing number of endoscopy centres using flexible bronchoscopy as the first-choice method (20% of the studied centres)⁽⁴²⁾. A similar trend was observed by researchers from Israel who analysed FBA cases in six medical centres between 2016 and 2021⁽⁷⁾.

Endoscopy of the respiratory tract in children is recommended under general anaesthesia to ensure sedation, retrograde amnesia, and analgesia. Anaesthetic drugs used include propofol, ketamine, fentanyl/remifentanyl, and sevoflurane. An adequate level of patient sedation and local anaesthesia with lidocaine is needed to suppress the coughing reflex, which can reduce complications.

In the case of FBA, it is important to remember that when traditional bronchoscopy is initiated, a fibroscope should also be available. When flexible bronchoscopy is performed first, the option to switch to rigid bronchoscopy should be ensured. In many cases, they are complementary methods. Although ERS recommendations indicate traditional bronchoscopy as the primary technique, some centres remove foreign bodies from the airways using bronchial fibroscopy in nearly all cases^(30,43).

The efficacy of bronchoscopy in removing foreign bodies reaches 95%, while the risk of complications is less than 1%. Both rigid and flexible bronchoscopy are used, but

the success ratio is in favour of the first method (99.9% vs. 86–91%, respectively). The procedure should be performed by experienced personnel to reduce the risk of complications⁽⁴⁴⁾. The process of removing a foreign body from the respiratory tract with a bronchial fibroscope consists of three stages: gripping, retrieving the item while securing it with intrabronchial tools, and removing the foreign body while simultaneously withdrawing the bronchial fibroscope⁽⁴⁵⁾. Furthermore, if numerous fine foreign bodies or foreign body fragmentation are suspected, complete flexible bronchoscopy of the entire bronchial tree is recommended. If the aspirated items are organic, freezing the foreign body with a cryoprobe before removal is an option. A secondary bronchoscopic evaluation is recommended when symptoms persist despite removing the foreign body^(46,47). If the inflammatory response in the bronchial tree is acute, a selected antibiotic therapy, sometimes combined with a systemic course of glucocorticosteroids for 3–7 days, can alleviate inflammation and enable foreign body evacuation during successive bronchoscopy procedures⁽¹³⁾.

If the foreign body is removed within a short time after aspiration, antibiotic therapy is typically unnecessary; in cases of inflammatory complications, antibiotic treatment and adjunctive therapies, e.g. physical therapy and sometimes short-term corticosteroid therapy, have to be implemented.

If irreversible bronchopulmonary complications have occurred, resection of the pulmonary tissue (especially in cases of cystoid lesions) or long-term conservative treatment (for cylindrical bronchiectasis) may be necessary⁽¹⁵⁾.

COMPLICATIONS AFTER FOREIGN BODY EVACUATION ATTEMPTS

European and American associations recommend the Heimlich manoeuvre for managing FBA in children over one year of age. However, the literature mentions its complications, such as rib fractures, mediastinal emphysema, and injuries to the abdominal cavity and chest. Most complications are reported in the adult population, mainly individuals over 65, and attributed to medical procedures performed incorrectly by non-qualified persons. In children, complications include rib damage, mediastinal emphysema, and post-injury pancreatic pseudocyst formation. Contrary to American and European recommendations, the Australian and New Zealand Committee on Resuscitation (ANZCOR) advises against the Heimlich manoeuvre as a first aid procedure for FBA due to a high number of complications. Instead, it recommends performing back blows between the shoulder blades and chest compressions^(48,49). Severe complications associated with bronchoscopic evacuation of foreign bodies from the airways include pneumothorax, mediastinal emphysema, intrabronchial haemorrhage, bronchospasm/laryngospasm, laryngeal oedema and respiratory arrest – rarely occurring (approximately 3.8% for bronchoconstriction and up to 0.6% for the remaining complications)⁽⁵⁰⁾.

Even though FBA to the airways statistically occurs more often in otherwise healthy children, one should consider the impact of comorbidities, including but not limited to acute respiratory tract infections, on the course of bronchoscopy and potential complications during the procedure. Special attention is required in cases of SARS-CoV-2 infection, as a higher frequency of respiratory complications was demonstrated after general anaesthesia in children with a non-severe course of coronavirus infection (11.8% risk) compared to non-infected children (1% risk). The complications included laryngospasm, tracheal spasm, bronchospasm, hypoxia, stridor, and atelectasis. There is no established consensus on managing FBA in children infected with SARS-CoV-2. The literature offers only case descriptions where bronchoscopy was performed regardless of the infection status, or the procedure was delayed until a negative swab test result was obtained^(51,52). Bronchoscopy should be performed immediately if FBA is suspected in a child, regardless of the patient's infection status. However, it is important to remember that there is a higher frequency of anaesthesia-related complications in SARS-CoV-2-positive patients. Thoracotomy combined with bronchotomy is the procedure of choice when a foreign body cannot be removed with a bronchoscope due to its distal location, size, or technical difficulty⁽⁵³⁾.

PREVENTION

Primary prevention is the fundamental strategy to reduce the risk of FBA in children by eliminating small or hazardous objects from their environment. This includes implementing legal processes, providing clear labelling for caregivers, and ensuring appropriate food-giving methods. Directive No. 2009/48/EC of the European Parliament and the Council of 18 June 2009 on the safety of toys is effective in the European Union. Annex II to the Directive describes the physical features of such objects determining their marketing approval in the EU⁽⁵⁴⁾.

The AAP Committee on Injury, Violence, and Poison Prevention has issued recommendations to reduce the occurrence of FBA in children. Recommendations include educating parents and caregivers, involving paediatricians and dentists in prevention efforts, placing information on the packaging of foodstuffs with a higher aspiration risk, and increasing the frequency of inspections of products sold in vending machines. A ban on the sale of Kinder Surprise in the USA is an example. Recurrent education of parents, caregivers and teachers was also recommended to provide first aid in case of a FBA⁽¹⁰⁾.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organisations which might negatively affect the content of this publication and/or claim authorship rights to this publication.

Author contribution

Original concept of study; writing of manuscript: MS. Critical review of manuscript: AP, HM. Final approval of manuscript: HM.

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