



FOREIGN BODY ASPIRATION AND INGESTION IN CHILDREN

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SUMMARY – Aspiration and ingestion of a foreign body is most frequently seen in children younger than 3 years. Foreign body aspiration is always a life-threatening, urgent state demanding quick recognition and treatment to avoid potentially lethal complications. Most foreign bodies that are ingested pass spontaneously through the gastrointestinal tract without complications, however, some could lead to problems if they become lodged. A literature review was performed *via* MEDLINE database using key terms. Primary care providers should be trained to give proper initial care. Aspirated/ingested foreign bodies in children removed by rigid or flexible bronchoscopy/gastroscopy always are challenging procedures that require well-planned anesthesia management and excellent intercommunication between anesthesiologists and surgeons. Extracorporeal membrane oxygenation can be used as a rescue mode of support in children with life-threatening foreign body aspiration for stabilization before, during and after removal of the aspirated foreign body. It is of utmost importance that all foreign body extractions, if possible, be done in centers supplied with all the necessary equipment and trained personnel. However, prevention of foreign body aspiration and ingestion is still the best therapy.

Key words: *Aspiration of foreign body in children; Ingestion of foreign body in children; Airway management; Anesthesia*

Introduction

Aspiration of foreign body in children is an urgent state, especially in small children where it can be life-threatening. This is due to their decreased respiratory reserve and small airway diameter. Such cases demand quick recognition and treatment in order to avoid potentially lethal complications. Generally speaking, aspiration of foreign body is connected to high morbidity rates (10%-20%), and it is responsi-

ble for 7% of accidental deaths in children under three years of age¹⁻⁶.

Guidelines recommend performing bronchoscopy in any suspected or confirmed foreign body aspiration⁷. Foreign bodies that cannot be removed by bronchoscopy require tracheostomy or open thoracotomy and bronchotomy or lung resection. Thoracotomy has been reported to be necessary in less than 1% to 2.5% of cases⁷.

The challenges faced by the anesthesiologist during removal of aspirated foreign body include maintenance of patent airway; induction and maintenance of anesthesia; high risk of hypoxemia due to the surgeon and anesthesiologist sharing the same field of work, 'shared

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airway'; and prevention and management of possible postoperative airway and respiratory problems.

Ingestion of foreign body is most common in children. It can create a potentially serious problem that peaks in children aged six months to three years. Those below three years of age use chewing to explore the world around them, and the older ones mostly during the play⁸⁻¹⁰. Coins are the most common foreign object children swallow, besides fish bones⁸⁻¹⁰. It is important to mention that children with mental health issues are at the highest risk of ingestion⁸⁻¹⁰. However, most of the objects pass through the digestive tract without any issues. Complications arise when the object is too big, sharp, caustic, magnetic, or if it is a pill which adheres to the esophageal mucosa⁸⁻¹⁰.

Methods

I used MEDLINE to search the English language literature from 2010 to 2022 for articles using the following search terms: "foreign body aspiration in children", "foreign body ingestion in children", "anesthesia management for removal of foreign body in children", "airway management during rigid and flexible bronchoscopy in children", "ECMO in foreign body aspiration in children", and "prevention of foreign body aspiration and ingestion in children". I focused on the airway management and anesthesia maintenance for the removal of foreign body in children. All sources were screened and selected for inclusion to determine their relevance in the framework of the current report.

Results

Primary care providers should be trained to recognize signs and symptoms of respiratory failure caused by foreign body aspiration, and to give proper initial care in order to help reduce the risks of complications. Aspirated/ingested foreign bodies in children removed by rigid or flexible bronchoscopy/gastroscopy are the procedures which require well-planned anesthesia management and excellent intercommunication between anesthesiologists and surgeons. Extracorporeal membrane oxygenation (ECMO) can be used as a rescue mode of support in children with life-threatening foreign body aspiration for stabilization before, during, and after removal. Primary goal is delivering oxygen and optimizing oxygenation in the management of difficult pediatric airway.

Discussion

Foreign body aspiration

Foreign body aspiration is an urgent, potentially life-threatening state, as well as one of the leading causes of mortality and morbidity in children younger than three years¹⁻⁶. If suspected, a child aspirating a foreign body requires urgent medical evaluation⁶. It is of utmost importance to establish a diagnosis or even to suspect foreign body aspiration during first examination, according to the patient history, general state, and data received from the parents/guardians⁶. In fact, 85% of cases are diagnosed in time, but in 15% of aspirated foreign bodies that were diagnosed later on, develop complications such as pneumonia, atelectasis and abscesses^{5,11,12}.

Why children below three years of age are at the greatest risk? Well, firstly, they are still exploring their environment by putting various objects into their mouth. Secondly, children cannot sit still while they are eating, moving around in their seat, and crying enhances the risk of aspirating the food. In addition, their teeth are not well developed yet (without molars, they can only cut food into smaller pieces with incisors, so the food is not properly chewed and thus, it is very easily aspirated). And lastly, children of that age do not have protective laryngeal reflexes completely developed.

In the United States of America, there were 3,700 child deaths in 2007 due to airway obstruction associated with aspiration or ingestion of a foreign body^{7,11,12}. Most commonly, dangerous food groups given to children are peanuts and other nuts, sunflower seeds, pumpkin seeds, carrots, apples, and tiny pieces of toys and jewelry¹². School children mostly inhale paper clips, pen caps, parts of whistles and zippers^{7,12}.

The American Academy of Pediatrics (AAP) recommended preventive measures in 2012 with the intention to reduce the incidence of foreign body aspiration. One of the measures was collaboration between the US Food and Drug Administration (FDA) and Consumer Product Safety Commission (CPSC) to provide a surveillance system and set of regulations for food items. At that time, CPSC already had legislation meant to reduce choking hazards coming from toys. The AAP offered extensive recommendations in their policy statement including routine food warning labeling and increased public education about new food

hazards as they import the consumer market. In 2016, the National Safety Council reported the rate of fatal choking in American children <5 years of age in the general population of 0.43 *per* 100,000⁷.

According to the SUSY SAFE (largest international registers that collect cases of foreign body accidents in children aged between 0-14 year from EU countries and some non-EU countries), which conducted a great study ten years ago, food is responsible for up to 26% of injuries due to the aspiration/ingestion of foreign bodies. Most often, the causes of accidents are chicken and fish bones (32%), followed by peanuts (22%) and seeds (16%); half of the foreign body accidents occurred under adult supervision, and more than half of the patients were male¹³.

Sudden cough, present in an otherwise healthy child, while eating or playing with smaller toys, along with signs of choking can insinuate aspiration of a foreign body. The severity of presentation depends on the characteristics of the aspirated foreign body and the site of impaction. Symptoms of aspiration can range from coughing, stridor, dyspnea, cyanosis, whizzing to respiratory arrest, depending on the part of airway that is obstructed. Complete airway obstruction can be recognized as the onset of sudden respiratory distress associated with inability to speak or cough^{7,12,13}. In laryngeal foreign body, severe coughing, choking, hoarseness, and gagging are frequently seen⁷. A subglottic or tracheal foreign body causing incomplete obstruction produces inspiratory stridor, cough, and dyspnea^{7,12,13}. Bronchial foreign bodies may produce minimal symptoms; unilateral whizzing and decreasing breath sound unilaterally are usually seen^{7,12,13}. It could very well be masked with signs and symptoms of an acute upper respiratory infection, bronchiolitis, pneumonia, asthma, which are common in children. When a child has recurrent pneumonia or croup which is not going away, or asthma that does not improve with treatment, aspiration of a foreign body should always be suspected, and the diagnostics should move towards that direction^{5,11,13}. The incidence of foreign body localization is 3% in the larynx, 13% in the trachea/carina, 59% in the right lung (52% in principal bronchus), 23% in the left lung (18% in principal bronchus), and 2% bilaterally (in both lungs)¹⁴.

In the evaluation of aspiration, the first diagnostic procedure is chest radiography which can help confirm the diagnosis but not rule it out as a possibility.

Reliable interpretation of chest radiography could be compromised because most aspirated objects are radiolucent, thus, the scans are normal in about 50% of tracheal inhalation cases, and in 25% of bronchial inhalation¹⁴. Inspiratory and expiratory phase chest x-ray can help with cooperative and older children¹⁴. First x-ray is taken when the child has inhaled and the second one when the child has exhaled the air out of their lungs. Inspiratory and expiratory phase films may show hyperinflation of air-trapping, which suggests an aspirated foreign body¹⁴. Pulmonary ultrasound is highly operator dependent but has the advantage of being chest x-ray free (parenchymal echogenicity and atelectasis)^{7,13,14}. Computed tomography (CT) of the chest may also be used in making the diagnosis of foreign body aspiration¹⁴.

In the hospital where I work, when aspiration is suspected but physical examination and chest x-rays are not definitive, flexible bronchoscopy is performed to confirm the diagnosis. The procedure is done under sedation and topical anesthesia. However, for both diagnostic and therapeutic purposes, rigid bronchoscopy performed under general anesthesia is used as the first instrumentation in case of high suspicion of foreign body aspiration, but one should keep in mind that this procedure is more invasive. On performing these procedures, in my hospital, the standard of care is the presence of double teams in the operating room.

Primary caregivers and local ambulance services out of hospital should be trained to recognize this emergency and start applying pediatric basic life support guidelines when faced with serious choking and respiratory distress in a child (<https://www.resus.org.uk/library/2021-resuscitation-guidelines/paediatric-basic-life-support-guidelines>)^{13,15}.

Intrahospital preoperative assessment in children with aspirated foreign body implies ensuring oxygenation and minimizing anxiety in children by trying to develop a rapport with the patient; parental presence; taking AMPLE history (**A**llergies, **M**edications, **P**ast medical/anesthesia history, **L**ast meal, **E**vents leading up to the presentation); and asking about family history of problems with anesthesia¹⁶.

During physical examination of the child, special attention should be paid to the airway. If patient is hemodynamically stable without signs of severe respiratory distress, recommended bronchoscopy could be performed in daytime operating hours with expe-

rienced anesthesiologists and surgeons and pre-anesthetic fasting could be completed¹⁶⁻¹⁹. If bronchoscopy is urgent, despite the presence of full stomach, rapid sequence induction of anesthesia should be performed and large-bore gastric tube can be used to aspirate the stomach contents before induction of anesthesia^{18,19}.

Aspirated foreign body in children is removed by rigid or flexible bronchoscopy, procedures which require well-planned anesthesia management and excellent communications between anesthesiologists and surgeons.

No consensus has been reached regarding the superiority of inhaled or intravenous anesthesia or spontaneous *versus* controlled ventilation for bronchoscopic removal of aspirated foreign body in children. The decision depends on each case. Techniques that reduce the risk of complications, morbidity, and mortality are most suitable¹⁷⁻¹⁹.

Although rigid bronchoscopy is considered the traditional bronchoscopy technique of choice for removal of aspirated foreign body in children, most recently, several studies have described the usage of flexible bronchoscopy in this context, applying a lot of different techniques²⁰. Advantages of flexible bronchoscopy are that it is less invasive, causes less trauma, lower risk of complications, allows identification and localization of foreign bodies in distal airways of the upper lobe bronchi, not requiring general anesthesia. Its disadvantages are limited suction and instrumentation, lack of ventilatory capability, and lack of airway control. To calculate estimated endotracheal tube (ETT) size, we use the following formula: $(\text{age}/4) + 4$, and maximal flexible bronchoscope size is given by: ETT-1. Exception is 2.8 size of flexible bronchoscope, which can fit in a 3.5 ETT very tightly, and size 3.0 ETT, which needs 2.2 flexible bronchoscope but this one is without

suction channel²⁰. Flexible bronchoscope through the laryngeal mask is very useful in pediatric patient as a diagnostic tool, gold standard in the management of difficult pediatric airway, as well as in detection and removal of aspirated foreign body^{16,20,21}.

Rigid bronchoscopy is necessary when dealing with more complicated airway instrumentation; it provides a large working channel; permits the use of a wide variety of extraction instruments for removal of aspirated foreign bodies and thick mucus plugs; allows good control of the airway; should be immediately available if flexible techniques prove ineffective or inadequate for safe extraction; presence of optical forceps on the rigid bronchoscope simplifies the procedure and makes it less hazardous²²⁻²⁵. An appropriate size of rigid bronchoscope must be selected according to the age of the child in order to avoid the high incidence of bronchospasm and prevent laryngeal edema²²⁻²⁵ (Table 1).

Sometimes aspirated foreign body is shrouded by granulation or scar tissue or difficult to grab completely with flexible bronchoscopy forceps because of its size or shape. In this situation, rigid bronchoscopy should be used for extraction. At the same time, cryotherapy could be performed through a bronchoscope to coagulate necrosis of the selected tissue and destroy the lesion to reduce scarring and prevent stenosis²⁶.

In the scenario of complete obstruction of the trachea and consequent asphyxia during an attempt to remove the foreign body, the rescue technique implies pushing the object into a bronchus and to ventilate the other lung²²⁻²⁵. After removing foreign body, it is necessary to check bronchi, trachea and mouth from the possible residual particles²²⁻²⁵.

As pointed out, the anesthesia maintenance and ventilation method (spontaneous or controlled) should ensure the least risks of mortality and complications

Table 1. Set for rigid bronchoscopy

Size	Length (cm)	Internal diameter (mm)	External diameter (mm)	Age
2.5	20	3.5	4.2	Premature
3.0	20, 26	4.3	5.0	Premature newborn
3.5	20, 26, 30	5.0	5.7	Newborn, 6 months
3.7	26, 30	5.7	6.4	6 months-1 year
4.0	26, 30	6.0	6.7	1-2 years
5.0	30	7.1	7.8	3-4 years
6.0	30, 40	7.5	8.2	5-7 years
6.5	43	8.5	9.2	Adult

for patients²⁷. A key challenge is oxygenation during rigid bronchoscopy. When the surgeon passes the vocal cords, the anesthesiologist attaches a breathing circuit to the connector on the bronchoscope²⁷. If the surgeon is working at the level of the larynx, then the anesthesiologist can attach oxygen tubing to surgical laryngoscope or insufflate oxygen through a nasotracheal tube just above the vocal cords²⁷. Transnasal humidified rapid-insufflation ventilatory exchange (THRIVE) may be useful to maintain oxygenation as well²⁸.

The most common anesthesiologist's approach for removal of aspirated foreign body positioned more proximally is by using smooth inhalation induction of anesthesia through the mask, or carefully give the anesthetic intravenously while maintaining spontaneous breathing^{27,28}. After placing a rigid bronchoscope below the vocal cords, spontaneous ventilation can be continued if the foreign body is positioned proximally, and only few minutes are required for its extraction²⁷⁻²⁹. If one expects the procedure should last longer and bronchoscope must be set further down, movement of the patient and their reflexes can be stopped with neuromuscular blockers, which would prevent airway trauma to the patient caused by coughing, while at the same time creating good conditions for surgeon's work. In that case, ventilation by positive pressure helps remove atelectasis, improve oxygenation, and overcome resistance in airways²⁷⁻²⁹. According to literature data, spontaneous ventilation during bronchoscopy for extraction of foreign body with the usage of different doses of propofol and remifentanyl intravenously resulted of body movement, cough, desaturation, delay recovery, and the authors suggest remifentanyl infusion with inhalation anesthetics and topicalization²⁷⁻²⁹.

Using manual jet ventilation during rigid bronchoscopy (without obstruction) prevents hypoxemia (it is well known that children are prone to reach desaturation faster) and, sometimes, could be more adequate than spontaneous and controlled ventilation²⁷⁻²⁹.

After removing the aspirated foreign body, if the patient has not developed any complications, ventilation can be continued through the mask until the signs of spontaneous breathing appear^{27,28}. However, if there are complications such as laryngeal edema or inadequate gas exchange, it is necessary to intubate the patient and perform controlled ventilation until the effect of neuromuscular blockers disappears, lungs have

re-expanded, the patient is awake, and all protective reflexes are working^{27,28}.

In the presence of complications such as rupture of trachea during extraction of aspirated foreign body it is imperative that the ETT be placed distally to the disruption to avoid the risk of rapid pneumothorax and death. In older children, double lumen intubation is preferred to protect both lungs from bleeding distal to the injury (the size of the smallest double lumen tube (DLT) is 26 and it suits standard ETT 6.5). In this scenario, early diagnosis and surgical repair is critical to preserve lung function^{23,29}.

For proximal tracheal lesions, trachea is explored through a U-shaped cervical incision, between the lower part of the cricoid cartilage and sternal notch. One ETT is placed in the trachea above the lesion^{23,29}. The second one, sterile ETT, is placed into distal trachea by the surgeon, then connected to a sterile anesthetic circuit across the surgical field²⁹. Ventilation is maintained by the anesthesiologist and confirmed by evaluating chest inflation, peripheral oxygen saturation, ET_{CO}2, and blood gas analysis²⁹.

For distal tracheal lesions or carinal injuries, anesthetic management and ventilation strategies during surgery involve one-lung ventilation (OLV), ECMO, or open chest cardiopulmonary bypass (CPB) *via* median sternotomy or right thoracotomy as surgical approach²⁹. OLV can be reached by using different approaches, e.g., after the ETT is pulled above the injury during the procedure; an endobronchial blocker; DLT or single lumen endobronchial tube may be placed into the left mainstem bronchus²⁹. According to the airway devices used, low-frequency jet ventilation or low tidal volume ventilation are applied during resection²⁹.

Indications for ECMO included not only surgical approach but also impossibility to perform rigid bronchoscopy due to the child's unstable respiratory state or trachea lodged by aspirated foreign body that could not be removed without potential loss of airway support²⁹. ECMO can be performed veno-venously, if circulatory support is not indicated, or veno-arterially for patients with cardiac comorbidities that require circulatory support²⁹. CPB has been used for decades in operative procedures of the trachea to ensure adequate gas exchange. Advantages of ECMO compared to CPB include less fluid overload due hemodilution and reduced demands for anticoagulation resulting in lower transfusions²⁹. Nevertheless, ECMO

is an integral part of the newest American Society of Anesthesiologists (ASA) practice guidelines as an advanced technique in the management of pediatric difficult airway (<https://pubs.asahq.org/anesthesiology/article/136/1/31/117915/2022-American-Society-of-Anesthesiologists>)³⁰.

Foreign body ingestion

In young children, ingestion of a foreign body is accidental. Apart from swallowing, children often put objects in their noses or ears. If the ingestion compromises breathing and destabilizes airway, it is necessary to remove the foreign object immediately. Button shaped battery erodes esophageal mucosa in less than 2 hours, and as such, it must be removed with no delay³¹⁻³³. Magnetic balls attract each other, and they cannot pass through the digestive tract freely, therefore they cause abrasions and perforation of a part of the intestine in which they attract³³⁻³⁵. Their removal cannot be delayed, just like fish bones stuck in the tonsils or palatine arches³¹⁻³⁵. However, death outcome because of ingestion is rare³³⁻³⁸.

Various abnormalities of the digestive system as consequences of surgical procedures (strictures and fistulas), esophagitis, neuromuscular illnesses, or presence of congenital malformations increase the risk of complications with ingestion of a foreign body³³⁻³⁸. Swallowed objects usually get stuck in the cricoesophageal sling at C6 vertebral level, then in the middle of the esophagus, where carina and aortic arch are located³³⁻³⁸.

The first symptom a child gets when they have a lodged foreign body in some part of the digestive tract is pain. Depending on the position of the object, small children experience chest pain, increased slobbering, tendency to and vomiting, refusing meals, hematemesis and cough (foreign body localized in the upper gastrointestinal tract) or abdominal pain, vomiting and bloody stool (foreign body localized in the lower gastrointestinal tract). If the obstruction lasts longer, it can cause some dramatic complications.

Sometimes, physicians are faced with often and purposeful swallowing of foreign bodies in older children, which requires prompt reaction and taking the child to a mental health specialist³⁷.

Signs and symptoms of the ingestion in children can simply not be visible because the ingestion happens when the children are alone and without super-

vision, or they can be covered by a general pathology. It is not uncommon that on chest radiography, while evaluating some unspecific symptoms such as cough, fever or weight loss, a foreign body is discovered³⁷. Radiolucent foreign bodies such as meat cannot be seen using radiography, but irregular shape of the organ where the ingested foreign body is stuck is of great help in diagnostics³³⁻³⁷. Next diagnostic steps include contrast CT or magnetic resonance imaging³³⁻³⁷.

Most children with ingested foreign body do not require invasive treatment. Usually, ingestions of objects in healthy children pass with normal passage through the digestive tract and offering some advice to the parents. Ingested foreign bodies stuck in the upper gastrointestinal tract are removed endoscopically, while those in the lower gastrointestinal tract require a multidisciplinary approach, and sometimes, they need to be removed surgically^{33,36-38}. Prognosis is mostly good, with low mortality and morbidity rates, even in situations when it is necessary to do an urgent extraction or when complications arise, such as systemic allergic reactions, mediastinitis, perforations or pneumomediastinum³³⁻³⁶.

Conclusion

The aim of this review is to discuss recent scientific literature and provide a comprehensive approach to the management of aspirated/ingested foreign bodies. Primary goal is always to provide proper child oxygenation. It is of utmost importance that all the extractions of foreign body, if possible, be done in centers supplied with all the necessary equipment and trained personnel. However, prevention of aspiration and ingestion of a foreign body is still the best therapy, and we can accomplish it by systematic education of parents by medical workers, especially those engaged in parental support as the best way to keep their child healthy and happy.

Strategies for the prevention of foreign body aspiration/ingestion should be that children below three years of age should not consume high-risk food such as popcorn, peanuts or other nuts, raw fruits and vegetables, they should also avoid small toys or toys made with smaller pieces, magnetic balls, as well as keys, remote controllers, etc. that contain button shaped batteries.

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Sažetak

ASPIRACIJA I INGESTIJA STRANOG TIJELA U DJECE

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Aspiracija i ingestija stranih tijela najčešće se viđa u djece mlađe od 3 godine. Aspiracija stranog tijela uvijek je za život opasno, hitno stanje koje zahtijeva brzo prepoznavanje i liječenje kako bi se izbjegle potencijalno smrtonosne komplikacije. Većina stranih tijela koja se ingestiraju spontano prolaze kroz probavni trakt bez komplikacija, no neka mogu dovesti do problema ako se nezgodno zaglave. Proveden je pregled literature putem baze podataka MEDLINE koristeći ključne pojmove. Pružatelji primarne zdravstvene zaštite trebaju biti obrazovani za pružanje odgovarajuće početne skrbi. Aspirirana/ingestirana strana tijela u djece uklonjena rigidnom ili fleksibilnom bronhoskopijom/gastroskopijom uvijek su zahtjevni postupci koji zahtijevaju dobro planirano vođenje anestezije i izvrsnu komunikaciju između anesteziologa i kirurga. Izvantelesna membranska oksigenacija može se primijeniti kao način spašavanja u djece s aspiracijom stranog tijela opasnom za život radi stabilizacije prije, tijekom i nakon uklanjanja aspiriranog stranog tijela. Od iznimne je važnosti da se sva vađenja stranog tijela, ako je moguće, obavljaju u centrima koji imaju svu potrebnu opremu i za to obrazovano osoblje. No, prevencija aspiracije i ingestije stranog tijela i dalje je najbolja terapija.

Ključne riječi: Aspiracija stranog tijela kod djece; Gutanje stranog tijela kod djece; Zbrinjavanje dišnog puta; Anestezija