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Selected Topics: Critical Care

THE USE OF EXTRACORPOREAL MEMBRANE OXYGENATION IN LIFE-THREATENING FOREIGN BODY ASPIRATION: CASE SERIES, REVIEW OF EXTRACORPOREAL LIFE SUPPORT ORGANIZATION REGISTRY DATA, AND SYSTEMATIC LITERATURE REVIEW

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☐ **Abstract—Background: Foreign body aspiration (FBA) is a common cause of morbidity and mortality in children < 3 years of age. Guidelines recommend performing a bronchoscopy in any suspected or confirmed FBA. Extracorporeal membrane oxygenation (ECMO) can be used as a rescue mode of support in children with life-threatening FBA for stabilization before, during, and after removal. Case Report: We present a series of children with life-threatening FBA who were placed on ECMO for stabilization before or after FB removal and a review of the literature and the Extracorporeal Life Support Organization database. Foreign bodies were removed without complications, and all patients survived ECMO support and were promptly discharged home. Why Should an Emergency Physician be Aware of This?: ECMO can be safely used in the stabilization of children with life-threatening FBA before, during, and after bronchoscopic removal. ECMO should be considered in the stabilization of children presenting with FBA to facilitate removal.** © **2019 Published by Elsevier Inc.**

☐ **Keywords—bronchoscopy; Extracorporeal Life Support Organization; extracorporeal membrane oxygenation; foreign body aspiration**

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INTRODUCTION

Foreign body aspiration (FBA) is a significant cause of morbidity and mortality in children < 3 years of age and is the third most common cause of death caused by unintentional injury in children < 1 year of age (1). Toddlers have a higher risk of aspirating foreign material because of their developmental stage, lack of supervision, or neurological disorders (1). The majority of aspirated objects are organic, with 75% of them being small food items (1). Despite the diverse human defense mechanisms involved in clearing the airway, none are ideal, and FBA may occur (1).

Diagnosis of FBA can be a challenge and may not be recognized by the caregiver. History, physical examination, and imaging are important first steps, but bronchoscopic evaluation is required to achieve a definitive diagnosis (2). Airway occlusion or bronchoscopic retrieval of a FB may be complicated by life-threatening respiratory compromise leading to a respiratory arrest (2).

Extracorporeal membrane oxygenation (ECMO) was developed as a rescue therapy for intractable respiratory, cardiac, or combined cardiopulmonary failure. It supports cellular respiration by improving tissue oxygenation or

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carbon dioxide removal until the primary disease process resolves or as a "bridge" to organ transplantation or another form of long-term mechanical support. A standard ECMO circuit consists of a mechanical pump, an oxygenator, and a heat exchanger connected with circuit tubing. There are 2 types of ECMO support: venoarterial (VA), which provides cardiac and respiratory support, and venovenous (VV), which provides respiratory support. Advances in ECMO practice have expanded the application of this technique beyond traditional uses. Literature describing the use of extracorporeal support in the stabilization of life-threatening FBA is limited (3–12). The purpose of this study is to describe a single institution experience in the use of ECMO for stabilizing pediatric patients in the removal of FB or for management of persistent severe hypoxemia after FB extraction, along with a systematic review of the literature and data on the use of ECMO for FBA from Extracorporeal Life Support Organization (ELSO) registry (13).

CASE REPORTS

Patient information is listed in Table 1.

Patient 1

A 16-month-old male presented with a 2-day history of fever, respiratory distress, cough, and swelling of the anterior neck. Chest radiography (CXR) revealed a right-sided consolidation and pneumothorax that required intubation for respiratory failure and subsequent chest tube insertion. His respiratory status continued to deteriorate with persistent hyperinflation of the right lung despite antibiotic therapy and chest physiotherapy. On hospital day 5 (HD5), a flexible bronchoscopy revealed a granuloma at the right main stem bronchus and a bean husk at the entrance of the right lower lobe, which was subsequently removed under rigid bronchoscopy. Despite the extraction of the FB, the patient remained persistently hypoxemic on maximal conventional ventilatory support over the following days. He underwent 2 more bronchoscopies on HD7 and HD9 that showed no further inflammation or remaining FB. A computed tomography (CT) scan of the chest revealed diffuse parenchymal lung disease. His clinical condition continued to deteriorate with worsening hypoxemia and hemodynamic instability despite high frequency oscillatory ventilation (HFOV), inhaled nitric oxide, and inotropic support. The patient was cannulated on VA ECMO on HD7. Bronchodilators, steroids, and lung recruitment maneuvers were subsequently initiated. His respiratory status continued to improve and was successfully weaned off ECMO on HD15, extubated to nasal cannula on HD23 and discharged home in stable condition after 37 days of hospitalization.

Patient 2

A 14-month-old male presented with a sudden onset of fever, cough, respiratory distress, and hemoptysis hours after an uncertain episode of choking while playing. He was emergently intubated for severe respiratory distress and underwent a CXR and CT scan of the chest that showed areas of consolidation consistent with pneumonia. Despite broad spectrum antibiotics, his respiratory status continued to deteriorate with frank pulmonary hemorrhage and persistent hyperinflation of the right lung on CXR. On HD2, a flexible bronchoscopy revealed a crayon located at the entrance of the right main stem bronchus. Because of the difficulty retrieving the FB and subsequent life-threatening hypoxemia with hemodynamic compromise, the patient was initiated on VA ECMO to facilitate the removal of the FB. During extracorporeal support, the FB was successfully extracted under rigid bronchoscopy. Bronchodilators, steroids, and lung recruitment maneuvers were initiated, and he underwent 3 more bronchoscopies on HD6, HD7, and HD8 during ECMO support to provide airway clearance and assess airway inflammation. His respiratory status continued to improve, and he was weaned off ECMO support on HD9, extubated to room air on HD18, and discharged home in stable condition after 22 days of hospitalization.

Patient 3

A 2-year-old male presented with fever, respiratory distress, and profound hypoxia after an apneic spell while being fed that required rescue breaths. His initial CXR revealed a complete consolidation of the right lung. He was subsequently intubated for hypoxemic respiratory failure and rapidly escalated to HFOV. His right lung remained persistently collapsed despite chest physiotherapy and antibiotic therapy for which he underwent a flexible bronchoscopy on HD2. The bronchoscopy revealed a questionable FB lodged in his right main stem bronchus surrounded by thick secretions that could not be removed. His hypoxemic respiratory failure continued to worsen despite maximal ventilatory therapy and inhaled nitric oxide, so the patient was initiated on VV ECMO the same day. A rigid bronchoscopy performed after ECMO stabilization successfully removed an almond from his right main stem bronchus. Bronchodilators, steroids, and lung recruitment maneuvers were initiated. The patient was weaned off ECMO support 42 hours after the FB extraction, extubated 4 days later, and discharged home with no signs of respiratory or neurologic compromise after 17 days of hospitalization.

Table 1. Patient Review

Patient Characteristics	Patient 1	Patient 2	Patient 3	Patient 4
Age/gender	16 mo/male	14 mo/male	2 yo/male	18 mo/male
Primary symptoms	Fever, respiratory distress, cough, and neck swelling	Fever, cough, respiratory distress, and hemoptysis	Fever, respiratory distress, and hypoxemia	Unresponsive, respiratory arrest
Suspected episode	No	Yes (questionable choking episode)	Yes (witnessed apneic spell while feeding)	Yes (witnessed choking episode)
CXR finding	Pneumothorax, consolidation, and hyperinflation	Lung consolidation	Lung consolidation	Lung consolidation
Chest CT finding	Diffuse parenchymal lung disease	Multilobar bilateral consolidation	Not performed	Not performed
No. bronchoscopies (type)	4 (3 flexible + 1 rigid)	5 (3 flexible + 2 rigid)	2 (1 flexible + 1 rigid)	2 (1 flexible + 1 rigid)
Type of FB	Bean husk	Crayon	Almond	Insect
FB location	Right main bronchus	Right main bronchus	Right main bronchus	Midtrachea
Time from ER presentation to ECMO initiation	7 days (postbronchoscopic extraction)	2 days	2 days	1 day
Reason for ECMO	Severe hypoxemia/hypotension after FB extraction	Severe hypoxemia/hypotension during FB extraction	Severe hypoxemia during FB extraction	Severe hypoxemia during FB extraction
Type of ECMO (cannula sites)	VA (RCA/RIJV)	VA (RCA/RIJV)	VV double lumen (RIJV)	VV double lumen (RIJV)
ECMO duration	8 days	7 days	42 h	48 h
Time to extubation/hospital discharge after decannulation (days)	8/22	9/13	4/13	9/17
Outcomes	Survival/no complications	Survival/no complications	Survival/no complications	Survival/neurologic injury postarrest

CT = computed tomography; CXR = chest radiograph; ECMO = extracorporeal membrane oxygenation; FB = foreign body; M = male; RCA = right carotid artery; RIJV = right internal jugular vein; VA = venoarterial; VV = venovenous.

Table 2. Published Cases of Foreign Body Aspiration on Extracorporeal Support

n	Author, year, Journal	Age/Gender	Primary symptoms	Type of FB	FB Location	Type of Support
1	Higashi et al (3), 1989, Kokyu To Junkan	17 y/M	Fall into loading chute with sawdust	Sawdust	Both main bronchi	ECLA
2	Mellema et al (4), 1995, Chest	6 y/M	Unconscious	Sand	Both main bronchi	CPB
3	Brown et al (5), 2003, Pediatr Crit Care Med	14 mo/M	Choking, arrest 15 min	Grape	Left main bronchus	VA ECMO
4	Ignacio et al (6), 2006, J Pediatr Surg	14 mo/F	Unconscious, apneic	Bean	Distal trachea	VA ECMO
5	Freemayer et al (7), 2008, J Trauma	11 y/M	Buried by gravel slide, polytrauma	Gravel	Both main bronchi	CPB
6	Holliday et al (8), 2010, Crit Care Resusc	33 y/M	Unknown	Food bolus	Left main bronchus	VV ECMO
7	Isherwood et al (9), 2011, Interact Cardiovasc Thorac Surg	13 y/M	3 wks of fevers and cough	Pin	Right main bronchus	VV ECMO
8	Metcalf et al (10), 2013, J Emerg Med	52 y/F	Near-drowning, arrest 10 min	Sand	Both main bronchi	VA ECMO
9	Park et al (11), 2014, Int J Pediatr Otorhinolaryngol*	8 mo/M	Respiratory distress, arrest during admission	Bean	Right main bronchus	VV ECMO
		22 mo/M	Respiratory distress	Almond	Distal trachea	VA ECMO
		2 y/F	Respiratory distress, arrest during admission	Peanut	Left main bronchus	VV ECMO
10	Deng et al (12), 2017, Int J Pediatr Otorhinolaryngol	6 y/F	Respiratory distress, unresponsive	Plastic ball	Right main bronchus	CPB

CPB = cardiopulmonary bypass; ECLA = pumpless extracorporeal lung assist; ECMO = extracorporeal membrane oxygenation; F = female; FB = foreign body; LOS = length of stay; M = male; mo = months; NRL = neurologic; RA = right atrium; RCA = right carotid artery; RFA/LFA = right/left femoral artery; RFV/LFV = right/left femoral vein; RIJV = right internal jugular vein; VA = venoarterial; VV = venovenous; y = years.
* Multicenter study.

Patient 4

An 18-month-old male was witnessed choking and becoming unresponsive after placing a bug in his mouth while playing. Cardiopulmonary resuscitation maneuvers were initiated for respiratory arrest at the field for about 15 min. On admission the patient remained severely hypoxic and was taken emergently to the operating room from the emergency department to perform a bronchoscopy given the suspected aspiration episode. The airway could not be fully evaluated because of profound hypoxia, so he was emergently placed on VV ECMO. A rigid bronchoscopy performed after ECMO stabilization showed a nearly total obstruction of the airway by an insect at the level of the midtrachea that was successfully extracted. Antibiotics, steroids, and lung recruitment maneuvers were initiated. The patient's respiratory status continued to improve, and he was weaned off ECMO support 48 h after FB extraction and successfully extubated to heated high flow cannula 9 days later. His hospital course was complicated by hypoxic-ischemic encephalopathy, for which he was discharged to a rehabilitation facility after 19 days of hospitalization.

ELSO Registry Data

The ELSO registry was queried for FBA in children between 1990 and 2017. This voluntary database, which our center participates in, collects data on patients undergoing ECMO support in participating centers from 1990 with a total of 251 centers and 2807 cases through July 2017 (13). All neonatal and pediatric cases (patients 0–18 years of age) on VA and VV ECMO for FBA were extracted. FBA was defined based on *International Classification of Diseases, 9th revision* codes (933.0, 933.1, and 934.0) and *International Classification of Diseases, 10th revision* codes (T17.2, T17.300A, T17.400A, T17.500A, T17.8, T17.800A, and T17.900A). Other types of aspirations, multiple ECMO runs and patients with missing data were excluded. A total of 42 patients with a median age of 1.54 years (range 0.04–16.7 years) and median weight of 12 kg (range 7.5–98 kg) were analyzed. Gender distribution was similar, with 52% males. FBA in white patients accounted for 62%, followed by African American

Cannulation Location	Support Duration	Extraction Method	LOS Hospital	Outcome	NRL/Respiratory Sequelae
RFV-RFV	36 h	Bronchoscopy	Unknown	Survival	No
RFA-RFV	3 h	Rigid bronchoscopy	9 d	Survival	No
RCA, RIJV	6 d	Bronchoscopy	17 d	Survival	No
RCA, RIJV	1 d	Rigid bronchoscopy	5 d	Survival	No
RA-LFA	4 h	Open surgery, tracheostomy/flexible, bronchoscopy	20 d	Survival	No
RFV-LFV	36 h	Rigid bronchoscopy	2 d	Survival	Mild exercise tolerance dysfunction
Unknown	8 d	Open surgery, thoracotomy/lobectomy	5 wks	Survival	No
RFA, RFV	During bronchoscopy	Rigid bronchoscopy	>1 mo	Survival (died of cancer 1 y after)	No
Unknown	During bronchoscopy	Bronchoscopy	1 d	Survival	No
RCA, RIJV	2 d	Rigid bronchoscopy	Unknown	Survival	No
Unknown	1 d	Rigid bronchoscopy	4 d	Survival	No
Aorta, bicaval	68 min	Open surgery, rigid bronchoscope	10 d	Survival	No

with 16.7% and Hispanic children with 9.5%. Before ECMO cannulation, 10 patients (23.8%) required HFOV and 11 (26.2%) required hand bagging to achieve adequate oxygenation. Extracorporeal cardiopulmonary resuscitation was performed in 2 patients (4.7%). The mode of ECMO support was VV in 24 patients (57.1%) and VA in 15 (35.7%), while three (7.1%) were VV converted to VA. The median duration of the ECMO runs was 89.5 h (range 1–833 h). Survival to hospital discharge accounted for 88% of the patients.

Systematic Literature Review

We performed a literature review using MEDLINE's database through PubMed, Web of Science, and Google Scholar with the search terms "foreign body aspiration," "ECMO," "extracorporeal membrane oxygenation," "cardiopulmonary bypass," "pumpless extracorporeal lung assist" and any of their synonyms, and found 10 case reports published between 1989 and 2017 (Table 2). A total of 12 patients (2 adults and 10 children) required extracorporeal support for stabilization after a FB aspiration. The ages ranged from 8 months to 52 years, with 67% of patients being males. Eleven patients presented with acute symptoms (2 of them had out of hospital arrests), while 1 patient presented with 3 weeks of fever and cough and acutely deteriorated during airway manipulation. The FBs were organic in 6 patients (50%) and had variable airway locations. One patient was supported on a pumpless extracorporeal lung assist device, 3 on cardiopulmonary bypass, and the remaining 8 on ECMO (VA = 4, VV = 4). Choice of the extracorporeal device seemed to be related to the anticipated timing of support and type/location of FB in the airway because some patients required open surgery to facilitate extraction. Bronchoscopy was used for FB retrieval in 10 patients (83.3%), while open surgery with/without bronchoscopy was used in 2 patients because of technical difficulties. All patients survived to hospital discharge without neurologic sequelae and only 1 had mild exercise intolerance (3–12).

DISCUSSION

Our study is the largest pediatric series of FBA requiring stabilization on ECMO from a single center experience. Our findings add data to the previous literature demonstrating the feasibility of achieving adequate

cardiopulmonary stabilization on ECMO support to safely extract FBs lodged in the airway. Our data are also consistent with the reported challenge to clearly identify a potential FBA episode. The clinical picture and radiologic imaging of our patients were nonspecific, but a clear history of witnessed aspiration prompted to a faster bronchoscopic evaluation in half of them. Furthermore, our study is the first to date to report the use of ECMO stabilization after FB removal.

FBA is a common, potentially life-threatening emergency and a significant cause of morbidity and mortality in young children, especially in toddlers (1). The majority of aspirated objects are small food items, although nonorganic materials have also been described (1). Despite complex defense mechanisms to maintain the airway clear, aspiration may occur (1). FBs are more likely to enter the right main bronchus because of its anatomy and angulation (14). After aspiration, a reactive spasm of the larynx results in coughing, choking, dyspnea, and cyanosis. If the larynx is completely obstructed and treatment is delayed, hypoxia can cause death. If the obstruction is partial, the spastic reaction continues, and the FB is either expelled or passed down. If the size is small, the object may pass down and impact into a narrow bronchus where the stretch receptors' ability to accommodate the FB and the lack of sensitivity of the bronchial mucosa lead to less intense clinical response (14). With time, retained FBs usually cause chronic lung parenchymal or airway damage and infection (14). Identification of FBA can be challenging because a history of choking is only present in 75–80% of the cases, physical examination is nonspecific and CXRs are usually normal or nonspecific (hyperinflation, atelectasis, and mediastinal shift), with < 10% revealing a radiopaque FB (14). CT scans are valuable to delineate the exact shape, location, and volume of a FB and to help bronchoscopic removal, especially if 3-dimensional integration is performed (15). Guidelines usually recommend performing a bronchoscopy in any suspicion of FBA (2). Although rigid bronchoscopy is usually preferred for children under general anesthesia, pediatric studies have demonstrated successful removal of FBs with flexible bronchoscopes under local anesthesia (14). Flexible bronchoscopy is useful for both confirmation of the presence and exact location of a FB as well as for its removal, while preventing the risks of general anesthesia related to rigid bronchoscopy (2,14).

Acute and chronic complications, such as pneumonia, air leak, bronchial stenosis, lung abscess or empyema, atelectasis, bronchiectasis, FB dislodgment, tracheal laceration, recurrent bronchospasms, and obstructive emphysema have been reported in ≤ 20% of patients after FB aspiration (14). Furthermore, life-threatening complications occur in ≤ 5% of the patients (14). Postobstructive complications, such as pulmonary edema and acute lung injury, contribute to intractable cardiopulmonary failure. Death is usually related to hypoxemic respiratory arrest caused by airway occlusion before or during FB bronchoscopic extraction. ECMO is useful to manage these life-threatening complications. Extracorporeal support can restore end-organ perfusion if severe intractable cardiorespiratory failure occurs, can also provide a safe modality to facilitate bronchoscopic removal of the FB, and can support lung recovery from associated injury. Data on the use of ECMO support for the stabilization of children with life-threatening FBA is scant and limited to case reports (3–12).

A descriptive comparison of the cases reported in our study, the ELSO registry, and the literature review revealed a predominance of toddler males with acute respiratory symptoms. FBs were mainly organic and located in the main bronchi or trachea. Extracorporeal support courses were short with no predominance of ECMO type. Survival to hospital discharge was > 90%. Our study and the literature review highlight the need for safety measures (including ECMO support) in preparation for extraction of FBs lodged in the airway of pediatric patients.

WHY SHOULD AN EMERGENCY PHYSICIAN BE AWARE OF THIS?

Over the last decade, ECMO has being increasingly used in the adult and pediatric emergency department for cardiopulmonary failure (16–20). There are no data on the use of ECMO in the emergency department to support patients who are at risk for life-threatening hypoxia and cardiorespiratory arrest in the setting of FBA. However, we believe that ECMO is feasible and safe for patient stabilization before, during, or after bronchoscopic removal of FB causing life-threatening aspiration. In these cases, both the ECMO team and surgical team should be promptly contacted in the emergency department, because the early use of ECMO can improve the outcome of cardiorespiratory function and increase survival and morbidity rates in these critically ill patients (16–20).

REFERENCES

1. Saki N, Nikakhlagh S, Rahim F, et al. Foreign body aspirations in infancy: a 20-year experience. Int J Med Sci 2009;6:322–8.
2. Cutrone C, Pedruzzi B, Tava G. The complimentary role of diagnostic and therapeutic endoscopy in foreign body aspiration in children. Int J Pediatr Otorhinolaryngol 2011;75:1481–5.
3. Higashi K, Takeshita J, Terasaki H. A case of acute airway obstruction with sharp sawdust particles, successfully treated by extracorporeal lung assist. Kokyu To Junkan 1989;37:329–33.
4. Mellema JD, Bratton SL, Inglis A, Morray JP. Use of cardiopulmonary bypass during bronchoscopy following sand aspiration. A case report. Chest 1995;108:1176–7.

5. Brown KL, Shefler A, Cohen G, et al. Near-fatal grape aspiration with complicating acute lung injury successfully treated with extracorporeal membrane oxygenation. Pediatr Crit Care Med 2003;4:243–5.
6. Ignacio RC, Falcone RA, Brown RL. A case report of severe tracheal obstruction requiring extracorporeal membrane oxygenation. J Pediatr Surg 2006;41:E1–4.
7. Freemyer R, McLean S, Tyroch A, Santoscoy R. Cardiopulmonary bypass and bronchoscopy for removal of large gravel in the bronchial tree. J Trauma 2008;65:719–21.
8. Holliday T, Jackson A. Emergency use of extracorporeal membrane oxygenation for a foreign body obstructing the airway. Crit Care Resusc 2010;12:273–5.
9. 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.
10. Metcalf KB, Michaels AJ, Edlich RF, Long WB. Extracorporeal membrane oxygenation can provide cardiopulmonary support during bronchoscopic clearance of airways after sand aspiration. J Emerg Med 2013;45:380–3.
11. Park AH, Tunkel DE, Park E. Management of complicated airway foreign body aspiration using extracorporeal membrane oxygenation (ECMO). Int J Pediatr Otorhinolaryngol 2014;78:2319–21.
12. Deng L, Wang B, Wang Y, et al. Treatment of bronchial foreign body aspiration with extracorporeal life support in a child: a case report and literature review. Int J Pediatr Otorhinolaryngol 2017;94:82–6.
13. Extracorporeal life support organization website. International summary. Available at: https://www.elso.org/Registry/Statistics/InternationalSummary.aspx. Accessed December 20, 2017.
14. Gang W, Zhengxia P, Hongbo L. Diagnosis and treatment of tracheobronchial foreign bodies in 1024 children. J Pediatr Surg 2012;47:2004–10.
15. Manach Y, Pierrot S, Couloigner V. Diagnostic performance of multidetector computed tomography for foreign body aspiration in children. Int J Pediatr Otorhinolaryngol 2013;77:808–12.
16. Mosier JM, Kelsey M, Raz Y, et al. Extracorporeal membrane oxygenation (ECMO) for critically ill adults in the emergency department: history, current applications, and future directions. Crit Care 2015;19:431.
17. Siao FY, Chiu CC, Chiu CW, et al. Managing cardiac arrest with refractory ventricular fibrillation in the emergency department: conventional cardiopulmonary resuscitation versus extracorporeal cardiopulmonary resuscitation. Resuscitation 2015;92:70–6.
18. Johnson NJ, Acker M, Hsu CH, et al. Extracorporeal life support as rescue strategy for out-of-hospital and emergency department cardiac arrest. Resuscitation 2014;11:1527–32.
19. Nevet A, Polak T, Dagan O, Waisman Y. Extracorporeal membrane oxygenation as a resuscitation measure in the pediatric emergency department. Isr Med Assoc J 2015;17:639–41.
20. Chew SP, Tham LP. Extracorporeal life support for cardiac arrest in a paediatric emergency department. Singapore Med J 2014;3:e37–8.