Flexible bronchoscopy in foreign body removal in the pediatric population: A Systematic Review

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Abstract

Background: Foreign body aspiration (FBA) in the tracheobronchial tree is a common problem in the pediatric population. Rigid bronchoscopic procedure is currently the gold standard method for treatment in pediatric patients, whereas recent reports present flexible bronchoscopy as an alternative method. The aim of this study was to summarize all available evidence regarding the application and the success rate of flexible bronchoscopy in foreign body (FB) removal. Methods: Systematic review of the use of flexible bronchoscopy as the first-line treatment in FBA cases in PubMed from 2001 to 2021. Results: Out of 243 citations, 23 studies were included on the use of flexible bronchoscopic procedure as a treatment of choice in 2,587 children with FBA. The FBs were successfully removed in 2,254/2,587 (87.1%) patients with a low complication rate. The majority of FBs retrieved were organic materials 1,073/1,370 (78.3%), and they were most commonly lodged in the right bronchial tree 708/1,401 (50.5%). General anesthesia was applied in most studies (14/23) before proceeding to a flexible bronchoscopy and laryngeal mask airways (LMAs) were mostly used (10/23 studies) to secure the airway during the procedure. Ancillary equipment, usually forceps 1,544/1808 (85.4%) assisted in the FB retrieval. Conclusion: The use of flexible bronchoscopy is shown to be a feasible and safe alternative therapeutic procedure in FBA cases. There is a need for development of extraction equipment and techniques to assist the procedure. Finally, future studies focusing on the comparison between clinical outcomes of flexible and rigid bronchoscopies are necessary.

Introduction

Foreign body aspiration (FBA) represents a common cause of emergency visits in the pediatric population. Foreign bodies (FBs) are reported in the literature as one of the most frequent causes of endobronchial obstructions in childhood[1]. Inhalation of a FB may lead to complications ranging from acute dyspnea/asphyxia and life-threatening airway obstruction to long-term adverse events, such as recurrent respiratory infections, coughing, wheezing, atelectasis, and bronchiectasis[2–7]. Late recognition of such cases is associated with increased morbidity and mortality, which indicates the crucial role of early diagnosis[4,8,9]. Children younger than 3 years old are mostly affected[10–13] with a predominance of males[4,14] to females, whereas organic materials, especially foods, represent the majority of aspirated FBs[4,7,14,15].

A high index of clinical suspicion is required in order to diagnose a FBA since an eyewitness to the aspiration episode is usually not present and pediatric patients are unable to communicate verbally[4,16]. The key clinical manifestation of a tracheobronchial FBA is the "penetration syndrome", which consists of acute onset of asphyxia, with stridor and cyanosis after an episode of choking and coughing that may potentially lead to respiratory failure[9,17,18]. However, the way of presentation in patients with FBA is highly variable, and often signs and symptoms are not specific. Physical examination may be normal or reveal signs, including stridor,

localized wheezing, or unilateral diminished breath sounds, which are of low sensitivity and specificity as they overlap with various pulmonary diseases[17,19–22]. In addition, radiological imaging studies may be helpful in achieving better diagnostic accuracy. When FBA is suspected, a chest X-ray may detect the FB itself (if radiopaque) or reveal indirect signs, which indicate a FBA (i.e. obstructive emphysema with air-trapping, atelectasis, and more rarely pneumothorax or pneumomediastinum). However, pathologic findings may be absent in both X-rays[14,16,23–25] and Chest CT[8]. Consequently, if history and clinical findings are suggestive of a FBA, physicians should not be deterred from performing a bronchoscopy, due to negative radiological findings[17,18,24].

Rigid bronchoscopic procedure is the current gold standard method for the treatment of FBA cases in the pediatric population[4,11,25,26]. Advantages of rigid bronchoscopy (RB), include the ability to control the airway and ventilate, the wide working channel of rigid bronchoscopes, and the availability of a variety of combined equipment[9,18]. On the contrary, rigid bronchoscopes are not available at all medical centers, general anesthesia[16,27] is necessary, and a significant degree of training and skill for the operator to become proficient are required[5,18]. Moreover, recorded complications associated with RB, although rare, include subglottic edema, tracheal laceration, bronchospasm, pneumothorax, pneumomediastinum, and hypoxic arrest[8,9,16,17,28,29].

Flexible bronchoscopes became available in the 1970s[26]and the first reported pediatric use was described in 1978 by Wood[30]. Ever since, flexible bronchoscope has been used as a tool, in both diagnostic and therapeutic procedures, for various diseases of the respiratory system[31]. Common indications to perform flexible bronchoscopic procedures include chronic cough, wheezing, recurrent croup or pneumonia. Regarding its abilities, they include -but are not limited to- the dynamic view of the upper and lower airway, the collection of bronchoalveolar lavage, and the performance of transbronchial or endobronchial procedures[32,33]. The use of flexible airway endoscopy in suspected FBA cases was included by the American Thoracic Society (ATS) in the Official Statement on Flexible Endoscopy of Pediatric Airways regarding the frameworks and the standards of performing flexible bronchoscopy in children[34].

The aim of this study is to summarize all available evidence regarding the application and the success rate of flexible bronchoscopy in retrieving pediatric airway FBs.

Materials and methods

Data sources and search

This review was performed under the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines[35]. The review protocol was not registered in any database. We performed a literature search in the PubMed database from 2001 through 2021 (the last day of the search was October 9$^{\text{th}}$, 2021). We applied the following search term algorithm in PubMed: ("foreign body" OR "foreign bodies" OR "tracheobronchial foreign body" OR "tracheobronchial foreign bodies" OR aspiration) AND (removal OR extraction OR treatment OR management) AND (fibrobronchoscopy OR fibro-bronchoscopy OR "flexible bronchoscopy" OR "fiberoptic bronchoscopy" OR "flexible bronchoscope" OR "fiberoptic bronchoscope" OR "fiber-optic bronchoscope" OR "fiber-optic bronchoscopy") AND (pediatric OR child* OR infant* OR neonat*). Additionally, references of included articles were subsequently also searched for potentially relevant articles.

Study selection

Articles were eligible for inclusion, provided they fulfilled the following criteria: (1) inclusion of more than 10 pediatric patients (2) population age was [?]18 years old (3) inclusion of patients with proven FBA, independent of the time interval between inhalation and examination (4) use of flexible bronchoscopy alone or combined with ancillary equipment as the first-line treatment (5) included extractable data regarding the success rate of flexible bronchoscopy.

Exclusion criteria were as follow: studies that used flexible bronchoscopy for diagnostic purposes or cases in which RB was part of the performed treatment of choice. Studies providing insufficient data to assess

the success rate of flexible bronchoscopies carried out to extract FBs from the pediatric airway and studies published in languages other than English were also excluded.

Outcomes

The primary outcome was the success rate of the flexible bronchoscopic procedure in removing an aspirated FB out of the pediatric airway. Success rate was defined in this study as the number of patients having airway FBs successfully removed using flexible bronchoscopy, independently of the number of tries needed, out of the total number of patients where flexible bronchoscopies were performed. Secondary outcomes included the following: the clinical decision algorithm for performing flexible bronchoscopy, the consistency of the removed FBs, the location of the FBs in the airway, the anesthetic and airway management techniques applied, ancillary equipment used in flexible bronchoscopy, and potential complications related to the flexible bronchoscopic procedure. The quality of evidence of included studies was assessed using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) algorithm[36].

Data extraction

Titles and abstracts of potentially included studies were independently assessed and reviewed by two of the authors (APC and SAK) using Rayyan[37]. Full texts publications of potentially relevant articles were retrieved and rescreened by the same two investigators. Disagreements were resolved by consensus with a third author (PP). Data were extracted by CAP and SAK, using an Excel® datasheet and included: author, year of publication, type of study, the geographic region the study was conducted, number and demographic characteristics of included population, the success rate of flexible bronchoscopic technique, and data regarding outcomes as defined above.

Results

Literature search

For this systematic review, we initially screened 242 non-duplicate citations; we excluded 178 and 64 articles were retrieved for full-text review. The study selection process is presented graphically in Figure1. Of these, 23 studies met our inclusion criteria[2–13,15,16,18,23,26,28,31,38–41]. The majority of the included studies were retrospective, apart from one[6] which was prospective. All studies were published between 2001 and 2021, whereas 17/23[2,3,7,8,10–13,15,16,18,23,28,38–41] were published during the last 5 years. Among the studies fulfilling the inclusion criteria, 5 [3,12,18,23,31] were conducted in Europe, 15 in Asia[2,4,5,7,8,10,11,13,15,16,28,38–41], 2 in North America[9,26], and 1 in Africa[6]. Most of the included studies were retrospective cohorts; thus, the overall quality of evidence was rated as low to very low[36].

Patients' characteristics

Data were available for 2,587 patients who underwent FB removal via flexible bronchoscopy (Table 1). The age of patients ranged from >1 month to [?]18 years. Information regarding gender was reported in 15/23[2,3,6–8,10–13,15,28,38–41] studies showing that the majority of included patients were males 738/1,179 (62.6%).

Success rate

Data regarding the success rate of flexible bronchoscopy in removing FBs from the pediatric airway in the included studies were available for 2,587 patients who had FBA. The FBs were successfully removed in 2,254/2,587 (87.1%) patients with success rate ranging from 10.7% to 100%[2–13,15,16,18,23,26,28,31,38–41].

Clinical decision for flexible bronchoscopy

Only 18 studies[3–11,13,15,18,23,28,31,38,39,41]reported clear reasoning on the decision to proceed with either flexible or rigid bronchoscopy as the first-line therapeutic method for the removal of FBs, as shown in Table 2. In the majority of the included studies, patients' stable clinical presentation played a key role in choosing flexible bronchoscopy as the first option. Reasons for non-performing flexible bronchoscopy included -but were not limited to- severe respiratory distress and asphyxiation[5,6,10,18,23]. Moreover, flexible bronchoscopies

were typically avoided in patients with aspirated FBs near the larynx, as the patency of the airway could not be guaranteed. Thus, these patients were treated directly with RB[5,6,10,18,23]. In 2 studies[13,18]the nature of the inhaled FBs (sharp objects) was the main criterion on the decision to proceed with RB. Another important factor was the experience of the clinicians with flexible bronchoscopy and ancillary equipment[28].

Foreign body characteristics

Nineteen studies reported data regarding the characteristics of 1,370 removed FBs[2,3,6–8,10–13,15,16,18,26,28,31,38–41]. The most common retrieved FBs were organic materials 1,073/1,370 of total FBs (78.3%). In 13 studies which included more specific data about the nature of organic materials, peanuts were the most common extracted FBs, representing 620/1,150 (53.9%)[2,3,6–8,11,12,15,26,31,39–41].

Location of FBA

Concerning the location in the airway where FBs were lodged, 20 studies[2,3,6–8,10–13,15,16,18,23,26,28,31,38–41]included data regarding 1,401 FBs. A FB in the bronchial tree (both right and left bronchial tree) was the most common finding in 1,093/1,401 (78%) of the cases. Among them, the most common placement was the right bronchial tree 708/1,401 (50.5%).

Anesthesia-Airway management

The anesthetic technique applied before proceeding to a flexible bronchoscopy was reported in 22 studies[2–13,15,16,18,23,26,28,31,38,39,41]. General anesthesia was the preferred method in 14 studies[3,6,8,9,11–13,15,16,18,23,26,31,39] whereas in the remaining 8 studies[2,4,5,7,10,28,38,41]bronchoscopies were performed under sedation.

Equipment used for securing the patency of the airway was reported in 17[2,3,6,8–13,15,16,18,26,28,38,39,41] studies. Laryngeal mask airways (LMAs) were used in 10 studies[3,6,9,11,13,16,28,38,39,41], endotracheal tubes in 3 studies[9,12,18], facemasks in 2 studies[8,26], and supraglottic airways in 1 study[15]. In 1 study "PhO2-NC-AC" ventilation was used[2].

Ancillary equipment used in flexible bronchoscopy

Data regarding ancillary equipment for the removal of FBs were reported in 15 of the studies[3,4,7,8,10–12,15,16,18,26,28,38–40] and 1,808 FBs. In 1,544/1,808 (85.4%) cases, FBs were extracted with the sole use of different types of forceps, whereas in 76/1,808 (4.2%) the FBs were extracted using only baskets. Detailed data concerning equipment and methods assisting the FB retrieval via flexible bronchoscopy are presented in Table 2.

Complications

Complications related to the flexible bronchoscopic procedure were reported in 18 studies that included 982 patients[2,5,6,8–13,15,16,18,26,28,38–41]. Adverse events directly related to flexible bronchoscopies were recorded as following; transient hypoxia 35/982 (3.6%), bleeding of the airway mucosa 26/982 (2.6%), laryngeal edema 20/982 (0.2%), bradycardia 10/982 (1%), bronchospasm 2/982 (0.2%), fever 2/982 (0.2%), and pneumothorax 1/982 (0.1%). In 5/982 (0.5%) cases the FB was either fragmented, partially removed or slipped into the oral cavity. Complications potentially related to the procedure (fever, mucosa damage/bleeding, granulation formation) were present in 17/982 cases (1.7%).

Discussion

In this study, we evaluated the role of flexible bronchoscopy in tracheobronchial FB removal in pediatric patients. FBs were successfully removed in 87.1% of cases with a low complication rate. The majority of FBs were organic materials and were most commonly lodged on the bronchial tree.

The flexible bronchoscopy success rate was comparable with that of studies of FB removal with the use of RB which had shown a success rate that ranged from 95% to 99%[14]. In 3 of the studies[5,23,31] included in our analysis, the success rates were 10.7%, 31.8%, and 43.5% respectively, whereas in the remaining studies

it ranged from 82.9% to 100%. This difference may be attributed[23,31] to the lack of appropriate removal techniques and ancillary equipment in some centres, as well as the increasing experience in the use of flexible bronchoscopy in others.

Regarding complications from flexible bronchoscopy, these were mainly described as mild, of short duration, and well responding to medical interventions such as oxygen supplementation, corticosteroids, and antibiotics. However, there was one case of pneumothorax[39], and two cases in which the FB was partially removed or segmented[11,15]. Moreover, potentially related complications to the procedure included secondary endobronchial infections presenting a few days after the procedure[6], and granulation tissue formation in the FB endobronchial location[11]. Our results corroborate findings from previous studies where flexible bronchoscopy showed minimal complication rates during or after the procedure[32,42]. On the contrary, RB is reported to have a complication rate ranging between 2% to 22%, frequently including serious complications such as pneumothorax[17,43]. Additionally, RB is more traumatic in the respiratory tract[16], which is deterring factor in performing multiple tries to remove a FB whenever this is needed for the successful removal of a FB.

Concerning FBs, organic materials, mainly peanuts, were the most commonly reported aspirated FBs. The vast majority of FBs were found in the bronchial tree over the central airway; more than half of the FBs were located in the right bronchial tree. These findings are in line with previous studies[14,44–46]. Organic materials may break into small pieces that may migrate deeper into the bronchial tree during the bronchoscopic procedure. Flexible bronchoscopy enables a more detailed and quicker inspection of the bronchial tree, allowing the potential simultaneous removal of multiple foreign bodies[3]. Moreover, due to its low diameter and flexibility, it provides access to distal locations which are not easily accessible with the rigid bronchoscope (like a deeper or grade III bronchus, the upper right or left bronchus, and the basal segments of the lower lobes)[32,42]. Furthermore, it allows a secure final detailed inspection of the bronchial tree after the FB extraction has been completed[8]. Hence, flexible bronchoscopy could be the first choice not merely for the evaluation but also the FB extractionespecially if the FB is lodged in a distal bronchus.

In this review, most of the studies (14/22)[3,6,8,9,11–13,15,16,18,23,26,31,39] reported general anesthesia being performed before flexible bronchoscopy whereas in 8 studies[2,4,5,7,10,28,38,41] only sedation was applied. This implies that flexible bronchoscopy can be conducted under both general anesthesia and sedation, whereas RB can only be conducted under general anesthesia[27]. Sedation could be the preferred method when an operating room is not available, the patient is hemodynamically stable, and gas exchange can be sufficiently maintained[34]. General anesthesia contrariwise permits better airway control and easier introduction of the bronchoscope providing muscle relaxation and steady bronchial caliber. Additionally, it enables the possible shift to RB if deemed necessary. Rigid bronchoscopes have the ability to secure the airway and therefore are preferred in cases of respiratory distress. On the other hand, additional equipment is needed to achieve airway management during flexible bronchoscopies such as endoscopy masks, supraglottic airways (SGA), endotracheal tubes (ETT), and laryngeal mask airways (LMAs)[27]. Specifically, the use of LMAs was reported in most (10/17) studies[3,6,9,11,13,16,28,38,39,41] in cases of non-asphyxiating FBs, probably because of the large caliber that ensures efficient ventilation and the passage of a wide variety of tools during the procedure, as well as the ability to remove LMA, FB, and bronchoscope at once[6]. Overall, it should be pointed out that collaboration of the bronchoscopist with the anesthesia or sedation provider is of the utmost importance in order to optimize anesthetic depth, airway management, and accurate FB removal.

Another important factor noted in our study is the use of ancillary equipment and methods combined with a flexible bronchoscope in order to achieve the extraction of FBs. Different types of forceps assisted the efforts of specialists[2–9,13,15,16,18,26,28,38,39,41], as well as various types of baskets[2,5,12,18,28,40,41], cryotherapy[7,10,11], and fluoroscopy[38]. Equipment and methods used were not always part of the procedures used in pediatric pulmonology, but were often originally used in other medical specialities such as urology[5,9,12,15,18], gastroenterology[15,18], and vascular surgery[16,39]. This variety of equipment underlines the need for specific tools to improve further the removal of FBs with flexible bronchoscopy in children.

The type of the available bronchoscope (rigid or flexible) in a medical center is a critical factor defining the procedure selection. Flexible bronchoscopes are more widely available in many centers compared to

rigid ones[16]. Additionally, the training level of specialists in using flexible and RB differs among medical centres[47]. The expertise of the operating physician is fundamental to avoid acute or chronic iatrogenic complications. Competencies required by a pediatric flexible airway endoscopist were suggested by the American Thoracic Society in 2015[34]. Regarding the team surrounding a skilled bronchoscopist it includes -but is not limited to- an experienced and multidisciplinary team consisting of an anesthesiologist and nursing staff. Harmonic communication and coordination between the staff involved contribute to a successfully completed procedure[27].

Limitations of our study should be taken into consideration when interpreting the results. The retrospective nature of the included studies could not preclude selection bias; five studies[2,4,9,31,39] included FBA cases before 2001, and in 1 study[12] the period of the interventions was not reported; clinicians did not follow the same algorithm in selecting the bronchoscopic procedure; the time interval between aspiration and treatment was not taken into consideration.

Our findings are in line with the ERS statement in 2017 on interventional bronchoscopy in children and shows the increasing interest in recent literature regarding the use of flexible bronchoscopes in the removal of FBs from the pediatric tracheobronchial tract[33]. Taking into account the high success and low complication rate, flexible bronchoscopy should be considered not only a feasible and safe method for diagnosis but also a valuable therapeutic procedure. The standardization of the equipment according to its technical characteristics is of great importance for the successful management of the different FBA cases. In this direction, medical centers should establish algorithms based on the availability of the equipment and the experience of their medical staff regarding the flexible bronchoscopic procedure.

In conclusion, this systematic review provides an overview of the existing literature on the successful removal rates of aspirated FBs in the pediatric population and describes the conditions under which flexible bronchoscopy could be chosen as a first-line treatment. Our findings highlight the need for future studies focusing on the comparison between clinical outcomes of flexible and rigid bronchoscopies in FBA cases and subsequently on developing an algorithm to assist clinical decisions. Finally, further evaluation of different equipment and extraction techniques is warranted.

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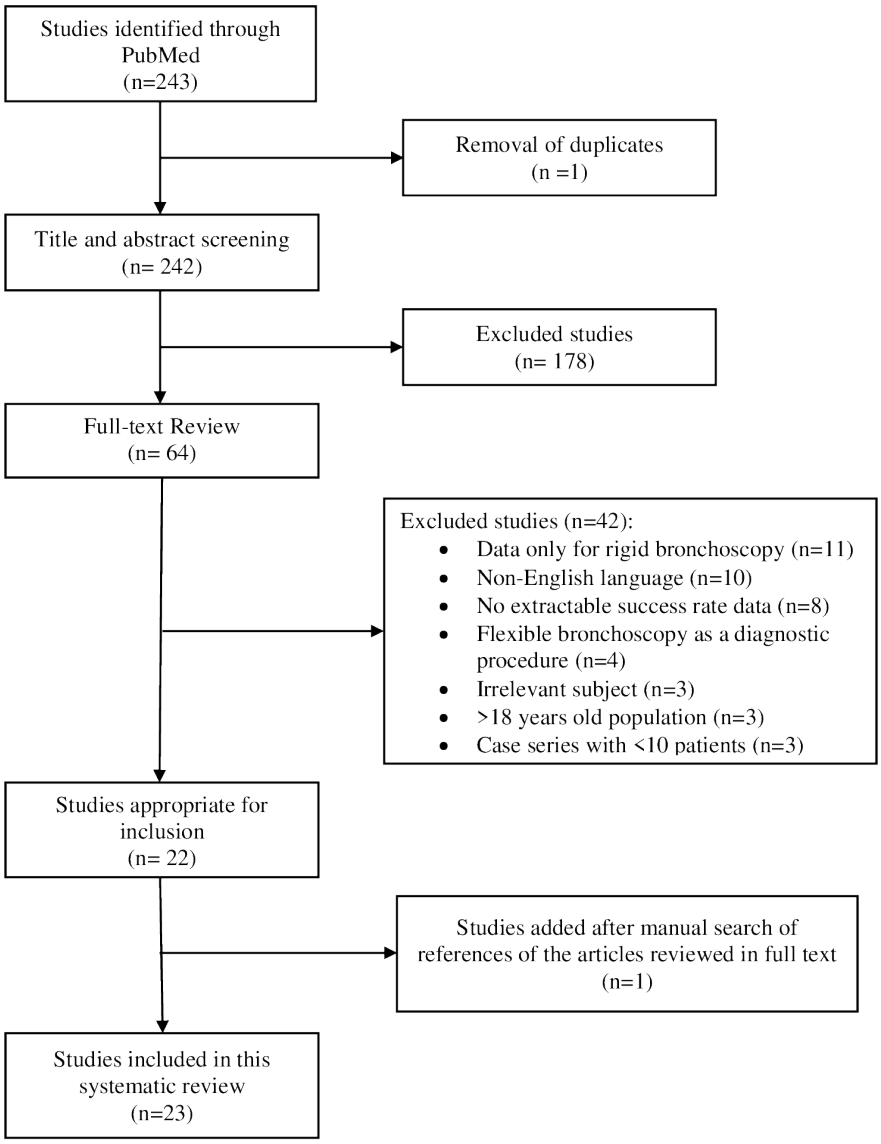

Figure1. Systematic review flowchart

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