Original Article

Pneumomediastinum Secondary to Foreign Body Aspiration: Clinical Features and Treatment Explorement in 39 Pediatric Patients

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Abstract

Background: Pneumomediastinum (PM) secondary to foreign body aspiration (FBA) is rare in children. Although it is mainly benign, some cases may be fatal. Due to the rare nature of this clinical entity, proper assessment and management have been poorly studied so far. Here, we characterized the presentation and management of this clinical entity and provided an evaluation system for the management.
Methods: We retrospectively reviewed children with PM secondary to FBA, who were treated in Beijing Children's Hospital from January 2010 to December 2015. All patients were stratified according to the degree of dyspnea on admission, and interventions were given accordingly. Bronchoscopic removals of airway foreign bodies (FBs) were performed on all patients. For patients in acute respiratory distress, emergent air evacuation and/or resuscitations were performed first. Admission data, interventions, and clinical outcomes were recorded.
Results: A total of 39 patients were included in this study. The clinical severity was divided into three grades (Grades I, II, and III) according to the degree of dyspnea. Thirty-one patients were in Grade I dyspnea, and they simply underwent bronchoscopic FBs removals. PM resolved spontaneously and all patients recovered uneventfully. Six patients were in Grade II dyspnea, and emergent drainage preceded rigid bronchoscopy. They all recovered uneventfully under close observation. Two exhausted patients were in Grade III dyspnea. They died from large PM and bilateral pneumothorax, respectively, despite of aggressive interventions in our hospital.
Conclusions: PM secondary to FBA could be life-threatening in some patients. The degree of dyspnea should be evaluated immediately, and patients in different dyspnea should be treated accordingly. For patients in Grade I dyspnea, simple bronchoscopic FBs removals could promise a good outcome. For patients in Grade II dyspnea, emergent air evacuation and/or resuscitation should precede a bronchoscopy before the children become exhausted.

Key words: Children; Foreign Body Aspiration; Pneumomediastinum; Pneumothorax; Subcutaneous Emphysema

Introduction

Foreign body aspiration (FBA) is a common and life-threatening emergency in children. The presentation varies from coughing, wheezing, recurrent pneumonia, and obstructive emphysema to respiratory distress. Occasionally, FBA could present with pneumomediastinum (PM), subcutaneous emphysema (SCE), or pneumothorax (PT).[1-4] In the presence of an airway foreign body (FB), persistence of expiratory outflow resistance and associated cough, crying, or vomiting leads to uninterrupted air leak through ruptured alveolus and thus progressive emphysema.[4] Besides, FB-associated pneumonitis could facilitate the alveolar rupture and precipitate the development of PM. PM could occur right on the inhalation of the FBs or several days later. The clinical presentation varies from

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chest pain, SCE, dyspnea, hemodynamic instability to death.[4] If the intramediastinum pressure rises abruptly or the decompression by air dissecting into subcutaneous tissue is insufficient to relieve the tension, the mediastinal parietal pleura may tear, resulting in concomitant PT, which would compromise the cardiopulmonary reserve.

Early diagnosis and proper intervention of PM secondary to FBA are critical in preventing life-threatening complications. However, given the infrequent nature and the lack of treatment guide, there was no consensus on the treatment and the management is often based on personal experience. While chest drainage is recommended if PM is present with FBA,[2] simple bronchoscopy is performed in some patients with good outcomes.[3,5] A simple and practical assessment is needed to differentiate those patients who simply need bronchoscopy from those who need the preceding air evacuation. In this study, we retrospectively reviewed our experience in the treatment of pediatric PM secondary to FBA from January 2010 to December 2015. The aims of this retrospective study were: (1) to introduce a fast and practical assessment system based on the degree of dyspnea and (2) to define the proper management according to the clinical severity.

Methods

Study setting and population

This was a retrospective study. Patients with PM secondary to FBA treated in Beijing Children's Hospital between January 2010 and December 2015 were included. The inclusion criteria included the presence of tracheobronchial FBs identified by rigid bronchoscopy and the presence of PM recognized by chest radiograph or chest computed tomography (CT) at admission. Exclusion criteria included asthma, chest wounds and injuries, infection by gas-producing germs, and PM developed during or after bronchoscopies. The study protocol was reviewed and approved by the Ethics Committee of Beijing Children's Hospital.

Clinical variables

Data were collected including demographic data, FBs characteristics, clinical presentation, precipitating factors, anteroposterior and lateral neck and chest films, interventions, hospital admission (regular ward versus Pediatric Intensive Care Unit [PICU]), length of hospital stay, time to resolution of PM, clinical outcomes, and recurrence.

Diagnosis measures

For all patients, a detailed history, careful physical examinations, neck and chest X-rays (anteroposterior and lateral) were conducted routinely. CT was performed when there was no choking episode or when other associated diseases were suspected. Follow-up chest radiographs were undertaken every 3–5 days to confirm the resolution of PM based on clinical status.

Assessment of stratification

All patients were clinically assessed based on a comprehensive medical history, physical examination, and radiographic findings. The clinical severity was stratified according to the degree of respiratory distress as follows: (1) Grade I was defined as mild to moderate dyspnea without anxiety or restlessness. The child had normal intake of food and drink and appeared interested in playing; (2) Grade II was defined as severe dyspnea with anxiety and restlessness. There was refusal of food and drink and no interest in playing; (3) Grade III was defined as exhausted child with slowing down of respiratory rate and heart rate. There were ashy-gray complexion, perspiration, and spells of somnolence.[6]

Intervention procedures

Treatment decisions were guided by the risk stratification. When dealing with clinically stable patients in Grade I dyspnea, emergent rigid bronchoscopy was performed under general anesthesia. For some small FBs in the distal bronchi which were difficult for the rigid bronchoscopy, flexible bronchoscopy was performed. For the clinically fragile patients in Grade II dyspnea, skin cutting preceded emergent rigid bronchoscopy. Intubation and resuscitation were prepared in case the status deteriorated. Patients of this grade were admitted for close perioperative observation. For exhausted children of Grade III, emergent skin cutting and chest drainage were performed followed by cardiopulmonary resuscitation. Rigid bronchoscopy was performed as soon as possible.

All bronchoscopies were performed under general anesthesia in the operating room, except for the exhausted patients for whom tropical anesthesia was applied to save time. Rigid bronchoscopy was performed in the same way as described by Zur and Litman.[7] Flexible bronchoscopy was performed as described by Swanson *et al*.[8] Air evacuation included skin cutting, which was bilateral infraclavicular 3 cm incisions,[9] and chest drainage, which was performed as described by Cerfolio.[10] Conservative management, which consisted of reassurance, sedation, oxygen, antibiotics, and analgesics when needed, was applied on all patients perioperatively. All patients were discharged when the condition stabilized. Valsalva maneuver and other activities, which could increase the pulmonary pressure, were prohibited for 2 weeks.

Statistical analysis

Descriptive data were expressed as frequency (percentage), median (range), or mean ± standard deviation (SD). Kruskal-Wallis rank sum test (for continuous nonnormal variable) and Chi-square test (for unordered categorical variable) were used to analyze differences among the subgroups. Statistical analysis was performed using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). A $P < 0.05$ was considered statistically significant.

Results

Patient characteristics

A total of 2643 patients with FBA were identified between January 2010 and December 2015 in Beijing Children's Hospital. Of all patients, PM occurred in 39 patients (1.5%), including 28 boys and 11 girls. The median age was 27.6 months (range 13–111 months). Most patients (87.2%) were between 12 and 36 months. A history of aspiration was recognized in 32 patients (82.1%). The characteristics of patients and FBs and the clinical presentations and management are listed in Table 1.

Clinical features

Among the 39 patients, 37 patients (94.9%) had wheezing as the main symptom. Peanuts (in 23 patients, 59.0%) remained the most common aspirated FB. The most common site of FBs was right main bronchus in 20 patients (51.3%), followed by left main bronchus in 17 patients (43.6%), both bronchi in one patient (2.6%), and subglottis in one patient (2.6%). The precipitating factors for PM were unknown in 21 patients (53.8%). There was SCE in 27 patients (69.2%), which was the most common comorbid condition on radiograph [Table 1].

Assessment and management

Thirty-nine patients were assessed and categorized into three grades according to the degree of dyspnea. Thirty-one patients fell into Grade I; six into Grade II; and two into Grade III. The management among the three subgroups were different (χ^2 = 35.858, P = 0.000). Rigid bronchoscopies were performed on 34 children, and flexible bronchoscopies on six children. Skin cutting was applied on eight patients while chest drainage and intubation on three children. Of all patients, two patients died while 37 got uneventful recovery with a mean time of 5.5 ± 1.9 days for the PM resolution. The median lengths of hospital stay were 5.7 days (range 1–20 days) for Grade I, 9.5 days (range 5–17 days) for Grade II, and 5.0 days (range 1–9 days) for Grade III. However, the median lengths of hospital stay among the three subgroups had no statistical difference (H = 4.415, P = 0.110). The assessment and management of 39 patients are listed in Table 2.

Thirty-one children in Grade I dyspnea underwent early bronchoscopies. Rigid bronchoscopies were performed on 26 patients (83.9%) while flexible bronchoscopies on six patients (19.4%). In one case, a small peanut particle was removed by a flexible bronchoscopy from the distal right bronchus after the failure of a rigid bronchoscopy. All PM resolved spontaneously with a mean time of 5.3 ± 1.9 days.

Six children fell into Grade II. Skin cutting preceded rigid bronchoscopy in all patients. After a short period of observation in hospital, they all recovered uneventfully and their PM resolved spontaneously with a mean time of 6.7 ± 1.5 days. One patient, a 13-month-old male child, got cyanosis and swelling over neck and face after an inhalation of a peanut for 5 h. Although a skin cutting

Table 1: Demographics, clinical characteristics, and management in PM secondary to FBA (n = 39)

Items	Values
Demographics	
Gender	
Males	28 (71.8)
Females	11 (28.2)
Age	
12–36 months	34 (87.2)
>36 months	5 (12.8)
Clinical features	
Types of FBs	
Peanuts	23 (59.0)
Other nuts	8 (20.5)
Beans	2 (5.1)
Pen caps	4 (7.7)
Tooth	1 (2.6)
Candy	1 (2.6)
Location of FBs	
Right main bronchus	20 (51.3)
Left main bronchus	17 (43.6)
Subglottis	1 (2.6)
Bilateral bronchi	1 (2.6)
Time duration from aspiration to treatment	
<1 day	10 (26.3)
1–7 days	17 (44.7)
>7 days	11 (28.9)
Clinical presentations	
Wheezing	37 (94.9)
Coughing	32 (82.1)
Chest pain	8 (20.5)
Swelling over neck and face	26 (66.7)
Reduced breath sound	39 (100.0)
Hamman syndrome	13 (33.3)
Precipitating factors	
Coughing	9 (23.1)
Vomiting	3 (7.7)
Crying	6 (25.4)
Unknown	21 (53.8)
Choking episode	
Yes	32 (82.1)
No	7 (17.9)
Radiological findings	
PM alone	7 (17.9)
SCE alone	0 (0.0)
PM + SCE	21 (53.8)
PM + PT	5 (12.8)
PM + SCE + PT	6 (15.4)
Length of hospital stay (days)	6.3 (1–20)
Emphysema disappear time (days)	5.5 ± 1.9
Management	
Rigid bronchoscopy	34 (87.2)
Flexible bronchoscopy	6 (15.4)
Trachea cannula	3 (5.1)
Chest drainage	3 (5.1)
Skin cutting	8 (5.1)

The data are shown as n (%), median (range), or mean ± SD. FBs: Foreign bodies; FBA: Foreign body aspiration; PM: Pneumomediastinum; SCE: Subcutaneous emphysema; PT: Pneumothorax; SD: Standard deviation.

Table 2: Radiographic findings, management and clinical outcomes for patients with different grades of dyspnea (*n* = 39)

Items	Grade I (*n* = 31)	Grade II (*n* = 6)	Grade III (*n* = 2)	Statistical values	*P*
Radiological findings, *n*				27.730*	0.000
PM	7	0	0		
PM + SCE	19	2	0		
PM + PT	5	0	0		
PM + SCE + PT	0	4	2		
Management, *n*				35.858*	0.000
Rigid bronchoscopy	26	6	2		
Flexible bronchoscopy	6	0	0		
Skin cutting	0	6	2		
Chest drainage	0	1	2		
Trachea cannula	0	1	2		
Outcomes	Full recovery	Full recovery	Death		
Time to emphysema disappearing (days), mean ± SD	5.3 ± 1.9	6.7 ± 1.5	–		
Length of hospital stay (days), median (range)	5.7 (1–20)	9.5 (5–17)	5.0 (1–9)	4.415†	0.110
Recurrence, *n*	0	0	–		

*Chi-square values; †*H* values. PM: Pneumomediastinum; SCE: Subcutaneous emphysema; PT: Pneumothorax; SD: Standard deviation.

was performed immediately for decompression, he got acute progressive SCE with tachycardia and unstable blood pressure immediately after an episode of violent crying. Given the breath sound disappeared on the right side, a pleural aspiration was performed immediately and the right-sided PT was confirmed. Thereafter, a chest drainage and intubation were put immediately. On the rigid bronchoscopy, a small candy in the right main bronchus was recognized and removed. He was intensively observed in the PICU for overnight. The chest tube was removed and he was extubated on the following day. A chest radiograph on the 7th day revealed good lung expansion with resolution of PM, and he was discharged. During follow-up, the child was thriving well without any respiratory complaint.

Two patients fell into Grade III. They had been intubated outside our hospital and got skin cutting and chest drainage immediately on admission. Thereafter, rigid bronchoscopies were performed as soon as possible. After the FBs removals, they were transferred to PICU for supportive treatment. Unfortunately, they both died despite aggressive interventions. These two cases are described as follows.

Deceased cases in Grade III dyspnea

A 22-month-old male child was admitted to the emergency department of another hospital for respiratory arrest. The patient had suffered from a choking episode for 3.5 h until he reached a physician. Since there was a swollen neck and face with anxiety and restlessness, intubation and artificial ventilation were performed, and the child was transferred to our hospital in an ambulance. On admission, there were coma, cyanosis, progression of SCE, and hemodynamic instability. Cardiopulmonary resuscitation was performed immediately. The skin cutting and chest drainage were performed once the diffuse PM, SCE, and bilateral PT were confirmed on a bedside radiograph [Figure 1]. An emergent rigid bronchoscopy under tropical anesthesia revealed peanut particles obstructing both the bronchi completely, which were removed successfully. The child was sent to PICU for supportive management. Despite intensive intervention, the clinical status deteriorated and he died of progressive and irreversible hypoxia and hypoxic encephalopathy 9 days later.

Another 39-month-old female child was admitted to another hospital with swollen over neck and face after inhalation of a bean 9 h ago. After an episode of violent crying 1 h later, the swelling progressed suddenly with cyanosis and anxiety. After immediate intubation and cardiopulmonary resuscitation, she was transferred to our hospital for further treatment. There were coma and massive swelling over the neck, face, and chest. The breath sound on the right-side disappeared. An emergent bedside radiograph revealed diffuse PM and right-sided PT [Figure 2]. Given the desaturation and hemodynamic instability, an intercostal chest tube and skin cutting were put to drain the air. On subsequent rigid bronchoscopy, a swollen soybean obstructing the right main bronchus completely was identified and removed. She died of hypoxic encephalopathy the day she was sent to PICU.

Discussion

PM secondary to FBA is a rare clinical entity in children. The incidence in our study was 1.5% (39/2643), which was similar to previous reports in the USA and Israel.[11] In this study, we characterized the presentation and management for this clinical entity in the past 6 years. A quick assessment system based on the degree of dyspnea was applied to evaluate the clinical severity, and management was

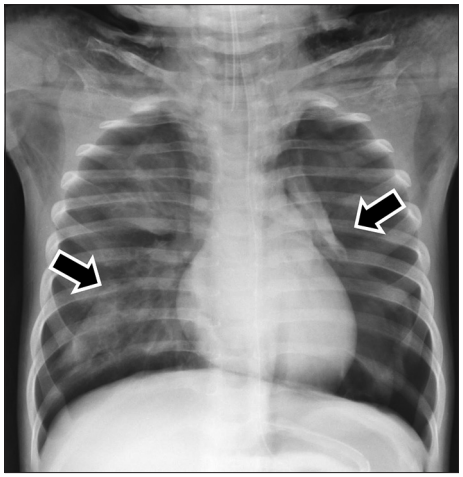

Figure 1: Chest radiograph showing mediastinal air, massive subcutaneous emphysema, and bilateral pneumothorax compressing both lungs to 50%. The tracheal cannula was in good place.

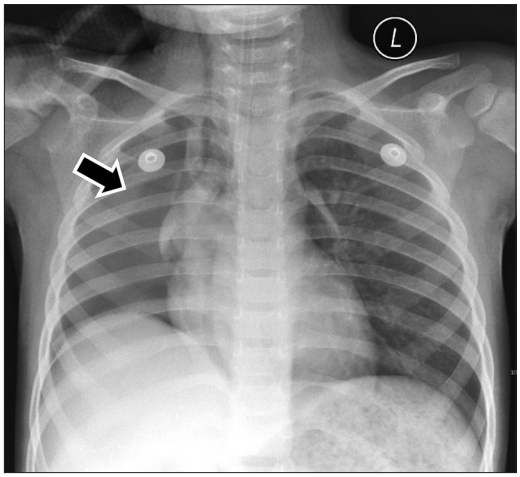

Figure 2: Chest radiograph showing mediastinal air and right-sided pneumothorax with the right lung compressed to approximately 30%. The tracheal cannula was in good place.

performed accordingly on all patients. To the best of our knowledge, this is the largest case series to date. We aimed to help guide pediatric physicians in their assessment and management with this rare clinical entity.

The clinical presentation of PM secondary to FBA varies from chest pain, SCE, dyspnea, hemodynamic instability to death. In this study, the most common presentations were wheezing, coughing, reduced breath sounds, and swelling over face and neck, which was similar to those with spontaneous PM.[12,13] Even though the majority of patients were generally well or with minimal symptoms, life-threatening complications should be kept in mind, including tension PM, tension PT, and increased pressure in the pulmonary interstitial.[14] In our study, there were six patients in severe dyspnea and two in respiratory failure. The diagnosis of PM resulting from FBA could be made from a comprehensive history, clinical signs, and radiographic studies. However, since some complications are life-threatening,[15] the first and most important thing in practice is to identify clinical severity.[12]

The treatment principle for PM secondary to FBA is early bronchoscopic FBs removals and supportive perioperative care. We believe rigid bronchoscopy and flexible bronchoscopy are both effective for the removal of airway FBs in experienced hands. Skin cutting and chest drainage, which could be accomplished quickly at the patient's bedside under local anesthesia, have already been reported as effective and safe procedures for air decompression for massive SCE and PM[9] and large PT,[10] respectively. It is noted that for children with PM secondary to FBA, a team of experienced emergency physicians, otolaryngologists, thoracic surgeons, and anesthetists should be available immediately to proceed with air evacuation, cardiopulmonary resuscitation, bronchoscopy, or tracheotomy in case of any accident. Most importantly, the management must be decided cautiously on a case-by-case basis depending on the status of the child.

In clinical practice, a simple and rapid assessment is needed to differentiate those patients who need bronchoscopy simply from patients who need both air evacuation and bronchoscopy. However, there are no well-defined criteria that could grade the severity of PM to date. Since PM-associated compression of the airway and cardiac venous return can lead to dyspnea, desaturation, and consequent hemodynamic instability,[15] we believe the degree of dyspnea could be used for stratification. It is simple and practical with initial careful observation. In this study, all patients were assessed on admission and patients in different degree of dyspnea were treated differently.

For children with mild to moderate dyspnea (Grade I), an early bronchoscopy under general anesthesia is recommended with careful preparations. In our series, 31 children fell into Grade I dyspnea and underwent early bronchoscopies. After the removal of airway FBs, PMs resolved spontaneously and all patients were discharged within a few days. It is noted that high-frequency jet ventilation is not advocated to prevent the potential aggravation of air trapping.[16] In a generally well child, we recommend that an early bronchoscopy and a short period of observation are sufficient to promise a good outcome.

For children in severe dyspnea (Grade II), air evacuation for decompression should be the first step while intubation and cardiovascular resuscitation should be available if condition deteriorates. After the decompression, rigid bronchoscopy should be performed as soon as possible to remove the FBs. In our series, there were six children in severe dyspnea with diffuse PM, SCE, and/or small PT. They all received immediate skin cutting for decompression, followed by rigid bronchoscopy. With subsequent supportive treatment, PMs resolved spontaneously with a mean time of 6.7 days and they all got full recovery.

The two deceased cases highlighted early air evacuation. Both the children fell into Grade II dyspnea on their initial visits to the doctors. The air leakage might occur right on the aspiration and progress aggressively afterward. However,

PM and PT were not recognized and no efforts were made to withdraw air from the mediastinum or thoracic cavity, a simple and fast procedure which might have saved their lives. Besides, the intubation and artificial ventilation might have aggravated the air trapping and the mediastinal compression. Similarly, a child was reported to die from possible tension PM secondary to FBA due to lack of air evacuation.[4] This reminds us that for patients in severe dyspnea with suspected PM and/or PT, immediate air evacuation, a simple and fast procedure, should come first for decompression.

PM could progress at any time with activities which could increase the alveoli pressure. In our study, there was a 13-month-old male child who fell into Grade II on admission. However, PM progressed suddenly after an episode of violent crying. It was immediate air evacuation for decompression that guaranteed the uneventful resolution. Therefore, if there is sudden onset of dyspnea in a previously stable patient, such complications as tension PM or large PT should be suspected and air evacuation should come first to save life.

Supportive care for PM secondary to FBA includes bed rest, oxygen therapy, analgesics, treatment of comorbidities, and avoidance of Valsalva maneuver. In light of the benign and self-limiting nature of pediatric PM, we recommend a short period of observation in hospital and avoidance of Valsalva maneuvers for approximately 2 weeks. Besides, the hospital stay should depend on patient's clinical condition instead of the presence of SCE or the radiologic presence of PM.

Given the retrospective nature of this study, there are some inherent limitations. First, there may be some possibility for selection bias. Second, the volume of PT in some children was assessed on supine chest X-rays instead of upright chest X-rays because of severe dyspnea or young ages. In addition, time to resolution was based on chest X-rays, and thus patients who were discharged may have a longer time to their next chest X-rays when compared with admitted patients. Moreover, the hospital stay was gradually reduced along the study from 14 days in severe patients to few hours in stable children with our experience increasing although 48-h medical supervision seems necessary for stable children. Despite this, we felt the data are valid to help guide pediatric physicians in their assessment and management with this rare clinical entity.

In conclusion, PM is a rare presentation of FBA. Early diagnosis and treatment are crucial to reduce the mortality and morbidity. An assessment system based on the degree of dyspnea is critical to help make intervention options and anticipate the outcomes. For patients with mild and moderate dyspnea, simple bronchoscopic removal of airway FBs, an effective and less invasive procedure, is recommended. For patients with severe dyspnea, immediate air evacuation followed by bronchoscopy, a simple and fast procedure to improve the cardiopulmonary reserve, could promise a good outcome.

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Conflicts of interest

There are no conflicts of interest.

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