Bronchoscopy for Foreign Body Removal

13

Erik Folch and Adnan Majid

Abstract

Suspected airway foreign body aspiration is an important indication for bronchoscopy. The clinical presentation of airway foreign body aspiration varies from asymptomatic and incidental finding to acute and life-threatening central airway obstruction. Most cases of foreign body aspiration are encountered in children and elderly patients. Several comorbid conditions such as alcohol intoxication, dementia, and other chronic neurological disorders increase the risk of foreign body aspiration. A high index of suspicion is essential in order to avoid delay in diagnosis. Bronchoscopy is the gold standard for diagnosis and management of patients with suspected aspiration of foreign bodies. Rigid bronchoscope is superior to flexible bronchoscope in removal of large airway foreign bodies, especially in pediatric patients. However, due to lack of training and expertise in rigid bronchoscopy, it is usual to employ flexible bronchoscope for airway foreign body removal, especially in adult patients. Several accessory instruments are available to facilitate removal of foreign objects from the airways using flexible bronchoscope. In recent years, the cryoprobe has become a useful adjunct for removal of organic foreign bodies. Experienced and skillful operators are able to remove the majority of airway foreign bodies using the flexible scope. In this chapter, we discuss the clinical presentation, accessory instruments, and technical aspects of airway foreign body removal using flexible bronchoscope.

E. Folch, M.D., M.Sc. • A. Majid, M.D., F.C.C.P. (✉)
Division of Thoracic Surgery and Interventional Pulmonology, Beth Israel Deaconess Medical Center, Harvard Medical School, 185 Pilgrim Road, Deaconess 201, Boston, MA 02215, USA
e-mail: efolch@bidmc.harvard.edu; amajid@bidmc.harvard.edu

A.C. Mehta and P. Jain (eds.), *Interventional Bronchoscopy: A Clinical Guide*, Respiratory Medicine 10,
DOI 10.1007/978-1-62703-395-4_13,

Keywords

Airway foreign body • Foreign body aspiration • Rigid bronchoscopy • Pediatric airway foreign body

Introduction

The use of bronchoscopy in its rigid and flexible forms has become the standard for the diagnosis and treatment of patients with foreign body aspiration [1]. The debate whether to use flexible or rigid bronchoscope frequently depends on local resources and expertise. The advantages of rigid bronchoscopy include better protection of the airway and ability to use tools that allow removal of large foreign bodies (FB), thus making it the safer technique for FB removal. In children, rigid bronchoscope with or without adjuvant flexible bronchoscope is often needed for successful removal of airway foreign bodies. However, in the United States the availability of operators trained in rigid bronchoscopy is highly variable [2–4] and for this reason in adult patients, flexible bronchoscopy with moderate sedation is frequently employed for FB removal from airways [5], as it is more widely available. Unfortunately, even the expertise, skill, and the facilities for flexible bronchoscopy and the accessory instruments needed for foreign body retrieval may not be available in smaller institutions or in many centers in the developing world. In this situation, an early referral to tertiary care centers is recommended for timely removal of aspirated foreign body.

Aspiration of foreign bodies occurs most commonly in the young and the elderly. Several risk factors for foreign body aspiration have been identified (Table 13.1). Although it is not uncommon for patients to present with nonspecific symptoms, a detailed history and physical examination, as well as chest imaging, are invaluable (Table 13.2). Occasionally, the patient will not recall the event and a high index of suspicion is needed to establish diagnosis in a timely fashion. Not surprisingly, in a significant number of patients the diagnosis can only be made through direct visualization with a bronchoscope. In the majority of these cases, the removal can be accomplished during the initial bronchoscopic procedure.

It is important to realize that each case of foreign body aspiration follows a different clinical course. The variables include the type of object and its location in the airway, time interval from aspiration to removal, and host's reaction to the

Table 13.1 Risk factors for foreign body aspiration in adults

Alcohol intoxication
Sedative or hypnotic drug use
Poor dentition
Senility
Mental retardation
Parkinson's disease
Primary neurologic disorders with impairment of swallowing or mental status
Trauma with loss of consciousness
Seizure
General anesthesia
Zenker's diverticulum

Table 13.2 Signs and symptoms of foreign body aspiration

History of choking episode
Chronic cough
Unilateral decrease in breath sounds
Atelectasis
Unilateral hyperinflation
Recurrent pneumonia
Unilateral or bilateral wheezing
Hemoptysis
Pneumothorax
Pneumomediastinum
Subcutaneous emphysema
Bronchiectasis
Lung abscess
Pleuritic chest pain

foreign body. The physical characteristics of the object, the clinical presentation, and the expertise of the bronchoscopist will also determine the ultimate outcome. For both patient and bronchoscopist, foreign body removal can be a very rewarding procedure, as the success rate is high and the complication rate is low.

Still, the removal of airway foreign body using bronchoscope remains a challenging task. In this chapter, we discuss the principles of diagnosis and removal of airway FB and provide a pathway that can be adapted to the specific setting, available local expertise, and technology.

Clinical Presentation

In adults, the swallowing reflex protects the airway from aspiration of foreign bodies. Whenever this protective mechanism fails, the cough reflex, which is reliably forceful, will likely be responsible for the self-resolution of most episodes of airway foreign body aspiration.

The clinical presentation of foreign body aspiration is highly variable, from trivial to life threatening, depending on the location and size of the object (Table 13.2). For example, even a small object will cause significant irritation and cough if it is located in the vicinity of the vocal cords, whereas a moderate size or occlusive object in the distal airway of the adult may cause only cough and obstructive pneumonitis. Therefore, a high degree of suspicion is critical in identifying patients at risk and when in doubt, a proactive approach will prevent serious future complications [6]. Approximately one-third of all objects are located proximal to the glottis after an episode of choking. These are usually large and can easily occlude the larynx. Patients, if alert, will present with severe cough, choking, hoarseness, and gagging.

In children, a witnessed or a reported episode of choking is the most common presentation. In some instances, children with foreign body aspiration present in extremis, and are found to have a radio-opaque object or unilateral hyperinflation on radiograph. On the other hand, in adults, aspiration of foreign bodies usually presents with chronic cough in the absence of a history of choking [7]. In acute episodes, Baharloo et al. described a "penetration syndrome" in which the patients present with sudden onset of choking and intractable cough with or without vomiting with less common symptoms being cough, fever, dyspnea, and wheezing [8]. It is important to remember that 39 % of patients with a foreign body aspiration will have no physical findings [9], and chest radiograph may be normal in 6–38 % of patients [9–15]. A significant, but unknown, number of patients expectorate the foreign body before presenting to the hospital, and some objects are even swallowed.

In the presence of a suggestive clinical scenario of aspiration, approximately 50 % of children with a history of choking have no foreign body in their airways. In these cases, it is difficult to determine whether the FB was ever aspirated or whether it is the result of spontaneous coughing out or swallowing of the foreign body.

Location

The majority of aspirated FB in adults tends to lodge in the right lower lobe. This is not seen in children as the size of the left main bronchus, and the angle of branching, is not acute, as is the case in adults [8, 16].

Mechanism

It is proposed that an inspiratory suction force frequently used while eating with chopsticks, drinking soup, or sucking on plant material may be responsible for propelling the food towards the epiglottis and predisposing to aspiration [17–19]. In the case of children, the use of incisors can propel the object into the retro-pharynx. Their natural curiosity during the oral phase as well as the habit of crying, laughing, and playing during meals are responsible for the increased incidence of FB aspiration among young children [5, 18].

Timeline

The time interval from aspiration to medical evaluation is variable among patients. Several authors describe a longer lag time for adults when compared to children. The average delay in presentation and diagnosis is also shorter for inorganic as compared with the organic foreign body aspiration [8]. Clearly, the timeliness of diagnosis also depends on the experience and clinical acumen of the clinician.

Radiologic Evaluation

The chest radiograph is often the initial diagnostic test whenever FB aspiration is suspected.

Most aspirated objects are radiolucent, thus limiting the role of standard X-rays for diagnosis. However, the use of inspiratory and expiratory films may show subtle signs such as air trapping, atelectasis, mediastinal shift, or pulmonary infiltrates that may suggest airway FB aspiration. In published studies, chest radiograph has a sensitivity of 70–82 %, specificity of 44–74 %, positive predictive value of 72–83 %, and negative predictive value of 41–73 % for detection of airway foreign bodies [11, 12]. Therefore, the presence of a radiopaque object on chest radiograph is diagnostic, but the normal or the subtle chest X-ray findings do not exclude the diagnosis and should be interpreted with caution in the context of the clinical history. In fact, whenever the possibility of foreign body aspiration is considered in the differential diagnosis, the clinician should have low threshold to advise the bronchoscopic examination, which is the cornerstone of the diagnostic workup in such patients.

In children, the presence of pneumomediastinum or subcutaneous emphysema should also alert the clinicians to consider the possibility of a foreign body aspiration [20, 21]. Lateral neck films revealing a subglottic density or swelling may suggest the presence of laryngotracheal foreign body [22]. The presence of a calcified foreign body on X-rays suggests the possibility of a previously missed airway foreign body or a broncholith, as vegetable materials in the airways can calcify over time [23].

In chronic obstruction, the computed tomography (CT) of the chest can show the late complications of FB aspiration, which include bronchial stenosis, bronchiectasis, endobronchial masses, or granulation tissue. The use of MRI to identify peanut aspiration has been described [24–26]. The presence of fat within the peanut produces a high signal on T1-weighted imaging. Sometimes the presence of mucus in the airway mimics the clinical and radiological features of airway foreign body. However, mucus on computed tomography appears to have a low-attenuation, bubbly appearance, in the dependent airways, and frequently can be mobilized by forceful coughing [27].

Recently, the use of virtual bronchoscopy (VB) in the diagnosis of suspected foreign body aspiration in 60 children was investigated [28]. The multidetector CT generated virtual bronchoscopy and demonstrated a lesion suggestive of foreign body in 40 cases and 33 objects were identified and removed with bronchoscopy. The authors suggest that VB can be used to determine the presence and localization of an FB, which can help with pre-procedural planning. In this series, foreign body was not detected on rigid bronchoscopy in any of the seven patients who had a negative VB, suggesting a high negative predictive value of VB in evaluation of airway FB. Unfortunately, virtual bronchoscopy is not therapeutic and is not available in most hospitals. It may also delay necessary interventions. A report from Sudan highlights the reach of computed tomography airway reconstruction as a diagnostic tool in centers that lack bronchoscopic equipment [29].

It is important to remember that both in children and adults, aspirated foreign bodies are frequently misdiagnosed as croup, recurrent laryngitis, asthma, recurrent pneumonia, or primary airway tumors, leading to unnecessary and inappropriate diagnostic and therapeutic interventions [30, 31].

Aspiration in Children

When compared to adults, children have a significantly higher rate of aspiration events, and life-threatening complications. The incidence of aspiration is highest from 1 to 3 years of age as curiosity and independent exploration expose infants to small objects in the prime of the oral phase [8]. This is coupled with poor airway protection mechanisms and forceful propulsion of the object to the retro-pharynx after biting with the incisors. Furthermore, children may cry, laugh, and play while attempting to swallow. The most common aspirated objects among children are peanuts, seeds, small foods, or toys.

Aspiration in Adults

The type of foreign bodies aspirated by adults vary widely and in many instances reflect cultural and lifestyle variations. The most common cause of aspiration in adults is meat [32]. However, a significant number of cases have retention of the foreign particle at the level of the glottis, which is coughed or amenable to postural drainage. Other common food particles aspirated by adults include nuts, pumpkin seeds [33], melon seeds [34, 35], watermelon seeds [35], dental fixtures, dental fillings, coins, safety pins, ear plugs, glass, fragments of tracheostomy tubes [36], and medication tablets [37] among others (Fig. 13.1). In the United States, the aspiration of nails and pins is seen in healthy young adult males [38, 39]. In Middle Eastern countries, the aspiration of prayer beads, worry beads, and pins are relatively common [35, 40, 41]. Notably, aspiration of foreign bodies in adults is seen in all age groups, but is most common in elderly patients with dental problems, swallowing difficulties, and altered mental status or dementia (Table 13.1). Some case series show a significant number of cases of aspiration of bones contained in food [42]. Aspiration of foreign bodies has also been described during medical or dental procedures

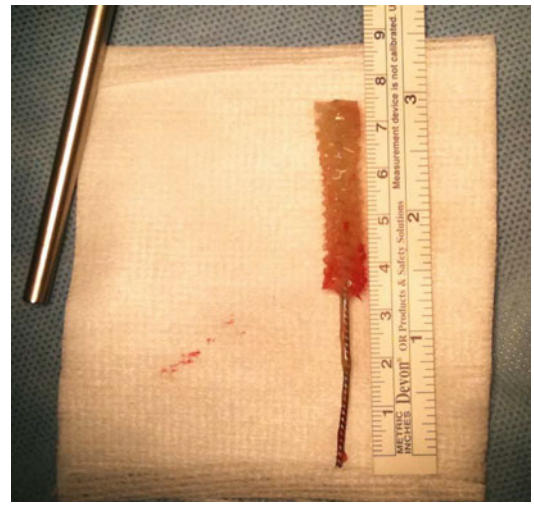

Fig. 13.1 Successful removal of tracheostomy brush accidentally aspirated during cleaning

such as esophagogastroduodenoscopy with band ligation [43].

Success Rates

Bronchoscopy is the frontline procedure for retrieval of airway foreign bodies. Several studies suggest high rates of success, 97–99 %, particularly when using a combination of rigid and flexible bronchoscope. Table 13.3 summarizes several studies of flexible and rigid bronchoscopy use for removal of foreign bodies. This list is not exhaustive and is just a representative sample of the published evidence.

All airway foreign bodies cannot be retrieved with rigid or flexible bronchoscopy. Failure to remove foreign bodies in some instances is related to deep impaction of FB in the airway that is not amenable to balloon dislodgement. Other cause is an externally impaled object, such as metal debris after an explosion [42]. Interestingly, several reports include failed initial bronchoscopies at outside institutions or by less experienced bronchoscopists that were later successful [8, 42], which attests to the importance of experience and proper training in this procedure.

Table 13.3 Case series of airway foreign body removal by flexible and rigid bronchoscopy

Author	Flexible(F), rigid(R), or both(B)	Total number of patients (*N*)	Successful removal	% of Success
Hiller [91]	F	7	6	86
Cunanan [92]	F	300	267	89
Clark [93]	F	3	3	100
Nunez [94]	F	17	12	71
Lan [95]	F	33	32	97
Limper [50]	F	23	14	61
Chen [18]	F	43	32	74
Moura e sa [96]	F	2[a]	2[a]	100
Ali Ali [41]	F	16	9	57
Gencer [40]	F	23	21	91
Debeljak [42]	B	63	61	97
Donado Uña [97]	F	56	53	95
Baharloo [8]	R	112	103	92
Kalyanappagol [98]	R	206	206	100
Lima [99]	?	83	83	100
Blanco-Ramos [100]	B	32	24	75
Saki [87]	R	967	967	100
Oguzkaya [101]	R	500	498	99
Rahbarimanesh [102]	R	44	44	100
Metrangelo [103]	R	70	70	100
Martinot [11]	R	40	40	100
Chik [104]	R	27	27[b]	100
Yetim [105]	R	38	37	97
Tang [106]	F	1027	938	91
Boyd [107]	F	20	18	90
Weissberg [108]	R	66	55	83
Zhijun [109]	R	1428	1424	99
Paşaoğlu	R	639	639	100
Skoulakis [110]	R	130	130	100
Maddali [111]	R	140	140	100
Kiyan [112]	R	153	153	100

[a]Two cases of a series of 77 patients in which the FB could not be removed with RB
[b]Four patients required repeated bronchoscopy for residual fragments

Therapeutic Approach to the Patient with Foreign Body Aspiration

All patients with suspected foreign body aspiration should remain in close observation until the diagnosis has been confirmed or excluded, and the foreign material has been removed. Even clinically stable patients can have a sudden change in their condition as a result of migration of the object, or occurrence of complications such as bleeding, or pneumothorax [44, 45].

The likelihood and extent of tissue reaction increase the longer a foreign body remains in the airway [13, 46, 47]. The delay in starting the procedure can only be justified in order to coordinate the necessary personnel and equipment, or to facilitate prompt transfer to another institution with capabilities to deal with foreign body aspiration. It is important to remember that during the first 24 h, the endobronchial mucosa suffers mild inflammation, erythema, and granulation tissue formation [13]. However, the degree of inflammatory response depends on the content of

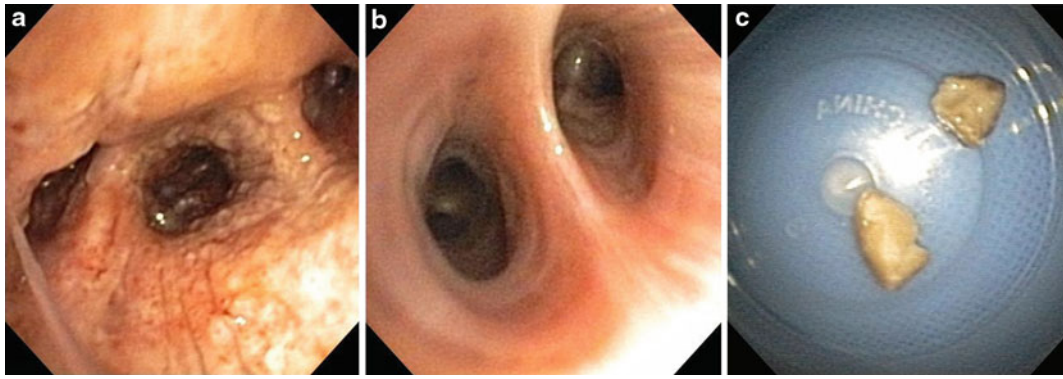

Fig. 13.2 (**a**) Localized endobronchial inflammation as a result of peanut aspiration (**b**) shows normal unaffected airways on the same patient. (**c**) Successful removal of two peanuts from the bronchi showing inflammatory changes

the FB aspirated. Nuts, peanuts, and grass are particularly irritating. Our group has removed peanuts and other nuts with various degrees of granulation tissue formation (Fig. 13.2). Unfortunately, the humid environment of the airways increases the probability of the peanuts to fragment and occlude the airways distally.

The overall management can be broken down into postural drainage, rigid bronchoscopy, and flexible bronchoscopy. Many accessory instruments specifically designed to facilitate retrieval of airway foreign body are available. In recent years, cryoprobe has emerged as the most suitable method for removal of organic material as discussed below.

Non-endoscopic Therapies

Bronchodilator inhalation and postural drainage are not recommended in the initial management of foreign body aspiration as proximal migration of the object may lead to cardiopulmonary arrest in a small percentage of patients [48]. A delay in proceeding to bronchoscopy increases the risk of complications such as pneumonia, atelectasis, and cardiopulmonary arrest while decreasing the likelihood of successful bronchoscopic removal. At least one clinical trial of bronchodilator inhalation and postural drainage for the treatment of FB aspiration has described cardiopulmonary arrest, while others have pointed out the potential for extended hospital stay and more complications with the use of such protocols [46, 48, 49].

Another technique seldom employed is the use of therapeutic percussion while the patient coughs. Nevertheless, despite anecdotal reports of success, these efforts should never delay a clearly safer and more effective therapeutic maneuver such as rigid or flexible bronchoscopy.

In patients with foreign bodies located in the oropharynx, it is important to have access to a Magill forceps since it facilitates extraction [5].

Rigid Bronchoscopy

In the most recent series, the reported success rate using rigid bronchoscopy for removal of aspirated foreign bodies is between 95 and 99 % [33–35, 44, 47, 50, 51]. The rigid bronchoscope offers several advantages. These include ability to maintain adequate ventilation, better visualization, and superior suctioning capabilities. With appropriate technique and under general anesthesia, rigid bronchoscopy is safe and effective while providing maximal comfort to the patient. A wide variety of instruments such as optical forceps, alligator forceps, four-prong hooks, baskets, cryotherapy probes, and several types of balloons are available for FB retrieval using rigid bronchoscope. The type and location of FB should dictate the type of instrument employed. In some instances more than one

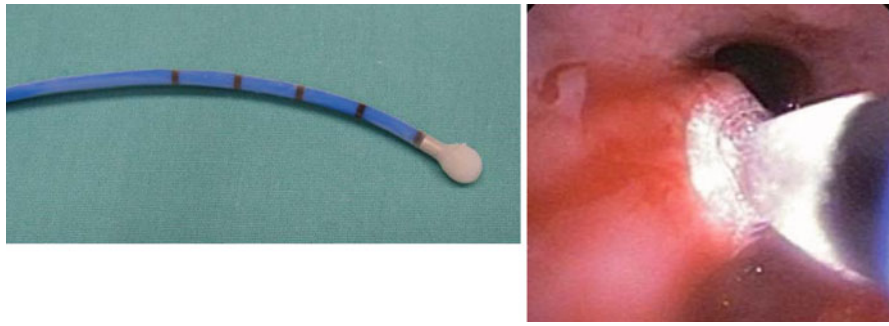

Fig. 13.3 Cryoprobe and application in benign airway disease

instrument may be needed for successful removal of airway foreign body. The rigid bronchoscope is particularly useful in the removal of sharp objects. However, several series describe successful removal of pins with the flexible bronchoscope [40, 41].

Unfortunately, rigid bronchoscopy is not widely available and only practiced by 4–8 % of pulmonologists in the United States [2–4].

Flexible Bronchoscopy

In the evaluation of foreign body aspiration in adults, the flexible bronchoscope is the usual initial diagnostic tool. Whenever foreign body is suspected, flexible bronchoscope should be introduced via oral route. A comprehensive examination is essential in every case because sometimes the foreign object is not immediately obvious to the examiner. This difficulty arises in some cases because the FB is covered by blood or granulation tissue. Less frequently, the foreign object is fragmented and is located in more than one distal airway.

Once the object type, size, and location have been identified, removal can be attempted. Whenever removal is attempted, several instruments should be readily available, ideally including a rigid bronchoscope. Instruments that have been developed for removal of FB through flexible bronchoscope include flexible forceps, ragged-tooth forceps, snares, Dormia basket, fishnet basket, cryotherapy probes (Fig. 13.3), balloon catheters (Fogarty), and magnet extractor.

A successful removal with the flexible bronchoscope spares the patient of a subsequent rigid bronchoscopy and its associated cost. Several reports attest to the successful application of the flexible bronchoscope to remove foreign bodies. These reports show a success rate of >90 % in experienced hands [42, 52, 53]. The list of FB removed is extensive and includes teeth, windscreen glass, earplugs, pins, nails, fish bone, peanuts, coins, and endodontic needles [40, 41, 54–59].

Some authors recommend the use of an endotracheal tube when removing some objects with flexible bronchoscope in order to minimize the injury risk to the upper airway [42].

Intense debate surrounds the use of flexible or rigid bronchoscope for removal of foreign bodies in the literature, partly fueled by the personal preference and individual expertise, and partly from the available instruments and technology at the time of such debate. It is the opinion of the authors that flexible bronchoscopy has acquired paramount importance in the diagnosis and removal of foreign bodies in adults. Rigid bronchoscope has an important complementary role and should be readily available whenever an FB removal is planned [2, 42, 60]. It is essential for all operators who use flexible bronchoscope to retrieve airway FB to understand the potential consequences of a failed procedure. Not every pulmonologist who performs flexible bronchoscopy is comfortable managing the potential consequences of a failed procedure. When in doubt, it is best to stabilize the patient and refer to an institution that has expertise in both flexible and rigid bronchoscopy.

Anesthesia and Analgesia

The flexible bronchoscope allows removal of the foreign body with local anesthesia under moderate sedation, unlike the rigid bronchoscope, which is performed under general anesthesia. An advantage of performing foreign body removal with moderate sedation is that it preserves the cough reflex, which can further facilitate the removal. An object brought forward to the trachea by bronchoscopic techniques can often be coughed out on command given to the patient.

The fact that foreign body removal by flexible bronchoscopy is done with moderate sedation and without a secure airway has led to much criticism. There has been some concern about the possibility of losing the object in a narrow subglottic area leading to potential asphyxiation. To our knowledge, no incident of this kind has been reported in the medical literature. Notwithstanding, in the rare event of this occurring, immediate intubation—either with bronchoscopic guidance or with a direct laryngoscope—can always be performed to secure the airway. Varying sizes of endotracheal tubes (ETT) and laryngoscopes should be readily available in most bronchoscopy suites for the rare happenstance of this complication occurring with bronchoscopy. Extraction can then proceed via ETT. Another approach (aside from emergent intubation) would be to reintroduce the flexible bronchoscope and push the foreign body into the distal airways, thus clearing up the upper-airway obstruction.

In difficult cases, when moderate sedation cannot be achieved adequately, proceeding with rigid bronchoscopy under general anesthesia is the best option. In those instances where the object is too distal and inaccessible to removal with the rigid bronchoscope, the foreign body can be removed with a flexible bronchoscope introduced via the ETT or the rigid barrel. When the object is larger than the diameter of the tube, the ETT or the rigid barrel may need to be withdrawn in conjunction with the bronchoscope and the secured foreign body [61, 62]. This should be followed by prompt reintubation and repeat inspection of the airway. An alternative to the use of ETT with general anesthesia is the laryngeal mask airway [63]. Flexible bronchoscopy can be performed with reasonable airway control even with deeper sedation [64, 65]. Recent experience with fospropofol, a prodrug of propofol, has proven it to be safe and effective during flexible bronchoscopy [66]. Interestingly, fospropofol is not a general anesthetic, and has distinct pharmacokinetic and pharmacodynamic characteristics and should not require anesthesia monitoring [67]. However, its use in therapeutic bronchoscopic procedures is yet to be described.

In children, there is no consensus on anesthesia. However, a very large review of 12,979 patients found that induction with maintenance of spontaneous ventilation is commonly practiced to minimize the risk of converting a partial proximal obstruction to a complete obstruction. Adequate ventilation combined with intravenous drugs and paralysis allows for appropriate rigid bronchoscopy conditions and a desired level of anesthesia [68].

Accessories for the Flexible Bronchoscope

Multiple instruments for the removal of foreign bodies with the flexible bronchoscope are available. The instrument of choice is largely dictated by the location, type of foreign body, and the accompanying host tissue reaction.

Grasping Forceps

The forceps is the most widely available and used instrument. These have different designs including a wide range of cup sizes and shapes, rotation mechanisms, presence or absence of teeth, and accessories such as central fenestrations or needles. Among the grasping forceps are the w-shaped, alligator jaw, rat-tooth, shark-tooth, and covered-tip forceps.

The selected forceps should have a jaw size large enough to enclose the full diameter of the foreign body. In cases where a firm grip is needed to prevent a hard object from slipping the alligator jaws, rat-tooth or shark-tooth

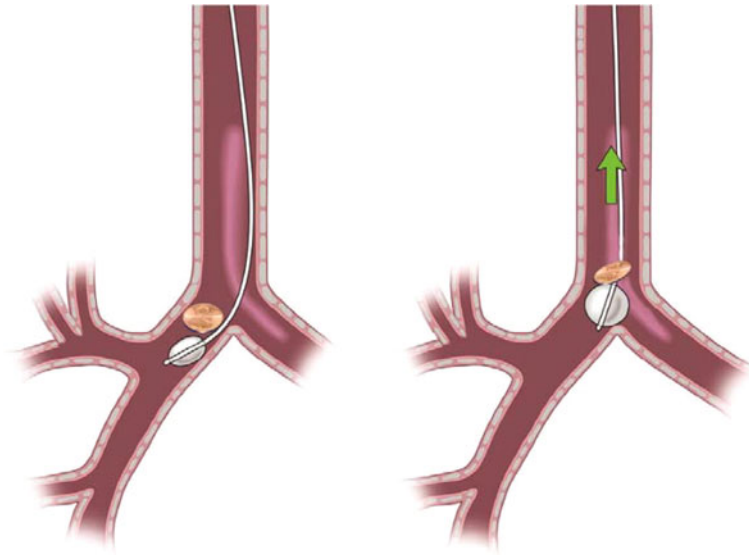

Fig. 13.4 Fogarty balloon catheter used as an aid to move foreign bodies to proximal airways

forceps are recommended. For more delicate manipulations, a w-shaped or a covered-tip forceps may be used. In general, grasping forceps are only used for the removal of flat or thin inorganic (e.g., coins, pins, screws, clips) or hard organic objects (e.g., bone), as attempted removal of friable organic foreign body will cause it to fracture, disintegrate, and disperse into the distal airways.

Balloon Catheters

Inflatable balloon catheters are probably the most useful but clearly underutilized tool available for removal of foreign objects (Fig. 13.4). Although there are a few commercially available, the Fogarty catheter remains the most frequently used. It has different sizes (4–7 F) and can be passed through the working channel of the flexible bronchoscope. The catheter is advanced distal to the object, then the balloon is inflated with 1–3 cc of saline, and the catheter is pulled until the object is dislodged proximally to facilitate removal.

Dormia Basket

A modified version of the Dormia basket used by gastroenterologists and urologists for the removal of calculi from the common bile duct and bladder is also available for the bronchoscopic removal of foreign bodies in the airway. The wings of the basket are normally retracted within a 1.6 mm diameter Teflon catheter. The basket is opened in the airway and maneuvered to allow its "wings" to surround and entrap the foreign body. The basket is most useful in the removal of large and bulky objects.

Fishnet Basket

The fishnet basket is a modified version of a polypectomy snare, in which a mesh of thin thread is attached to the snare wire for easy folding and unfolding (Fig. 13.5). The net is normally retracted within the catheter for easy passage through the channel of the flexible bronchoscope. When the snare is advanced, the fishnet is slowly released to surround the object. The snare is then

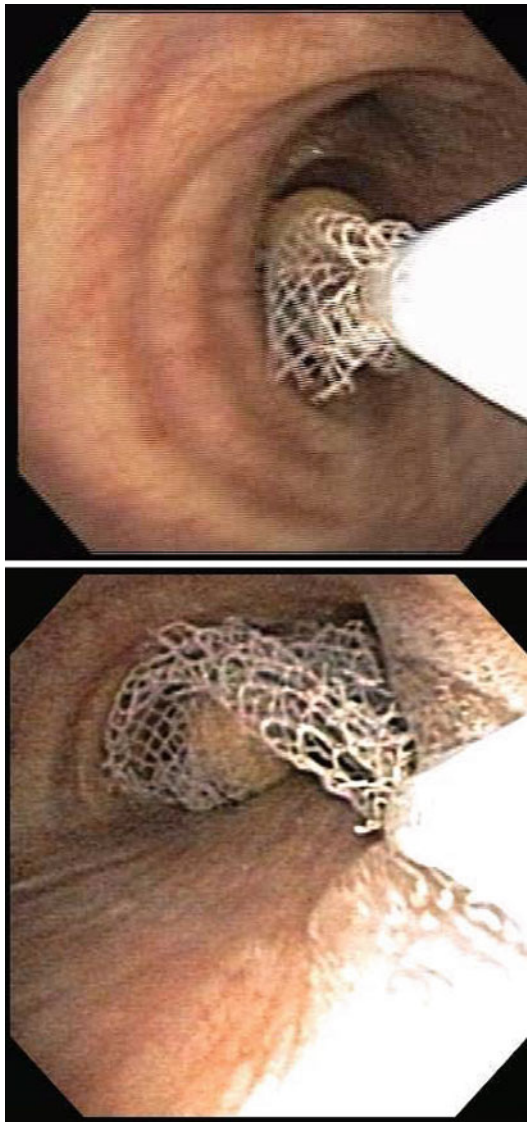

Fig. 13.5 Endoscopic use of fishnet basket to remove foreign body

slowly retracted to enclose the foreign object within the fishnet. Once this is accomplished, the basket, the captured object, and the bronchoscope are then removed as a unit. This fishnet basket is also most useful in the removal of bulky objects.

Three- or Four-Prong Snares

The snares are usually squeezed together inside the catheter. Whenever they are deployed, the snares are released surrounding the foreign object. When the operator squeezes the handle of the device, the prong's distal ends come together capturing the object. Once secured, the foreign body, snare, and flexible bronchoscope are withdrawn carefully as a single unit. Because the prongs are very flimsy, it is not advisable to use this accessory in the removal of hard, solid objects.

Magnet Extractor

A magnetic extractor consists of a flexible probe with a magnetic cylinder at its tip. This accessory is specially designed for passage through the working channel of the flexible bronchoscope. Small and mobile metallic foreign bodies, such as broken forceps or cytology brushes, can be removed easily with this instrument [69, 70].

Cryotherapy Catheter

The adhesive properties of the cryoprobe make it an ideal instrument for the removal of foreign bodies rich in water content. The system has a cryogen tank (e.g., nitrous oxide or nitrogen) that by rapid gas-decompression or principle of Joule–Thomson generates an extremely low temperature (−15 to −40 °C) at the tip of the specially designed cryoprobe (Fig. 13.3). When the cryoprobe is placed in direct contact with the object, the two become attached and the operator then removes the flexible bronchoscope along with the cryoprobe and the foreign body. This technique is extremely useful for the removal of blood clots, mucus balls, organic materials, and small inorganic objects [71].

In our experience, this is one of the most useful instruments for the removal of organic materials. We recently removed a fragmented peanut from the airway of a 2-year-old through the combined use of rigid bronchoscope, pediatric flexible bronchoscope, and pediatric cryoprobe.

The bronchoscopist should be careful to keep a clear field of view in order to prevent contact with the surrounding mucosa, and to inadvertently remove attached normal tissue.

Removal with the Flexible Bronchoscope

Whenever foreign body aspiration is suspected, the flexible bronchoscopy is performed through the oral route, in order to avoid the narrow nasal passage [72]. Initially, a thorough airway exam should be done, starting with the unaffected lung. The suspicious area of aspiration is examined last. This thorough and careful exam is done to assure that there is only one foreign object, or that fragments have not been dispersed to other airways. When the object is visualized, the shape and structure of the foreign body in relation to the surrounding areas are carefully examined before an extraction attempt is made. The entire foreign body may not be visible bronchoscopically and a review of radiologic films may be necessary during the procedure to determine the position of the unseen portion. The appropriate bronchoscopic accessory is then determined based on the size, shape, position, and density of the object.

Whenever the flexible bronchoscope is used, utmost care should be taken not to push the object farther down the airway. In general, we use the Fogarty balloon to dislodge the foreign body and to bring it proximally to the trachea, before attempting removal [54]. The Fogarty balloon catheter is positioned distal to the object. The balloon is then inflated and the foreign body is pulled out from the segmental or the lobar airways to the trachea (Fig. 13.4). Once in the trachea, the object is easily amenable to removal. We have often asked the patient to sit up and cough up the foreign body once it has been dislodged to the upper trachea. We usually employ this technique for small and soft objects and have had successful results in approximately 90 % of our cases.

The key to successfully removing a foreign body lies in being able to adequately secure the object by either grasping or enclosing it with the bronchoscopic accessory. Once the object is snared or trapped, all three (bronchoscope, grasping instrument, and object) are removed simultaneously from the patient as a unit. During removal, the bronchoscopist must make every attempt to continuously visualize the object and keep it in the center of the airway. Removal of a sharp object is a challenging task. The key to removing this type of object is to locate the sharp end and to attempt its dislodgement. Once the sharp end is freed, the object can be grabbed and removed. Grasping the shaft or the other end of a pointed instrument increases the difficulty of removal because this will most likely be caught in the mucosa.

Similarly, difficulty is also encountered when the tissue reaction surrounding the foreign body interferes with the removal process. Sometimes the surrounding granulation tissue has to be cleared prior to removal of the object. In some of these cases, bronchoscopic removal under general anesthesia may be necessary. Sometimes ablative therapies such as laser photoresection may help vaporize the surrounding granulation tissue. Laser may also be used to break a larger FB into smaller and more manageable pieces that can be easily removed with the bronchoscopic techniques [73–75]. Other modalities, such as bronchoscopic electrocautery, can also be used to similarly vaporize surrounding granulation tissue. Some authors suggest the use of a short course of steroids prior to removal of airway foreign bodies although the efficacy of this practice remains untested [14, 76].

Massive hemoptysis is a rare complication of foreign body removal and is better controlled with rigid bronchoscopy [74]. Whenever hemoptysis does occur, our practice is to instill an epinephrine solution (1:10,000 to 1:20,000) through the bronchoscope to achieve topical vasoconstriction with decrease in blood flow and eventual thrombosis of the bleeding vessels. We also find cold saline (4 °C) instillation to be effective in bleeding cessation. Cold saline causes hypothermic

vasoconstriction and eventual thrombosis of the bleeding vessel.

Elusive Foreign Body Aspirations

Almost everyone who has significant experience with foreign body removal can describe a case in which the foreign body was not found, lost during the removal at the mouth, or seems to have disappeared after it was seen on radiologic imaging. The most common cause is spontaneous expectoration of the foreign body without patient's knowledge. However, it is very important to do a thorough airway examination for small fragments of the original object, or for missing objects. Whenever removed, the object should preferably be sent for pathologic analysis as some have described the presence of concomitant malignancy as an incidental finding on pathologic samples [18]. And then there is the case of the dissolved aspirated pill. Lee et al. have described a case of iron pill aspiration that was not found on bronchoscopy 2 months after the aspiration event, but endobronchial biopsies confirmed the residue of iron being responsible for severe granulation tissue [37]. A recent report by Parray et al. also describes the migration of a foreign body from the right to the left [77].

About Multidisciplinary Teams

It has been our experience as well as that of others [11, 42] that an excellent working relationship with specialists from pulmonary, otolaryngology, and thoracic surgery is an asset that expedites and improves favorable outcomes in the management of airway foreign bodies.

Rare Cases Where the Object is Left Behind

The medical literature has a few case reports where the foreign object was left behind due to the inability to be removed or the clinical deterioration of the patient that prompted the interruption of the foreign body removal [78]. Although these situations may happen, we would like to emphasize that the long-term complications of foreign objects in the airway warrant that every effort should be made to guarantee its removal, including referral to a specialized center. In extraordinarily rare cases, the patient would expectorate the foreign body left behind [79]. Also, in rare cases, the unsuccessful endoscopic removal is followed by a surgical approach [80].

Respiratory Equipment Malfunction Causing Foreign Body Aspiration

Unfortunately, the progress of respiratory therapy and mechanical ventilation has been accompanied by an increase in the number of cases of aspiration of foreign bodies. Examples of this include aspiration of intubation stylets [81], suction catheters [81, 82], and tracheostomy brushes (Fig. 13.1).

Aspiration of Medication Tablets

A relatively more common occurrence is the aspiration of pills in the airway. The consequences of such events can be dramatic, and due to the quick expansion of the tablet when humidification occurs, it can cause acute airway obstruction as has been described with sucralfate [83]. In other cases, the medication can quickly dissolve and have long-term consequences due to inflammation and fibrosis as those described with iron tablet aspiration [37]. Our group recently reported experience with two cases, with metformin and pomegranate tablets [84].

Complications of Foreign Body Aspiration

The aspiration of foreign bodies carries a high risk of short- and long-term complications. All of these have been extensively described in the literature and include acute respiratory failure and asphyxia

[72], pneumonia, empyema [85], atelectasis, cardiopulmonary arrest, hemoptysis, granulation tissue formation, laryngeal edema, pneumothorax, pneumomediastinum, tracheobronchial rupture, trachea-esophageal fistula, bronchial stricture, localized bronchiectasis [86], mediastinitis, lung torsion [18], and anoxic brain injury [87]. An interesting report by Aziz [85] demonstrated the potential cascade of events leading from a foreign body aspiration including airway obstruction, post-obstructive pneumonia, and empyema.

The Case for ECMO and Foreign Body Aspiration

Treatment of near-fatal foreign body aspiration treated with ECMO has been reported in the medical literature [88, 89]. Recently, a complicated bronchoscopic removal of a foreign body required ECMO support due to worsening respiratory failure in the setting of purulent secretion aspiration and overwhelming sepsis [90]. Although rarely used, these cases support the advantages of rapid referral to specialized airway centers, whenever it is clinically feasible.

Conclusions

The clinical presentation of aspirated foreign bodies may vary from an asymptomatic and incidental finding to an acute and life-threatening airway obstruction. Regardless, removal of foreign bodies from tracheobronchial tree should always be attempted in order to relieve the current symptoms and to prevent future complications. Bronchoscopy remains the premier diagnostic as well as therapeutic option in these patients. Most experts would agree that rigid bronchoscopy is more effective than flexible bronchoscopy in removing large airway foreign bodies. In pediatric population, rigid bronchoscope is clearly preferred over flexible bronchoscope. Unfortunately, the facilities for rigid bronchoscopy are seldom available due to lack of training and expertise. Therefore, in practical terms, flexible bronchoscope is the most commonly employed tool for retrieval of airway foreign bodies in adults. In the hands of experienced and skillful operators, the majority of airway foreign bodies can be retrieved using flexible bronchoscopy techniques. It is essential for the operators to be familiar with a variety of accessory instruments that are available to facilitate removal of airway foreign bodies. Failure to remove foreign body with the flexible bronchoscope should be promptly followed by rigid bronchoscopy. Early referral to a tertiary care center is indicated if such facility is not locally available.

References

1. Rafanan AL, Mehta AC. Adult airway foreign body removal. What's new? Clin Chest Med. 2001;22:319–30.
2. Prakash UB, Offord KP, Stubbs SE. Bronchoscopy in North America: the ACCP survey. Chest. 1991;100:1668–75.
3. Tape TG, Blank LL, Wigton RS. Procedural skills of practicing pulmonologists. A national survey of 1,000 members of the American College of Physicians. Am J Respir Crit Care Med. 1995;151:282–7.
4. Colt HG, Prakash UBS, Offord KP. Bronchoscopy in North America: survey by the American Association for Bronchology, 1999. J Bronchol. 2000;7:8–25.
5. Marquette CH, Martinot A. Interventional bronchoscopy. Basel: Karger; 2000.
6. Paksu S, Paksu MS, Kilic M, et al. Foreign body aspiration in childhood: evaluation of diagnostic parameters. Pediatr Emerg Care. 2012;28:259–64.
7. al-Majed SA, Ashour M, al-Mobeireek AF, al-Hajjaj MS, Alzeer AH, al-Kattan K. Overlooked inhaled foreign bodies: late sequelae and the likelihood of recovery. Respir Med. 1997;91:293–6.
8. Baharloo F, Veyckemans F, Francis C, Biettlot MP, Rodenstein DO. Tracheobronchial foreign bodies: presentation and management in children and adults. Chest. 1999;115:1357–62.
9. McGuirt WF, Holmes KD, Feehs R, Browne JD. Tracheobronchial foreign bodies. Laryngoscope. 1988;98:615–8.
10. Mantor PC, Tuggle DW, Tunell WP. An appropriate negative bronchoscopy rate in suspected foreign body aspiration. Am J Surg. 1989;158:622–4.
11. Martinot A, Closset M, Marquette CH, et al. Indications for flexible versus rigid bronchoscopy in children with suspected foreign-body aspiration. Am J Respir Crit Care Med. 1997;155:1676–9.
12. Hoeve LJ, Rombout J, Pot DJ. Foreign body aspiration in children. The diagnostic value of signs, symptoms and pre-operative examination. Clin Otolaryngol Allied Sci. 1993;18:55–7.

13. Wiseman NE. The diagnosis of foreign body aspiration in childhood. J Pediatr Surg. 1984;19:531–5.
14. Banerjee A, Rao KS, Khanna SK, et al. Laryngotracheo-bronchial foreign bodies in children. J Laryngol Otol. 1988;102:1029–32.
15. Pasaoglu I, Dogan R, Demircin M, Hatipoglu A, Bozer AY. Bronchoscopic removal of foreign bodies in children: retrospective analysis of 822 cases. Thorac Cardiovasc Surg. 1991;39:95–8.
16. Cleveland RH. Symmetry of bronchial angles in children. Radiology. 1979;133:89–93.
17. Casson AG, Guy JR. Foreign-body aspiration in adults. Can J Surg. 1987;30:193–4.
18. Chen CH, Lai CL, Tsai TT, Lee YC, Perng RP. Foreign body aspiration into the lower airway in Chinese adults. Chest. 1997;112:129–33.
19. Case records of the Massachusetts General Hospital. Weekly clinicopathological exercises. Case 33-1997. A 75-year-old man with chest pain, hemoptysis, and a pulmonary lesion. N Engl J Med. 1997;337:1220–6.
20. Burton EM, Riggs Jr W, Kaufman RA, Houston CS. Pneumomediastinum caused by foreign body aspiration in children. Pediatr Radiol. 1989;20:45–7.
21. Nimrey-Atrash N, Bentur L, Elias N. Subcutaneous emphysema and pneumomediastinum due to foreign body aspiration in children with asthma. Pediatr Pulmonol. 2012;47:88–90.
22. Esclamado RM, Richardson MA. Laryngotracheal foreign bodies in children. A comparison with bronchial foreign bodies. Am J Dis Child. 1987;141:259–62.
23. Shepard JA. The bronchi: an imaging perspective. J Thorac Imaging. 1995;10:236–54.
24. Imaizumi H, Kaneko M, Nara S, Saito H, Asakura K, Akiba H. Definitive diagnosis and location of peanuts in the airways using magnetic resonance imaging techniques. Ann Emerg Med. 1994;23:1379–82.
25. Kitanaka S, Mikami I, Tokumaru A, O'Uchi T. Diagnosis of peanut inhalation by MRI. Pediatr Radiol. 1992;22:300–1.
26. O'Uchi T, Tokumaru A, Mikami I, Yamasoba T, Kikuchi S. Value of MR imaging in detecting a peanut causing bronchial obstruction. AJR Am J Roentgenol. 1992;159:481–2.
27. Marom EM, Goodman PC, McAdams HP. Focal abnormalities of the trachea and main bronchi. AJR Am J Roentgenol. 2001;176:707–11.
28. Cevizci N, Dokucu AI, Baskin D, et al. Virtual bronchoscopy as a dynamic modality in the diagnosis and treatment of suspected foreign body aspiration. Eur J Pediatr Surg. 2008;18:398–401.
29. Salah MT, Hamza S, Murtada M, Salma M. Delayed diagnosis of foreign body aspiration in children. Sudanese J of Public Health. 2007;2:48–50.
30. Atmaca S, Unal R, Sesen T, Kilicarslan H, Unal A. Laryngeal foreign body mistreated as recurrent laryngitis and croup for one year. Turk J Pediatr. 2009;51:65–6.
31. Barben J, Berkowitz RG, Kemp A, Massie J. Bronchial granuloma—where's the foreign body? Int J Pediatr Otorhinolaryngol. 2000;53:215–9.
32. Mittleman RE, Wetli CV. The fatal cafe coronary. Foreign-body airway obstruction. JAMA. 1982;247:1285–8.
33. Daniilidis J, Symeonidis B, Triaridis K, Kouloulas A. Foreign body in the airways: a review of 90 cases. Arch Otolaryngol. 1977;103:570–3.
34. Abdulmajid OA, Ebeid AM, Motaweh MM, Kleibo IS. Aspirated foreign bodies in the tracheobronchial tree: report of 250 cases. Thorax. 1976;31:635–40.
35. Elhassani NB. Tracheobronchial foreign bodies in the Middle East. A Baghdad study. J Thorac Cardiovasc Surg. 1988;96:621–5.
36. Yapici D, Atici S, Birbicer H, Oral U. Manufacturing defect in an endotracheal tube connector: risk of foreign body aspiration. J Anesth. 2008;22:333–4.
37. Lee P, Culver DA, Farver C, Mehta AC. Syndrome of iron pill aspiration. Chest. 2002;121:1355–7.
38. Clancy MJ. Bronchoscopic removal of an inhaled, sharp, foreign body: an unusual complication. J Laryngol Otol. 1999;113:849–50.
39. Vander Salm TJ, Ellis N. Blowgun dart aspiration. J Thorac Cardiovasc Surg. 1986;91:930–2.
40. Gencer M, Ceylan E, Koksal N. Extraction of pins from the airway with flexible bronchoscopy. Respiration. 2007;74:674–9.
41. Al-Ali MA, Khassawneh B, Alzoubi F. Utility of fiberoptic bronchoscopy for retrieval of aspirated headscarf pins. Respiration. 2007;74:309–13.
42. Debeljak A, Sorli J, Music E, Kecelj P. Bronchoscopic removal of foreign bodies in adults: experience with 62 patients from 1974–1998. Eur Respir J. 1999;14:792–5.
43. Betancourt M, Bekteshi E, Toth J, Alam S. Foreign body aspiration during esophagogastroduodenoscopy with band ligation. J Bronchol Intervento Pulmonol. 2008;15:204–5.
44. Kosloske AM. Bronchoscopic extraction of aspirated foreign bodies in children. Am J Dis Child. 1982;136:924–7.
45. Kosloske AM. Tracheobronchial foreign bodies in children: back to the bronchoscope and a balloon. Pediatrics. 1980;66:321–3.
46. Law D, Kosloske AM. Management of tracheobronchial foreign bodies in children: a reevaluation of postural drainage and bronchoscopy. Pediatrics. 1976;58:362–7.
47. Steen KH, Zimmermann T. Tracheobronchial aspiration of foreign bodies in children: a study of 94 cases. Laryngoscope. 1990;100:525–30.
48. Bose P, El Mikatti N. Foreign bodies in the respiratory tract. A review of forty-one cases. Ann R Coll Surg Engl. 1981;63:129–31.
49. Cotton EK, Abrams G, Vanhoutte J, Burrington J. Removal of aspirated foreign bodies by inhalation

and postural drainage. A survey of 24 cases. Clin Pediatr (Phila). 1973;12:270–6.
50. Limper AH, Prakash UB. Tracheobronchial foreign bodies in adults. Ann Intern Med. 1990;112:604–9.
51. Hsu W, Sheen T, Lin C, Tan C, Yeh T, Lee S. Clinical experiences of removing foreign bodies in the airway and esophagus with a rigid endoscope: a series of 3217 cases from 1970 to 1996. Otolaryngol Head Neck Surg. 2000;122:450–4.
52. Surka AE, Chin R, Conforti J. Bronchoscopic myths and legends: airway foreign bodies. Clin Pulm Med. 2006;13:209–11.
53. Swanson KL, Prakash UB, MdCougall JC, Midthun DE, Edell ES, Brutinel MW, et al. Airway foreign bodies in adults. J Bronchol. 2003;10:107–11.
54. Heinz 3rd GJ, Richardson RH, Zavala DC. Endobronchial foreign body removal using the bronchofiberscope. Ann Otol Rhinol Laryngol. 1978;87:50–2.
55. Mehta AC, Grimm M. Breakage of Nd-YAG laser sapphire contact probe inside the endobronchial tree. Chest. 1988;93:1119.
56. Fieselmann JF, Zavala DC, Keim LW. Removal of foreign bodies (two teeth) by fiberoptic bronchoscopy. Chest. 1977;72:241–3.
57. Klayton RJ, Donlan CJ, O'Neil TJ, Foreman DR. Letter: foreign body removal via fiberoptic bronchoscopy. JAMA. 1975;234:806.
58. Lee M, Fernandez NA, Berger HW, Givre H. Wire basket removal of a tack via flexible fiberoptic bronchoscopy. Chest. 1982;82:515.
59. Rohde FC, Celis ME, Fernandez S. The removal of an endobronchial foreign body with the fiberoptic bronchoscope and image intensifier. Chest. 1977; 72:265.
60. Prakash UB, Midthun DE, Edell ES. Indications for flexible versus rigid bronchoscopy in children with suspected foreign-body aspiration. Am J Respir Crit Care Med. 1997;156:1017–9.
61. Downey RJ, Libutti SK, Gorenstein L, Mercer S. Airway management during retrieval of the very large aspirated foreign body: a method for the flexible bronchoscope. Anesth Analg. 1995;81: 186–7.
62. Verea-Hernando H, Garcia-Quijada RC, Ruiz de Galarreta AA. Extraction of foreign bodies with fiberoptic bronchoscopy in mechanically ventilated patients. Am Rev Respir Dis. 1990;142:258.
63. Rodrigues AJ, Scussiatto EA, Jacomelli M, et al. Bronchoscopic techniques for removal of foreign bodies in children's airways. Pediatr Pulmonol. 2012;47:59–62.
64. Hirai T, Yamanaka A, Fujimoto T, Shiraishi M, Fukuoka T. Bronchoscopic removal of bronchial foreign bodies through the laryngeal mask airway in pediatric patients. Jpn J Thorac Cardiovasc Surg. 1999;47:190–2.
65. McGrath G, Das-Gupta M, Clarke G. Bronchoscopy via continuous positive airway pressure for patients with respiratory failure. Chest. 2001;119:670–1.
66. Silvestri GA, Vincent BD, Wahidi MM, Robinette E, Hansbrough JR, Downie GH. A phase 3, randomized, double-blind study to assess the efficacy and safety of fospropofol disodium injection for moderate sedation in patients undergoing flexible bronchoscopy. Chest. 2009;135:41–7.
67. Jantz MA. The old and the new of sedation for bronchoscopy. Chest. 2009;135:4–6.
68. Fidkowski CW, Zheng H, Firth PG. The anesthetic considerations of tracheobronchial foreign bodies in children: a literature review of 12,979 cases. Anesth Analg. 2010;111:1016–25.
69. Saito H, Saka H, Sakai S, Shimokata K. Removal of broken fragment of biopsy forceps with magnetic extractor. Chest. 1989;95:700–1.
70. Mayr J, Dittrich S, Triebl K. A new method for removal of metallic-ferromagnetic foreign bodies from the tracheobronchial tree. Pediatr Surg Int. 1997;12:461–2.
71. De Weerdt S, Noppen M, Remels L, Vanherreweghe R, Meysman M, Vincken W. Successful removal of a massive endobronchial blood clot by means of cryotherapy. J Bronchol. 2005;12:23–4.
72. Mehta AC. Nasal versus oral insertion of the flexible bronchoscope. J Bronchol. 1996;3:224–8.
73. Boelcskei PL, Wagner M, Lessnau KK. Laser-assisted removal of a foreign body in the bronchial system of an infant. Lasers Surg Med. 1995;17:375–7.
74. Rees JR. Massive hemoptysis associated with foreign body removal. Chest. 1985;88:475–6.
75. Hayashi AH, Gillis DA, Bethune D, Hughes D, O'Neil M. Management of foreign-body bronchial obstruction using endoscopic laser therapy. J Pediatr Surg. 1990;25:1174–6.
76. Bolliger CT, Mathur PN. Interventional bronchoscopy. Basel: Karger; 2000.
77. Parray T, Abraham E, Apuya JS, Ghafoor AU, Saif Siddiqui M. Migration of a foreign body from right to left lung. Internet J Anesthesiol. 2010;24.
78. Mohnssen SR, Greggs D. Iatrogenic aspiration of components of respiratory care equipment. Chest. 1993;103:964–5.
79. Pinals M, Pinals D, Tracy JD, Brandstetter RD. Expectoration of an occult foreign body six asymptomatic years after aspiration. Chest. 1993;103: 1930–1.
80. Karapolat S. Foreign-body aspiration in an adult. Can J Surg. 2008;51:411; author reply -2.
81. Mohnssen SR. Iatrogenic aspiration. Follow-up. Chest. 1994;105:976.
82. Iannuzzi M, De Robertis E, Rispoli F, Piazza O, Tufano R. A complication of a closed-tube endotracheal suction catheter. Eur J Anaesthesiol. 2009;26:974–5.
83. Overdahl MC, Wewers MD. Acute occlusion of a mainstem bronchus by a rapidly expanding foreign body. Chest. 1994;105:1600–2.
84. Kinsey CM, Folch E, Majid A, Channick C. Evaluation and management of pill aspiration: case discussion. In: 17th World Congress for bronchol-

ogy and interventional pulmonology, Cleveland, OH; 2012.
85. Aziz F. Natural history of an aspirated foreign body. J Bronchol. 2006;13:161–2.
86. James P, Christopher DJ, Balamugesh T, Thomas R. Multiple foreign body aspiration and bronchiectasis. J Bronchol. 2006;13:218–20.
87. Saki N, Nikakhlagh S, Rahim F, Abshirini H. Foreign body aspirations in infancy: a 20-year experience. Int J Med Sci. 2009;6:322–8.
88. Brown KL, Shefler A, Cohen G, DeMunter C, Pigott N, Goldman AP. Near-fatal grape aspiration with complicating acute lung injury successfully treated with extracorporeal membrane oxygenation. Pediatr Crit Care Med. 2003;4:243–5.
89. Ignacio Jr RC, Falcone Jr RA, Brown RL. A case report of severe tracheal obstruction requiring extracorporeal membrane oxygenation. J Pediatr Surg. 2006;41:E1–4.
90. Isherwood J, Firmin R. Late presentation of foreign body aspiration requiring extracorporeal membrane oxygenation support for surgical management. Interact Cardiovasc Thorac Surg. 2011;12:631–2.
91. Hiller C, Lerner S, Varnum R, et al. Foreign body removal with the flexible fiberoptic bronchoscope. Endoscopy. 1977;9:216–22.
92. Cunanan OS. The flexible fiberoptic bronchoscope in foreign body removal. Experience in 300 cases. Chest. 1978;73:725–6.
93. Clark PT, Williams TJ, Teichtahl H, Bowes G, Tuxen DV. Removal of proximal and peripheral endobronchial foreign bodies with the flexible fibreoptic bronchoscope. Anaesth Intensive Care. 1989;17:205–8.
94. Nunez H, Perez Rodriguez E, Alvarado C, et al. Foreign body aspirate extraction. Chest. 1989;96:698.
95. Lan RS, Lee CH, Chiang YC, Wang WJ. Use of fiberoptic bronchoscopy to retrieve bronchial foreign bodies in adults. Am Rev Respir Dis. 1989; 140:1734–7.
96. Moura e Sa J, Oliveira A, Caiado A, et al. Tracheobronchial foreign bodies in adults—experience of the Bronchology Unit of Centro Hospitalar de Vila Nova de Gaia. Rev Port Pneumol. 2006;12:31–43.
97. Donado Una JR, de Miguel Poch E, Casado Lopez ME, Alfaro Abreu JJ. Fiber optic bronchoscopy in extraction of tracheo-bronchial foreign bodies in adults. Arch Bronconeumol. 1998;34:76–81.
98. Kalyanappagol VT, Kulkarni NH, Bidri LH. Management of tracheobronchial foreign body aspirations in paediatric age group—a 10 year retrospective analysis. Indian J Anaesth. 2007;51:20–3.
99. Lima AG, Santos NA, Rocha ER, Toro IF. Bronchoscopy for foreign body removal: where is the delay? Jornal Brasileiro de Pneumologia: Publicacao Oficial da Sociedade Brasileira de Pneumologia e Tisilogia. 2008;34:956–8.
100. Ramos MB, Fernandez-Villar A, Rivo JE, et al. Extraction of airway foreign bodies in adults: experience from 1987–2008. Interact Cardiovasc Thorac Surg. 2009;9:402–5.
101. Oguzkaya F, Akcali Y, Kahraman C, Bilgin M, Sahin A. Tracheobronchial foreign body aspirations in childhood: a 10-year experience. Eur J Cardiothorac Surg. 1998;14:388–92.
102. Rahbarimanesh A, Noroozi E, Molaian M, Salamati P. Foreign body aspiration: a five-year report in a children's hospital. Iran J Pediatr. 2008;18:191–2.
103. Metrangelo S, Monetti C, Meneghini L, Zadra N, Giusti F. Eight years' experience with foreign-body aspiration in children: what is really important for a timely diagnosis? J Pediatr Surg. 1999;34: 1229–31.
104. Chik KK, Miu TY, Chan CW. Foreign body aspiration in Hong Kong Chinese children. Hong Kong Med J. 2009;15:6–11.
105. Yetim DT, Bayarogullari H, Arica V, Akcora B, Arica SG, Tutanc M. Foreign body aspiration in children; analysis of 42 cases. J Pulmon Resp Med. 2012;2:121–5.
106. Tang LF, Xu YC, Wang YS, et al. Airway foreign body removal by flexible bronchoscopy: experience with 1027 children during 2000–2008. World J Pediatr. 2009;5:191–5.
107. Boyd M, Watkins F, Singh S, et al. Prevalence of flexible bronchoscopic removal of foreign bodies in the advanced elderly. Age Ageing. 2009;38: 396–400.
108. Weissberg D, Schwartz I. Foreign bodies in the tracheobronchial tree. Chest. 1987;91:730–3.
109. Zhijun C, Fugao Z, Niankai Z, Jingjing C. Therapeutic experience from 1428 patients with pediatric tracheobronchial foreign body. J Pediatr Surg. 2008;43: 718–21.
110. Skoulakis CE, Doxas PG, Papadakis CE, et al. Bronchoscopy for foreign body removal in children. A review and analysis of 210 cases. Int J Pediatr Otorhinolaryngol. 2000;53:143–8.
111. Maddali MM, Mathew M, Chandwani J, Alsajwani MJ, Ganguly SS. Outcomes after rigid bronchoscopy in children with suspected or confirmed foreign body aspiration: a retrospective study. J Cardiothorac Vasc Anesth. 2011;25:1005–8.
112. Kiyan G, Gocmen B, Tugtepe H, Karakoc F, Dagli E, Dagli TE. Foreign body aspiration in children: the value of diagnostic criteria. Int J Pediatr Otorhinolaryngol. 2009;73:963–7.