Usefulness of extracorporeal membrane oxygenation in status asthmaticus with severe tracheal stenosis

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ABSTRACT

Extracorporeal membrane oxygenation, traditionally used to treat refractory hypoxemic respiratory failure due to acute respiratory distress syndrome, is being used to treat other etiologies of severe respiratory failure refractory to conventional mechanical ventilation. We present a 30-year-old woman with concomitant life-threatening airway obstruction due to severe tracheal stenosis and status asthmaticus treated effectively with veno-venous extracorporeal membrane oxygenation.

KEYWORDS Acute severe asthma; extracorporeal membrane oxygenation; tracheal stenosis

bstruction of the central airways, the trachea and mainstem bronchi, can complicate many disease processes and in tracheal stenosis can be a complication of prior tracheostomy placement due to excess scar tissue formation. Asthma is an allergic condition characterized by bronchoconstriction with periods of exacerbation and remission. During severe exacerbations, patients may need mechanical ventilation. Severe asthma exacerbation in a patient with a compromised central airway due to tracheal stenosis can be challenging to manage. Veno-venous (VV) extracorporeal membrane oxygenation (ECMO) involves diversion of blood for extracorporeal oxygenation and carbon dioxide removal by an artificial “membrane lung” and is a salvage treatment for respiratory failure. There are reports of successful outcomes where VV ECMO has enabled performance of lifesaving procedures in high-risk patients with central airway obstruction.¹

CASE PRESENTATION

A 30-year-old woman presented to an outside hospital with severe progressive dyspnea. She was in severe respiratory distress at the time of presentation and was ultimately intubated. The intubation was a difficult one and the intubating team was only able to pass a 6.5 mm endotracheal tube a short distance past the vocal cords because of resistance. She had known asthma, substance abuse (methamphetamines and tobacco), and a previous motor vehicle accident resulting

in intubation and tracheostomy. After the intubation, a chest radiograph showed a left pneumothorax for which a 14 French Wayne Cook chest tube was placed. She was transferred to our facility for further management.

On arrival, she was obtunded, and the end-tidal carbon dioxide reading was 98. Arterial blood gas had a pH of 6.9, and the partial pressure of carbon dioxide ($p\text{CO}_2$) was too high to read. She was tachycardic, with a heart rate of 135 beats per minute, and had a respiratory rate of 12 cycles per minute, blood pressure of 141/71 mm Hg, and oxygen saturation of 92% on 100% fraction of inspired oxygen. Auscultation revealed diminished breath sounds bilaterally. The chest tube was in a good position and functioning. Emergent bedside bronchoscopy showed severe subglottic stenosis (<5 mm airway lumen) just distal to the endotracheal tube. *Figure 1* shows the stenosis on computed tomography imaging.

Our initial ventilator management strategy was to decrease the positive end-expiratory pressure to 0; this was done to minimize the possibility of worsening intrinsic or “auto”-positive end expiratory pressure (PEEP). We reduced the respiratory rate to 12 cycles per minute as a way of giving more time for exhalation and kept the fraction of inspired oxygen at 100%. We still noticed she had peak inspiratory pressures >55 with a plateau of 14, indicating increased airway resistance. She received nebulized albuterol and ipratropium, as well as magnesium sulfate. She was also treated

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with 125 mg of intravenous methylprednisolone. Sedation was achieved with ketamine, fentanyl, and propofol infusions, and we proceeded to neuromuscular blockade with cisatracurium.

After consulting with cardiothoracic surgery, the patient was placed on VV ECMO. Her $p\text{CO}_2$ dropped to 35 mm Hg in <3 h. Her pH improved from 6.9 to 7.43. She underwent therapeutic bronchoscopy at the bedside (*Figure 2*). Electrocautery was performed using a gold probe and serial dilation using an 8-10 balloon followed by a 10-12 balloon. Finally, a 7.5 mm endotracheal tube was passed beyond the remaining stenosis. Her gas exchange improved after the procedures and she was decannulated from the ECMO circuit. She continued to do well and was extubated. Over the next few days, she was transferred out of the intensive care unit to a general medical floor and was discharged home with

instructions to follow-up with thoracic surgery for tracheal resection.

DISCUSSION

This case illustrates the management of a case of respiratory failure from concomitant central airway obstruction and severe asthma exacerbation with the aid of ECMO. VV and veno-arterial ECMO are now increasingly used for acute respiratory distress syndrome and refractory cardiogenic shock, respectively, but also for nontraditional indications such as upper airway surgery,² pulmonary embolism,³ and malignant airway obstructions.⁴ There are several case reports of VV ECMO utilization in refractory bronchospastic states like acute severe asthma⁵⁻⁸ and anaphylaxis⁹ for carbon dioxide removal. In our scenario, ECMO was a bridge to treat the patient's severe asthma exacerbation and tracheal stenosis.

In a report from South Korea, VV ECMO was used to care for 18 patients with severe central airway obstruction over a 5-year period.¹ In their series, 16 patients had a malignant infiltration of the airway as the cause of the central airway obstruction. One of the 18 patients had a tracheobronchial stenosis; although he had a successful tracheal stent insertion and was weaned off ECMO after 113 h, he died by the 60-day follow-up. Most of their patients (94.7%) were successfully weaned off ECMO, and death related to complications of ECMO was seen in only one patient. Another report and review of existing literature,¹⁰ noting the apparently good outcome in many reported cases, suggested ECMO for acute severe tracheal obstruction. In another report from Spain,¹¹ ECMO was used successfully in a case of severe life-threatening airway obstruction due to complications of inflammatory bowel disease.

Status asthmaticus remains a lethal condition, with an estimated 2000 deaths annually in the United States.¹² ECMO has also been used in refractory cases of status asthmaticus and refractory bronchospasm.^{13,14} In cases of intractable respiratory acidosis, where it is impossible to adequately ventilate the patient, ECMO can be an invaluable resource, as it can be much more efficient at carbon dioxide

Figure 1. Sagittal section of the computed tomography scan of the neck demonstrating area of stenosis.

Figure 2. Bronchoscopy with gold probe electrocautery of tracheal stenosis.

removal.^{12,13} This was seen in our patient with the rapid drop in her pCO₂ once she was placed on VV ECMO. The major determinants of how quickly this can be achieved are the sweep gas flow and the partial pressure of carbon dioxide in arterial blood entering the membrane lung, i.e., the higher the pCO₂, the higher the efficiency with which the carbon dioxide will be removed. In our case, the successful application of VV ECMO facilitated her treatment, resolved her asthma exacerbation, and supported her until her tracheal stenosis could be treated. Our case is unique, as our patient had concurrent central and distal airway obstruction with successful treatment with VV ECMO and bedside dilation of the tracheal stenosis.

A 5-year retrospective study of the outcomes of ECMO for the treatment of severe asthma among 16 patients at a tertiary center revealed patient characteristics similar to those of our patient and reported rapid resolution of both hypoxemia and hypercapnia, with significant improvement noted in the first hour.¹² Pneumothorax, which our patient had, was reported in 5 of their 16 patients. In our patient, we used a ventilator strategy that maximized expiration, with a relatively short inspiratory time. We used zero PEEP and only increased PEEP with clinical improvement.

The use of ECMO in respiratory failure allows for the lungs to rest (using ventilator settings that would minimize ventilator-induced lung injury—the so-called “ultra-low” and low tidal volume ventilation—usually tidal volumes in the order of 4-6 mL/kg of ideal body weight). In our case, ECMO allowed time for bronchiolar relaxation and resolution of the inflammation causing the bronchospasm. ECMO also allows for aggressive airway clearance. In our patient, we performed repeated therapeutic bronchoscopies for mucus plugging and then bronchoscopy-guided electrocautery to relieve her tracheal stenosis, which led to her successful decannulation from the ECMO circuit. She did well and was eventually discharged home.

1. Hong Y, Jo K-W, Lyu J, et al. Use of venovenous extra corporeal membrane oxygenation in central airway obstruction to facilitate interventions leading to definitive airway security. *J Crit Care.* 2013;28(5):669–674. doi:10.1016/j.jcrc.2013.05.020.
2. Hoetzenecker K, Klepetko W, Keshavjee S, Cypel M. Extracorporeal support in airway surgery. *J Thorac Dis.* 2017; 9(7):2108–2117. doi:10.21037/jtd.2017.06.17.
3. Zhong M, Tan L, Xue Z, et al. Extracorporeal membrane oxygenation as a bridge therapy for massive pulmonary embolism after esophagectomy. *J Cardiothorac Vasc Anesth.* 2014;28(4):1018–1020. doi:10.1053/j.jvca.2012.08.010.
4. Gourdin M, Dransart C, Delaunois L, et al. Use of venovenous extracorporeal membrane oxygenation under regional anesthesia for a high-risk rigid bronchoscopy. *J Cardiothorac Vasc Anesth.* 2012; 26(3):465–467. doi:10.1053/j.jvca.2011.02.013.
5. Tiruvoipati R, Haji K, Gupta S, Braun G, Carney I, Botha J. Low flow veno-venous extracorporeal carbon dioxide removal in the management of severe status asthmaticus: a case report. *Clin Respir J.* 2016;10(5):653–656. doi:10.1111/crj.12252.
6. Clifford C, Mhatre M, Craig S. Successful use of extracorporeal membrane oxygenation for status asthmaticus in a woman with a periviable pregnancy. *Obstet Gynecol.* 2018;132(4):1007–1010.
7. Maqsood U, Patel N. Extracorporeal membrane oxygenation for near-fatal asthma refractory to conventional ventilation. *BMJ Case Rep.* 2018. 2018:bcr-2017-223276 doi:10.1136/bcr-2017-223276.
8. Steinack C, Lenherr R, Hendra H, Franzen D. The use of life-saving extracorporeal membrane oxygenation (ECMO) for pregnant woman with status asthmaticus. *J Asthma.* 2017;54(1):84–88. doi:10.1080/02770903.2016.1193871.
9. Scaravilli V, Grasselli G, Benini A, et al. ECMO for intractable status asthmaticus following atracurium. *J Artif Organs.* 2017;20(2):178–181. doi:10.1007/s10047-016-0940-7.
10. Park J-H, Shin JH, Kim KY, et al. Respiratory support with venovenous extracorporeal membrane oxygenation during stent placement for the palliation of critical airway obstruction: case series analysis. *J Thorac Dis.* 2017; 9(8):2599–2607. doi:10.21037/jtd.2017.06.88.
11. Ramírez-Romero M, Hernández-Alonso B, García-Polo C, Abalde-Bechiari AJ, Garrino-Fernández A, Gordillo-Brenes A. Obstrucción de la vía aérea central por enfermedad inflamatoria intestinal y rescate terapéutico con membrana de oxigenación extracorpórea. *Med Intensiva.* 2018;42(5):317–319. doi:10.1016/j.medin.2017.04.008.
12. Di Lascio G, Prifti E, Messai E, et al. Extracorporeal membrane oxygenation support for life-threatening acute severe status asthmaticus. *Perfusion.* 2017;32(2):157–163. doi:10.1177/0267659116670481.
13. Malpas G, Hung O, Gilchrist A, et al. The use of extracorporeal membrane oxygenation in the anticipated difficult airway: a case report and systematic review. *Can J Anesth/J Can Anesth.* 2018;65(6):685–697. doi:10.1007/s12630-018-1099-x.
14. Jiang C, Galaydick J, Fernandez H, Caronia J. Adjunctive extracorporeal carbon dioxide removal in refractory status asthmaticus. *BMJ Case Rep.* 2017;2017:bcr-2017-220693. doi:10.1136/bcr-2017-220693.