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Pediatric plastic bronchitis associated with smoke inhalation and influenza A: case report and literature review

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Abstract
Plastic bronchitis is a relatively uncommon illness that has been reported in all age groups. This case report describes a specific manifestation of plastic bronchitis in two pediatric brothers influenced by both smoke inhalation and influenza A virus infection. The therapeutic approach mainly involved symptomatic supportive care, antiviral therapy, repeated bronchoscopic alveolar lavage, and bronchial cast removal. Eventually, both patients went into remission. Bronchoscopy proved to be helpful in diagnosing and treating these cases.

Keywords Plastic bronchitis, Smoke, Influenza A virus

Background

Plastic bronchitis (PB) is a relatively uncommon disease that can affect individuals of all ages. The Western medical literature indicates that this condition is primarily observed in children with congenital heart disease (CHD) who have undergone Fontan surgery [1]. In contrast, cases of PB induced by infections and asthma are more frequently reported in the domestic literature [2, 3]. This article reports on two brothers who developed PB after inhaling smoke during a fire. Their condition was characterized by hollow casts resembling necrotic pseudomembranes, a specific type of PB. Furthermore, both brothers had influenza A virus infection, as confirmed by the influenza antigen detection test.

Case presentation

Case 1

A 7-year-old boy was admitted to a local hospital after having inhaled smoke for 3 h due to a house fire in the absence of his parents. Laboratory evaluation performed at the local hospital, including complete blood count and liver and kidney function tests, were normal. Due to fever, the patient underwent an influenza A antigen test, which returned positive. Arterial blood gas analysis revealed a pH of 7.21, carbon dioxide partial pressure of 39 mmHg, oxygen partial pressure of 26 mmHg, oxygen saturation of 70%, and lactic acid level of 6.7 mmol/L. After endotracheal intubation, the patient was transferred to our hospital. Chest computed tomography (CT) at the referring hospital demonstrated increased and blurred texture of both lungs with scattered patchy high-density shadows, mainly in the dorsal segment; narrowing of the left main bronchus and lobar bronchi; and local obstruction of the right bronchus (Fig. 1). Bronchoscopy upon admission to our hospital revealed PB with black

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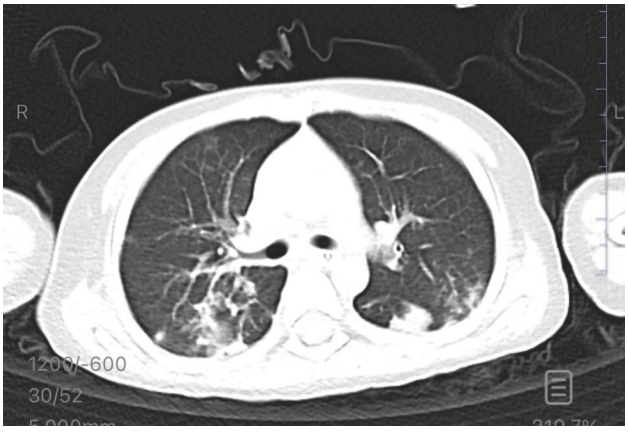

Fig. 1 Chest computed tomography demonstrating increased and blurred texture of both lungs with scattered patchy high-density shadows (mainly in the dorsal segment), narrowing of the left main bronchus and lobar bronchi, and local obstruction of the right bronchus

smoke particles embedded in the bronchial casts, which were subsequently removed using biopsy forceps during the procedure (Fig. 2). Histopathological examination of the casts revealed a cellulose-like necrotic exudate with black granular foreign material and neutrophilic infiltration (Fig. 3). The patient's condition improved following multiple bronchoalveolar lavages and a course of medical treatment (e.g., antiviral therapy with oseltamivir). He was successfully discharged after 7 days with a final diagnosis of necrotizing bronchitis, PB, and pneumonia, as evidenced by the bronchoscopic findings and chest CT features.

Case 2

A 5-year-old boy, the younger brother of the patient in Case 1, was admitted to the same local hospital following a 3-hour exposure to smoke from the same house fire. His condition was relatively mild because of his brother's protective actions during the incident. Initial laboratory data at the local hospital, including complete blood count and liver and kidney function tests, were within normal

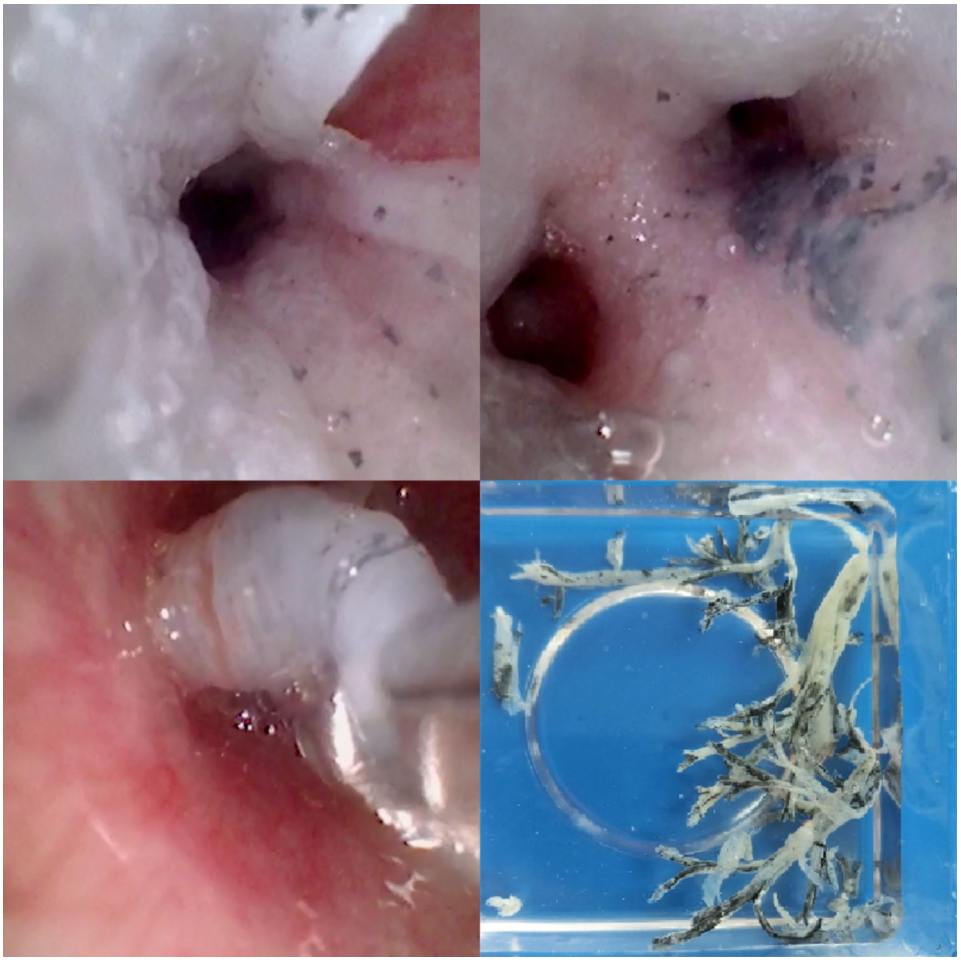

Fig. 2 Bronchoscopy in Case 1, revealing bronchial casts covered with dark smoke and dust particles

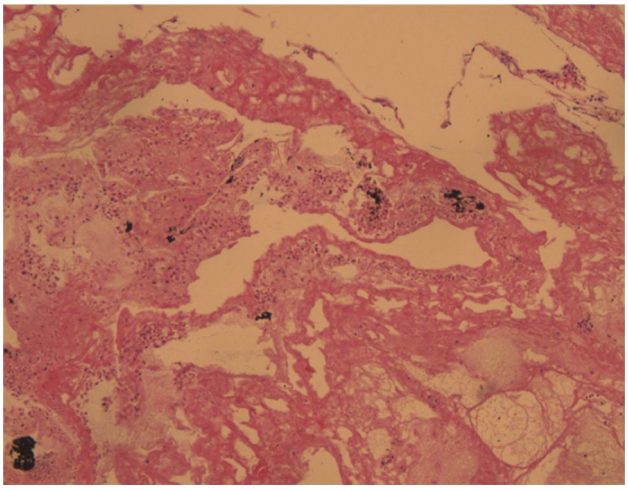

Fig. 3 Histopathological examination of casts in Case 1, indicating neutrophilic infiltration with black granular materials

limits. and kidney function. The influenza A antigen test was positive, while arterial blood gas analysis yielded normal results. However, the patient's dyspnea worsened progressively, necessitating endotracheal intubation at the local hospital before transfer to our hospital. Bronchoscopy upon admission revealed PB and evidence of smoke inhalation (Fig. 4). Bronchial casts were removed using biopsy forceps during the procedure. Chest CT demonstrated bilateral exudative changes characterized by scattered patchy and clumpy shadows of increased density, especially in both upper lobes. The bronchial walls of the left upper and lower lobes appeared irregular with luminal narrowing. After multiple bronchoalveolar lavages and medical treatment with oseltamivir, the patient's condition improved steadily, and he was successfully discharged after 7 days with a final diagnosis of PB and pneumonia.

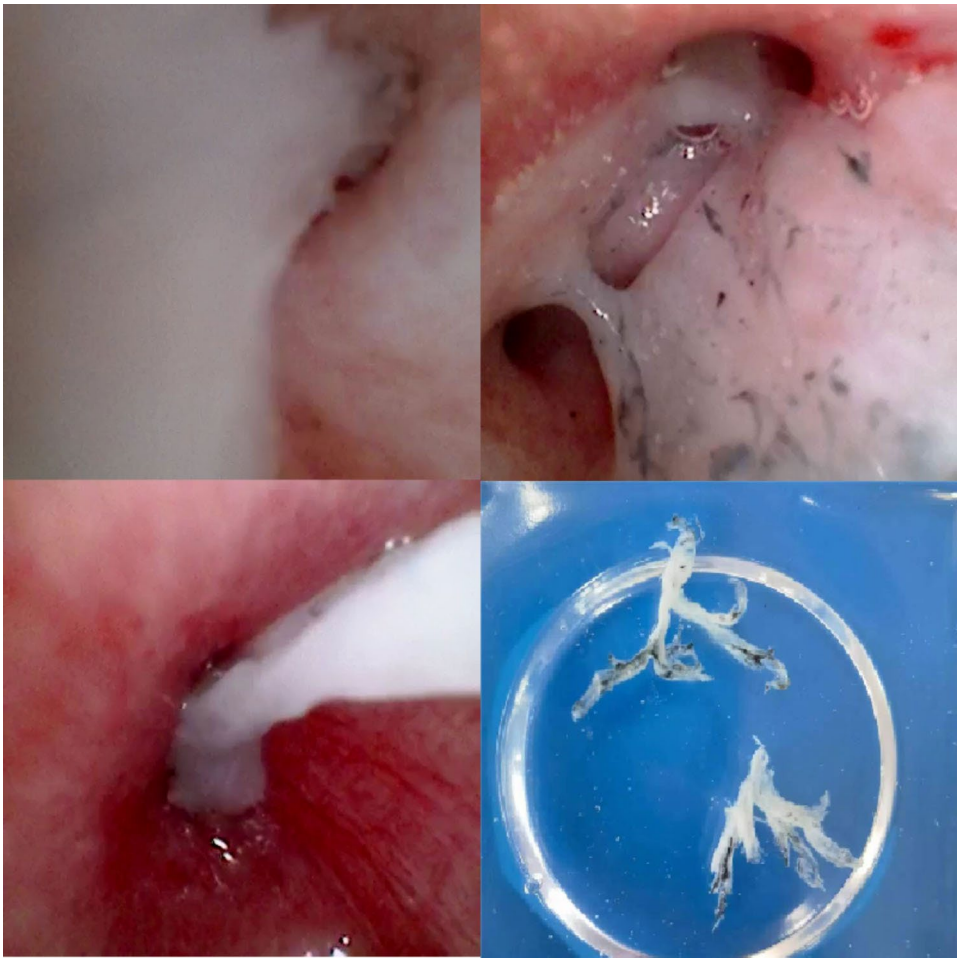

Fig. 4 Bronchoscopy in Case 2, revealing bronchial casts covered with dark smoke and dust particles

Table 1 A summarize of the literature on plastic bronchitis caused by influenza virus infection

Year of publication	2021	2011	2021
Author	Yoshida M et al.	Terano C et al.	Wang Y et al.
n	1	3	2
Age	5y	2y; 5y; 7y	4y; 8y
Gender	Boy	Boy; Boy; Girl	Boy; Boy
Symptoms	Fever, rhinorrhea, and cough	Case1: cough, fever	Case1: cough, wheezing, fever, shortness of breath, dyspnea
		Case2: cough, wheezing, and fever	Case2: fever, cough, dyspnea, wheezing, shortness of breath
		Case3: fever, chest pain and worsening dyspnea	
Imaging features	Atelectasis of the entire left lung and tracheal deviation to the left	Case1: complete opacification of the left hemithorax	Case1: atelectasis of the left upper lung
		Case2: complete opacification of the left lung	Case2: complete obstruction of the main right bronchus by thick secretions
		Case3: extensive pneumomediastinum and subcutaneous emphysema	
Bronchoscopy findings	The left upper and lower bronchi were obstructed with dense mucous casts	Case1: bronchial cast.	Case1: the left upper bronchi were obstructed with yellow-white mucus casts, and plastic casts were removed
		Case2: total obstruction of the main left bronchus by a large cast	Case2: a thick and tough plastic cast was removed from the left principal bronchus, and a dendritic plastic cast was removed from the middle lobe of the right lung
		Case3: bronchial casts	
Prognosis	Relieved	Returned to normal	Clinically healthy

Discussion

PB was first reported by Bettman in 1902 and subsequently classified based on anatomical location and etiology. In 1997, Seear et al. [4] classified it into two types based on pathological changes: Type I, characterized by inflammatory cell infiltration with fibrin and a significant number of inflammatory cells in the tracheal tube, primarily resulting from respiratory infections; and Type II (the acellular type), characterized by mucin with little to no cell infiltration and significant lymph fluid in the alveoli and mainly observed following Fontan surgery for CHD. In the cases presented herein, the pathological findings revealed significant neutrophilic granulocyte infiltration with black granuloid foreign bodies, consistent with Type I PB. New classification criteria (based on etiology) by Madsen et al. divided it into four types: mucin predominant casts, asthma, atopy and eosinophilic casts, lymphatic disorders and chylous casts, and SCACS and fibrinous casts [5]. On the other hand, Rubin [6], a leading expert in the field, has advocated for a simpler binary classification whereby all PB cases can be classified as either lymphatic or eosinophilic. However, the classification introduced by Seear et al. [4] has been widely used in the past years as it can reflect the underlying pathology of PB effectively. Several infectious agents are associated with the development of Type I PB, including human bocavirus, H1N1 influenza virus, adenovirus, SARS-CoV-2 virus, *Mycoplasma pneumoniae* (MP), and opportunistic fungi. In recent years, there have been increasing reports of PB in children in China, mostly associated with MP or respiratory virus infections [7]. Cases of influenza-induced PB have also been widely reported [8]. Following the 2009 H1N1 influenza pandemic, Terano et al. [9] published the first report of PB in children with a history of wheezing associated with H1N1 infection in the same year. Additionally, similar cases of PB in children with co-existing asthma and influenza A virus infection have been reported in China [10].

Over time, PB has been known by various terms, including Hoffmann bronchitis, tubular bronchitis, pseudomembranous bronchitis, and fibrinous bronchitis [5]. PB is an acute and severe disease characterized by the partial or extensive obstruction of the bronchi by an endogenous foreign body. This obstruction leads to the formation of branching, mucoid bronchial casts, causing partial or complete dysfunction in pulmonary ventilation. As illustrated by the cases reported herein, most patients with PB exhibit severe clinical symptoms with sudden onset and rapid progression, which may lead to acute respiratory failure and even death, although some may experience a more indolent course.

Therefore, PB requires prompt diagnosis and active treatment by clinicians. The definitive diagnosis relies exclusively on bronchoscopy, which reveals characteristic branching casts within the airways. Common symptoms include an expectorating cough, wheezing, and difficulty breathing. Chest radiography may show bronchial obstruction with atelectasis. Given the nonspecific nature of these signs and symptoms, a comprehensive clinical assessment involving a detailed history, a thorough physical examination, chest imaging, and potential

bronchoscopy is essential for accurate diagnosis and timely treatment initiation [11].

Both pediatric patients in this study had influenza A virus infection and exhibited significantly elevated total immunoglobulin E (IgE) levels. However, neither of them suffered from obvious dyspnea before smoke exposure during the fire, suggesting that smoke inhalation was a significant contributing factor to the development of their progressive dyspnea. We propose the following potential mechanisms whereby influenza virus infection may predispose to PB: (1) Inflammatory injury following infection can result in more severe epithelial cell damage, necrosis, and disruption of ciliary function [12]. (2) Infection increases IgE production and airway reactivity, contributing to antigen-induced airway inflammation and hyperreactivity [13]. (3) The high affinity of influenza viruses for the lower respiratory tract indicates the presence of virulence factors that mediate host–pathogen interactions [14]. These virulence factors may include eosinophils, whose accumulation and activation can lead to cytolysis and subsequent mucus airway obstruction. Yoshida et al. demonstrated the involvement of extracellular traps, primarily from activated eosinophils, in the pathogenesis of post-influenza PB (Flu-PB). However, our pathological findings demonstrated neutrophilic rather than eosinophilic inflammation, weakening the argument for eosinophil involvement in the pathogenesis of these specific cases. They also indicated that patients with Flu-PB may exhibit an overly specific immune response to the influenza virus [8]. (4) Infection with the influenza virus induces an imbalance between epithelial cells and immune cells in the airways, leading to abnormal activation of the innate immune response. In the early stages of viral infections, various proinflammatory cytokines can be released, resulting in excessive mucus production and prolonged airway hyperresponsiveness. While these mechanisms collectively may promote the development of PB in children with influenza, the exact pathophysiology remains unclear. Current literature on the exacerbation of influenza-related inflammation after exposure to smoke has shown that wood smoke exposure upregulates inflammatory gene expression and consequently exacerbates the inflammatory response [15], fecal biomass smoke exposure impairs post-influenza inflammatory regression and inhibits innate antiviral mediator expression [16], and cigarette smoke increases the expression of colony-stimulating factor 3 in neutrophils and complicates the alveolar–capillary barrier function during influenza infection [17]. These studies may explain the mechanism by which smoke inhalation accelerates bronchial cast formation in children with influenza. Table 1 summarizes the literature on PB caused by influenza virus infection.

The management of PB is multifaceted and varies with the underlying disease and different types of PB. Therapeutic approaches encompass both pharmacological interventions and procedural techniques, with bronchoscopy remaining the cornerstone of both PB diagnosis and treatment [11]. Both inhaled and systemic corticosteroids are effective in reducing bronchial cast formation and alleviating PB symptoms [18, 19]. Corticosteroids have also shown benefit in managing hemoptysis associated with PB [19]. Additionally, long-term treatment with low doses of macrolide antibiotics has demonstrated anti-inflammatory effects, particularly by reducing cast formation in Type I PB. N-acetylcysteine, a mucolytic agent commonly used to treat chronic obstructive pulmonary disease, has also been employed in PB management [13]. In bronchial casts where fibrin is present, plasminogen activators (e.g., urokinase and tissue-type plasminogen activator) have been found to reduce cast size and lung obstruction [11].

Although multiple pharmacological options are available, none can be effectively and consistently used to treat patients with PB. Additionally, most drug treatments data come from adults, with a paucity of information available for pediatric populations. In light of these limitations, bronchoscopic interventional therapy has emerged as an effective treatment modality that offers the dual benefits of direct cast removal and immediate symptom relief. The objectives of PB therapy are basically twofold: (1) to remove existing bronchial casts and (2) to prevent new cast formation [11].

In the cases presented herein, both patients successfully recovered after undergoing several bronchoscopic interventions and receiving symptomatic supportive treatment. With the wide application of flexible bronchoscopy, many patients with PB can receive early diagnosis and treatment.

Conclusion

The cases described here represent a distinct type of PB, characterized by hollow casts differing markedly from previously documented forms. These casts bore a striking resemblance to necrotic pseudomembranes, adhering circumferentially to the bronchial walls and extending along the bronchial tree. Interestingly, no clinical signs or symptoms suggestive of PB were present before bronchoscopy. The hollow nature of the casts allowed for partial airflow, which explained the absence of complete bronchial obstruction and the lack of atelectasis on chest radiographs and CT scans.

This report underscores the role of influenza as a significant predisposing factor for PB. Furthermore, smoke inhalation may accelerate and exacerbate the progression of pneumonia, leading to the rapid development of PB. Timely bronchoscopic intervention can save the

lives ofpediatric patients with PB, which is of extremely important value. The presented cases enhance our understanding of PB and contribute to the growing body of knowledge regarding its treatment in pediatric populations.

Author contributions
This study was supervised by YSW. The information of two cases and works of literature were collected and searched by JF, respectively. The data interpretation was performed by all authors. The final manuscript was read and approved for publication by all authors.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Written informed consent was obtained from all subjects legal guardian(s). For publication of identifying images or other personal or clinical details of this case report.

Competing interests
The authors declare no competing interests.

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