



# Foreign body aspiration: a review of current strategies for management

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**Abstract:** The management of foreign body aspiration requires careful planning and a good understanding of the physical properties of frequently aspirated objects as well as the array of tools available for securing them. Additionally, patient-specific factors must be taken into consideration during procedure planning, including patient age, respiratory status, the location of aspirated items and underlying patient comorbidities. The sequelae of foreign body aspiration are closely related to both the nature of the foreign body itself as well as their position in the tracheobronchial tree and chronicity after aspiration; these secondary effects frequently warrant specific therapeutic intervention. Rigid and flexible bronchoscopy are the main therapeutic approaches, with specific bronchoscopic tools suited to different clinical scenarios. Procedure planning also requires thoughtful consideration of the safest approach to anesthesia, balancing patient comfort and procedural success. Foreign body aspiration is a relatively infrequent event in adults but requires experience and careful planning to manage successfully.

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## Introduction and epidemiology

Aspiration of foreign objects into the airway presents an infrequent but potentially lethal clinical scenario. According to the National Electronic Injury Surveillance System, from 2000 to 2014, roughly 2,600 pediatric aspiration events occurred in American emergency departments (1). Nearly 300 annual deaths occur in the United States' pediatric population related to foreign body aspiration (2). The incidences of adult aspiration events are fewer and less fatal (3,4). Airway foreign bodies are commonly classified as comprised of either inorganic or organic material (5). Epidemiological patterns regarding the type of item found in airways are influenced significantly by the patient's age and demographics. For example aspiration of animal bone is reported more commonly in Asian countries whereas meat

aspiration is reported more frequently in Western nations (6,7). Inorganic items are more common in children than adults (8). The size and structural features of aspirated foreign bodies impact the ultimate location of the item in the airway. Overall the majority of aspirated objects in retrospective studies were found in the right bronchus intermedius and truncus basalis (9,10).

## Clinical symptoms

Structural attributes of airway foreign bodies along with patient co-morbidities impact initially presenting symptoms. Irrespective of the object's features or location, the most common symptom (up to 90%) noted in several case series is cough, followed by dyspnea (1,3,7,11). In retrospective studies, objects obstructing

distal airways were more likely to cause chest pain, wheezing, hemoptysis, and pneumonia. However, these symptoms were generally far less common than isolated cough (4,12). Patients with items localized in the upper airway and proximal lower airways including the trachea, and main bronchi, were more likely to complain of choking sensation, stridor, and change in voice or hoarseness (13,14). When comparing case series between children and adults, children are far more likely to have recollection of the precipitating aspiration events with onset of choking symptoms. In fact, fewer than half of adults recall an aspiration event and many do not correlate current symptoms with prior aspiration events (4,7). The delayed recognition of aspiration events and often non-specific symptoms may lead to complications related to foreign objects injuring the airways and lung parenchyma (15). These include but are not limited to granulation tissue, post-obstructive pneumonias, lung abscesses, bronchiectasis, cystic changes, pneumothorax and hemoptysis (16). Adult patients with pulmonary comorbidities, such as chronic obstructive lung disease, are often more symptomatic in regard to common symptoms such as cough and dyspnea. Nonetheless, in most case series, preexisting pulmonary conditions did not seem to impact overall respiratory morbidity and mortality after foreign body removal (17).

### Diagnostic imaging

Plain chest radiography (CXR) offers rapid and affordable evaluation for possible airway foreign bodies. However, only objects composed of radiopaque material are detectable. The majority of retrospective studies looking at imaging detection for foreign bodies found that CXR detected only about 20% to 50% of aspirated foreign bodies (18,19). Similarly, plain CXR can detect complications related to foreign airway bodies such as atelectasis, pneumonia, pneumothorax, and hyperinflation, but at a relatively low detection rate of 3% to 20% (20). Chest computed tomography (CT) has become the standard imaging modality used for the detection of foreign bodies in the respiratory tract. Several observational studies note sensitivities of nearly 100% and specificity ranging from 70–90% (21,22). Beyond identifying the presence and location of aspirated foreign bodies, chest CT scans provide crucial information regarding their orientation in the airway which is crucial to planning the therapeutic approach. Additionally, CT imaging provide more details regarding

associated anatomic consequences from foreign bodies, such as lobar collapse, post-obstructive consolidation, early tree in bud opacification, parenchymal hemorrhage and mucous plugging (23). Advancement in post imaging processing and 3-D modeling, such as two dimensional multi-planar reformatted reconstructions, provide more detailed imaging and modeling of subtle airway abnormalities (24). However, further studies are warranted for determining the clinical implications of these adjunctive imaging techniques.

### Objectives prior to object retrieval

Anticipatory guidance and pre-procedural planning are critical prior to any decision to perform therapeutic bronchoscopy for removing foreign bodies. Clinical presentation, imaging findings, type of object, and location of the object will influence the methods and tools to remove an item from the respiratory tract. Although pulmonologists are the primary providers in almost all observational studies involving retrieving aspirated objects, consultation with other airway specialists such as anesthesiologists, otolaryngologists, and thoracic surgeons should be strongly considered depending on the clinical scenario. The bronchoscopy team should prepare multiple methods and expect to utilize multiple tools in anticipation to changes in the object's morphology, the object's location, and the patient's clinical status during the retrieval process.

### Rigid versus flexible bronchoscopy

Bronchoscopy remains the method of choice in nearly every published observational study regarding foreign body removal from the airway (7,25,26). Although flexible bronchoscopy is more widely used than rigid bronchoscopy, there are several benefits offered by the rigid bronchoscope in this setting (26). The solid steel barrel of the rigid bronchoscope protects and reinforces the trachea, larynx, and vocal cords, shielding such structures from injury when removing sharp or irregularly shaped objects. The large bore lumen of the rigid bronchoscope is also beneficial in allowing adequate ventilation even when moving large objects with the potential to obstruct conventional endotracheal tubes. Additionally, the greater luminal dimension allows for the use of larger, rigid forceps and multiple tools simultaneously (27,28). Flexible bronchoscopes are typically passed through the lumen of the rigid bronchoscope when angled manipulation is required. Rigid bronchoscopy is the therapeutic approach of choice

for foreign body aspiration cases in the pediatric population. Due to the smaller respiratory tract anatomy in children, objects that have limited potential for oropharyngeal or tracheal obstruction in adults are a major source of critical airway obstruction in pediatric counterparts. Additionally, the smaller working channel and size of pediatric flexible bronchoscopes limits the use of many therapeutic tools (29). There are, however, several recent retrospective studies attesting to the success of foreign body removal through flexible bronchoscopy alone in children though a small number have required conversion to rigid bronchoscopy (30,31).

There are several considerations unique to rigid bronchoscopy which must be considered when deciding on the optimal therapeutic approach. First, it typically requires general anesthesia and an anesthesia team familiar with ventilation through the rigid barrel. The rigid bronchoscope does present additional risk of injury to the oropharynx, vocal cords, trachea though these risks are overall low. Overall, however the rate of airway-related complications in retrospective series of rigid bronchoscopy for foreign body retrieval are as low as 5% which may be attributed to increased training in the growing subspecialty field of interventional pulmonology (32,33). Generally, the need for specialized equipment and training amongst auxiliary staff and the need for experienced anesthesiologists limits the availability of rigid bronchoscopy to more specialized tertiary care centers.

The widespread availability of flexible bronchoscopy confers some benefits over rigid bronchoscopy. The procedure can be performed under moderate sedation. The small size and maneuverability have led to flexible bronchoscopy becoming the method of choice for retrieving foreign bodies found in peripheral airways. Newly developed ultrathin bronchoscopes allow operators to reach even further out in the periphery of the lung (34).

### Anesthetic considerations

The approach to anesthesia for therapeutic bronchoscopy, including the need for general anesthesia and invasive airway management is impacted by the clinical presentation of the patient, the type of object aspirated and the radiographic findings. In retrospective studies containing children and adults with foreign airway body findings without severe dyspnea or central airway obstruction, topical anesthetics and agents for moderate sedation (diazepam, midazolam, fentanyl) were sufficient for the

flexible bronchoscopy approach (35,36). For patients with both clinical or radiographic suggestion of central airway obstruction, or where there was potential for risk of airway injury, the use of general anesthesia and invasive airway management (laryngeal mask airway or endotracheal tube) was generally more common (35,37,38).

The presence of the cough and gag reflex during spontaneous ventilation can assist the repulsion of foreign airway bodies but can also hinder manipulation of the target. A retrospective study by Littman et al assessing the impact of spontaneous ventilation versus the use of neuromuscular blockade in 94 cases found no impact upon overall morbidity and mortality (39). For patients undergoing rigid bronchoscopy, observational studies have demonstrated that the use of manual jet ventilation directly through the rigid bronchoscope decreases the duration of intraoperative hypoxemia.

### Bronchoscopy tools

There are several commercially available tools compatible with flexible bronchoscopes available for use during foreign body extraction, each with advantages in specific clinical scenarios and with particular types of aspirated materials (Table 1). Essentially all of these tools require removal with the tool, foreign body and bronchoscope *en bloc* as most foreign bodies requiring bronchoscopic removal are too large to be suctioned through the working channel of the flexible bronchoscope.

#### Grasping forceps

Both smooth forceps and forceps with teeth are commonly used to secure the edge of foreign bodies for removal. Smooth forceps are available with bare metallic forceps or forceps coated with rubber for additional grip. They are designed to grasp and maneuver smooth, narrow, and nonmalleable objects. Most major manufacturers recommend use for narrow and sharp items such as needles and pins. Forceps lined with teeth come in three variants: “alligator”, “rat tooth”, and combined rat tooth with alligator jaw. The use of rat-tooth forceps is particularly useful for solid objects which can be at least partly encompassed between the hinge and the teeth of the forceps. In nearly every large retrospective study where the type of tool was documented the majority of items were retrieved using some type of grasping forceps (35,58-60).

**Table 1** Clinical pearls for distinct aspirated items based on clinical experience and reported findings

Item	Clinical pearls
Bone	<p>Consider rigid bronchoscopy for retrieval to limit upper airway injury</p> <p>Even for smaller bones, the presence of mucosal trauma supports the use of rigid bronchoscopy (40)</p> <p>Granulation tissue may be encountered, requiring endoscopic treatment (10,40)</p> <p>Forceps are often sufficient for removal, however for larger bones, adjunctive techniques to break apart the bone such as Nd-YAG laser can be considered (41)</p>
Seeds	<p>Flexible bronchoscopy has a very high success rate (42,43)</p> <p>Cryoprobe can be considered for removal of larger seeds (44)</p>
Meat	<p>Multiple tools are often required for complete removal (7,9,23)</p> <p>Cryoprobes may aid in extraction of friable aspirated meat products (45)</p>
Dental and airway prosthetics	<p>Flexible bronchoscopy with grasping tools are frequently successful in aiding retrieval (43,46-49)</p> <p>For larger prosthetics or those with sharp edges should consider general anesthesia with rigid bronchoscopy</p>
Medication pill	<p>Alendronate and ferrous sulfate are associated with increased local mucosal inflammation and granulation tissue formation (50)</p> <p>Large tablets, such as potassium chloride, have the potential for obstruction (51)</p> <p>Flexible bronchoscopy is usually sufficient for removal, however care should be taken to use grasping tools that do not break apart the pill (e.g., rubber tip forceps or nets) (52)</p>
Battery	<p>Ingestion of disk or button cell battery occurs quite frequently, but aspiration is infrequently reported (53)</p> <p>Using data derived from ingestion of battery acid, mucosal injury or burn from battery acid can occur within 2–3 h of ingestion (54)</p> <p>Tools less likely to impact the structural integrity of the battery are recommended (e.g., nets) (55)</p> <p>Based on the chronicity after aspiration, serious fistulas have been reported, often requiring multidisciplinary management (55,56)</p>
Needles or sharp narrow objects	<p>For smaller objects flexible bronchoscopy can be performed but rigid bronchoscopy should be considered strongly (5,57)</p> <p>Whenever possible the sharp tip should be grasped with forceps on removal to limit mucosal injury (5)</p>

This table summarizes unique methods for removing distinct types of foreign bodies based on our own clinical experience as well as from techniques described in peer reviewed literature.

### Baskets

Baskets are composed of four or more metallic wires that open when extended to allow positioning around objects then narrow when pulled back into the deployment sheath. They are designed to be placed around smooth, spherical, or spheroid objects that are too large to grasp and maneuver with forceps. In a retrospective study with 20 patients, Kim *et al.* described removing various inorganic and organic objects, mostly comprising of spherical features, at a 90%

success rate (61).

### Nets

Nets used during bronchoscopy are typically deployed through a deployment sheath and close when the distal end of the net is partly retracted into the sheath. They are designed for large, irregular objects. They require significant amount of maneuvering and thus are relegated to objects in the central airway.

### *Snares*

Snares are comprised of a thin flexible wire that can tighten around the mid-section of foreign bodies for removal. They can be used for irregularly shaped objects though generally work best on more solid objects. They need some room for manipulation and thus are better suited for objects in the central airways. Several retrospective studies attest to successful object retrieval with snares, mainly in the central airway (49,59).

### *Fogarty balloon*

The Fogarty balloon catheter is a small bore catheter with an inflatable tip of varying size which can be passed through the working channel of most flexible bronchoscopes. In the context of foreign body removal, it is often used to move objects from distal to central airways while preventing the object from moving distally into the airway. The catheter is first placed just distal to the object; the balloon is then inflated and the catheter is pulled proximally, pulling the object along with it. This technique was recently described by Hegde *et al.* in a retrospective series (62). The use of the Fogarty balloon catheter can help position a very distal foreign body in a more central airway where additional tools can be used for more definitive removal.

### *Cryoprobe*

The flexible cryoprobe consists of a catheter that conducts nitrous oxide gas and rapidly freezes at the tip on contact. The thermodynamic mechanism utilizes the Joule-Thomson effect, in which a liquid in transitory phase drastically cools from change in high pressure to low pressure. The cryoprobe catheter is insulated to prevent temperature equilibration, except at the very tip. Consequently, items touching the tip of the cryoprobe freeze almost immediately (63). The freezing effect is mostly effective on water-rich materials and is therefore ideally suited for organic foreign bodies including aspirated vegetables and meat. The rapid freezing causes immediate cell injury to organic tissue, by causing the formation of intracellular and extracellular crystals (64). Due to the need for water content within the target of the cryoprobe, the cryoprobe has limited effect on cartilage, providing some protective benefit to central airway structures. Once the object freezes and attaches to the probe, both are retracted in tandem and the object is

removed from the probe by re-warming the cryoprobe tip. There are several recent retrospective studies describing the use of cryoprobe in removing foreign bodies (65,66).

### **Post-operative care after foreign body removal from airway**

Much of the published data on post-operative management after foreign body removal comes from the pediatric population. In the majority of retrospective studies for foreign body removal, patients were admitted to the hospital post procedure for monitoring with pulse oximetry and supportive care (7,38,59). In retrospective studies, there is discrepancy as to whether the type of object impacts pulmonary symptoms and time to recovery. Some retrospective studies found organic items were associated with prolonged pulmonary symptoms and recovery (defined by more than one week), while others found no difference in outcomes based on the type of aspirated material (16,67). The presence of lung parenchymal changes prior to the procedure, from infiltrate to nonspecific inflammatory changes, were found to be predictive of prolonged symptoms and hospitalization in most studies (16,67,68). Similarly patients with persistently abnormal lung radiography post-procedure had prolonged symptoms and hospitalization, highlighting the importance of obtaining imaging post procedure to identify at-risk patients (67,69). Patients with post-obstructive bronchiectasis related to foreign bodies also had prolonged hospitalization and frequently warrant anti-inflammatory medications, bronchodilators, chest physical therapy and in rare circumstances antibiotic therapy (16). However, there are no standardized data regarding pharmacologic therapy. Patients with difficult to remove, friable foreign bodies, or procedural complications frequently have prolonged symptoms. Moreover, in patients with friable objects and persistent symptoms or new radiographic findings, residual material or associated complications such as mucous plugging or fibrotic material were found on repeat bronchoscopy (7,70). Repeating bronchoscopy thus should be considered, especially in aspirated material which is more difficult to remove in a single setting. Beyond common respiratory symptoms, a high-risk adverse event noted in most large retrospective analyses in the pediatric population is laryngospasm, reported in anywhere from 10–60 percent of subjects (68,69,71). Careful post-operative monitoring is therefore critical to minimize morbidity after removal of airway foreign bodies.



## Conclusions

Incidents of foreign body aspiration into the airway are less common in adults but remain a complex condition to manage. Clinical symptoms are often vague, especially in the adult population. Pre procedural planning and collaboration between airway specialists play central role in object extraction. Moreover, familiarity with the different types of bronchoscopy methods and tools are warranted for the most effective foreign body retrieval.

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