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Endobronchial occlusion with one-way endobronchial valves: A novel technique for persistent air leaks in children

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ABSTRACT

Purpose: In children, persistent air leaks can result from pulmonary infection or barotrauma. Management strategies include surgery, prolonged pleural drainage, ventilator manipulation, and extracorporeal membrane oxygenation (ECMO). We report the use of endobronchial valve placement as an effective minimally invasive intervention for persistent air leaks in children.
Methods: Children with refractory prolonged air leaks were evaluated by a multidisciplinary team (pediatric surgery, interventional pulmonology, pediatric intensive care, and thoracic surgery) for endobronchial valve placement. Flexible bronchoscopy was performed, and air leak location was isolated with balloon occlusion. Retrievable one-way endobronchial valves were placed.
Results: Four children (16 months to 16 years) had prolonged air leaks following necrotizing pneumonia (2), lobectomy (1), and pneumatocele (1). Patients had 1–4 valves placed. Average time to air leak resolution was 12 days (range 0–39). Average duration to chest tube removal was 25 days (range 7–39). All four children had complete resolution of air leaks. All were discharged from the hospital. None required additional surgical interventions.
Conclusion: Endobronchial valve placement for prolonged air leaks owing to a variety of etiologies was effective in these children for treating air leaks, and their use may result in resolution of fistulae and avoidance of the morbidity of pulmonary surgery.

Persistent air leaks represent rare and challenging clinical problems in children. Consisting of alveolopleural or bronchopleural fistulae, they can be associated with significant morbidity and increased hospital length of stay [1]. Common etiologies include necrotizing pneumonia, ruptured pneumatocele or cystic lesions, barotrauma, direct lung trauma, and following surgery. Many different strategies have been utilized to manage persistent air leaks, including chest tube manipulations, mechanical ventilation maneuvers, reoperative surgery, and extracorporeal membrane oxygenation (ECMO) in extreme cases [2]. All of these interventions have variable success rates.

In adults, bronchoscopic therapies for persistent air leaks include balloon occlusion, application of fibrin glue or other biodegradable substances, and most recently, the placement of one-way endobronchial valves [1,3–9]. One-way endobronchial valves are devices placed using bronchoscopy and have been used in the management of postoperative air leaks [6,7]. In one series of adult patients, complete resolution of air leaks was observed to be 48%, with an additional 45% of patients experiencing partial resolution. The principle of the valves is to allow mucus and trapped air to escape through the airway while preventing inspired air from entering through the bronchus into the fistula [1]. The use of endobronchial valves has not been previously reported in pediatric patients. We identified four pediatric patients with challenging air leaks from a variety of etiologies as candidates for valve placement (Table 1).

1. Materials and methods

Starting in 2012, children with refractory prolonged air leaks were evaluated by a multidisciplinary team consisting of pediatric surgery, interventional pulmonology, pediatric critical care, and thoracic surgery for endobronchial valve placement. Patients were considered candidates for valve placement after exhausting all conventional nonoperative measures and were being considered for surgical intervention. Endobronchial valve placement in children was approved by the Institutional Review Board of Penn State Milton S. Hershey Medical Center under a Humanitarian Device Exemption, and this study was approved by the Institutional Review Board.

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Table 1
Patient clinical characteristics prior to valve placement.

Patient	Age (years) sex	Diagnosis	Chest tube duration (pre-valve)	Total number of chest tubes (pre-valve)	Mechanical ventilation	Surgical procedures
A	3 F	Necrotizing pneumonia, bronchopleural fistula	76 Days	5	None	VATS decortication
B	14 F	Influenza A and B, superimposed necrotizing pneumonia, bronchopleural fistula	56 Days	7	Yes, 2 days, perioperative for VATS	1. VATS decortication 2. right thoracotomy RLL lobectomy
C	16 F	Influenza A, superimposed necrotizing pneumonia, ARDS, secondary spontaneous pneumothorax	2 Days	2	Yes, 10 days	None*
D	1.3 M	Aspiration pneumonia, ARDS, pneumatocele, secondary spontaneous pneumothorax	7 Days	3	Yes, continuous (home ventilator)	None*

Abbreviations: F = female, M = male, ARDS = acute respiratory distress syndrome, RLL = right lower lobe, RUL = right upper lobe, VATS = video-assisted thoracoscopic surgery.
* not counting chest tube thoracostomy.

2. Technique

The IBV Valve (Spiration, Redmond, WA) consists of an umbrella-shaped polyurethane membrane fixed to a nitinol frame within a delivery catheter that is passed through the working channel greater than 2.6 mm in a therapeutic flexible bronchoscope (Fig. 1A). Techniques of valve placement have been well described [10,11]. In all children, endobronchial valve placement was performed under general anesthesia. Three patients were ventilated with a single-lumen endotracheal tube and one was ventilated via tracheostomy with the cuff intermittently deflated as the bronchoscope was passed transorally.

A tapered adult hybrid scope (Olympus, Center Valley, PA, BF-MP160F) was used for initial identification of the affected airways by balloon occlusion of the bronchial segment contributing to the fistula in two patients. Airway sizing was then performed with the calibrated balloon, and an appropriate size valve was chosen: either a 5 mm, 6 mm, or 7 mm valve [12]. An adult therapeutic scope was then used to place the valve. Of note, in the smallest patient in this study (7.7 kg), the valve was deployed using the hybrid scope running parallel to the valve delivery catheter. Inpatients were then clinically assessed daily for cessation of air leak and with plain chest radiography. Outpatients were assessed weekly postvalve placement. Valves were removed bronchoscopically four–six weeks after placement, in accordance with current FDA guidelines, based on resolution of the air leak and patient's clinical status. Patients had immediate postremoval chest radiography and were again imaged at six months thereafter.

3. Results

Four children with persistent air leaks were treated with endobronchial valve placement. The population consisted of three females and one male ranging in age from 16 months to 16 years and weighing from 7.7 to 48.7 kg. Valve placement in all four patients was successful in controlling the fistulae. The average time to air leak resolution was 12 days after valve placement and ranged from 0 to 39 days (Table 2). All patients tolerated valve occlusion of airways without compromise of respiratory function. Two patients were treated on an outpatient basis, one patient was discharged 14 days after valve placement, while one remained in the hospital 55 days after valve placement owing to multiple comorbid conditions. Valve dwell time ranged from 38 to 69 days, and in three children they were removed without complications. One removal has been deferred until the patient's rehabilitation is completed. There were no complications regarding valve placement, dwell time, or removal as a result of valve placement.

Patients A and B both underwent VATS decortication with tube thoracostomy for necrotizing pneumonia. Patient A developed a bronchopleural fistula, and was discharged home with a one-way drainage pneumonostomy tube (16Fr Cook drainage catheter, Bloomington, IN) that remained in place with evidence of a persistent air leak for 53 days prior to valve placement as an outpatient (Fig. 1B). There was immediate resolution of the air leak at the time of the procedure. Patient B's tube thoracostomy demonstrated a persistent air leak, which, after two weeks necessitated thoracotomy and right lower lobectomy with one-way pneumonostomy tube drainage for three additional weeks prior to valve placement as an outpatient, with resolution of the air leak by the time of pneumonostomy tube removal. Both patients had weekly follow up and pneumonostomy tubes were withdrawn slowly over the next 38 days.

Patient C was intubated and mechanically ventilated for respiratory failure secondary to influenza A infection with superimposed methicillin-sensitive *Staphylococcus aureus* pneumonia. Two days after intubation she developed a large pneumothorax secondary to barotrauma necessitating urgent chest tube thoracostomy, which demonstrated a large, continuous air leak. Because of her unstable condition, she was taken to the operating room where three endobronchial valves were placed with immediate complete resolution of the air leak (Fig. 1C). Had valve placement been unsuccessful, immediate operative intervention would have been undertaken. Her chest tubes were

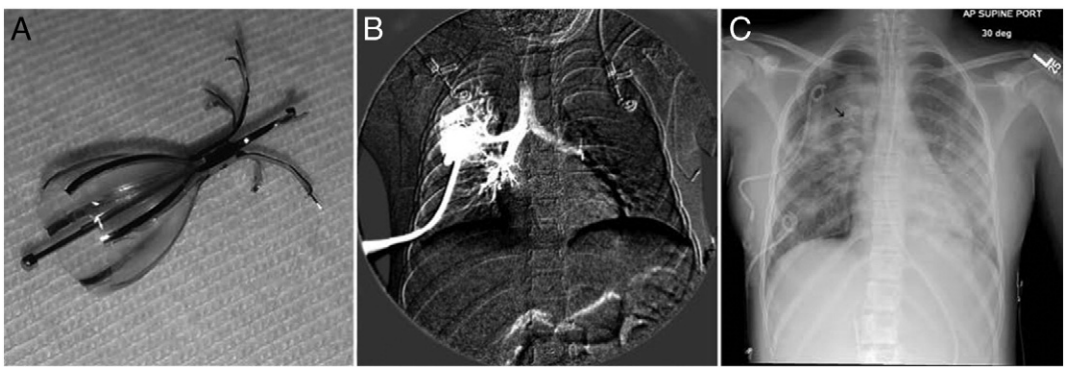

Fig. 1. A) Endobronchial valve. B) Patient A fistulogram. C) Patient C plain chest radiography. Arrow indicates location of three right upper lobe valves immediately after placement.