Ann Thorac Cardiovasc Surg 2020; 26: 327–331
Online May 29, 2020
doi: 10.5761/atcs.oa.20-00005

Original Article

Tracheal Reconstruction Surgery Supported by Extracorporeal Membrane Oxygenation for Patients with Traumatic Post-Tracheotomy Tracheal Stenosis

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Purposes: Patients who require surgeries for traumatic post-tracheotomy tracheal stenosis (PTTS) often cannot be supported using conventional airway management approaches. This study documents the use of extracorporeal membrane oxygenation (ECMO) in patients with PTTS.
Methods: Patient characteristics, procedure, and outcome of patients who required tracheal reconstruction surgery for PTTS supported by ECMO were retrieved and analyzed.
Results: Four patients (mean age 28 years; range 17–48 years) with traumatic PTTS underwent tracheal reconstruction surgery supported by ECMO. The mean time from removal of tracheotomy tube to admission was 3.2 months (range: 1–9 months). The mean diameter of the stenotic segment was 5 mm (range: 4–6 mm). One patient underwent tracheoplasty and semi-tracheostomy with venoarterial ECMO urgently. Three patients underwent tracheal resection and end-to-end anastomosis (TRE) with venovenous ECMO empirically. Intervention success was achieved in 100% (4/4) of patients. The mean duration of ECMO was 35.3 hours (range: 16–53 hours). The overall survival rate was 100% (4/4) within a mean follow-up of 26 months (range: 7–57 months).
Conclusions: ECMO is a safe and feasible method to support oxygenation for patients with critical traumatic PTTS during tracheal reconstruction surgery.

Keywords: extracorporeal membrane oxygenation, tracheal stenosis, tracheotomy surgery, airway reconstruction

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Introduction

Trauma is the leading cause and accounts for up to 45% of tracheotomy, especially when accompanied by multiple co-injuries.[1,2] The post-tracheostomy tracheal stenosis (PTTS) usually occurs 1 and 6 weeks after extubation, and the incidence of PTTS varies between 0.6% and 21%.[3] PTTS can have devastating consequences for patients due to high risk of increased respiratory distress, suffocation, and even death.[4] Although there are various therapeutic options, tracheal reconstruction surgery remains the optimal treatment for PTTS.[5] However, the severely narrowed trachea often makes the impossibility of conventional ventilation techniques and presents tremendous challenges for management of the life-threatening surgery.[6]

Case reports demonstrate the ability of extracorporeal membrane oxygenation (ECMO) to successfully support the most severely compromised patients with critical upper airway obstruction and tracheoesophageal fistula.[7,8] However, due to the limitations of single-patient case reports, ECMO is not recognized by authoritative sources as a viable mode of support for patients with anticipated difficult airways due to PTTS.[9]

The purpose of this study is to describe the use of ECMO to support oxygenation during high-risk tracheal reconstruction surgery for patients with traumatic |PTTS who could not be supported using conventional airway management approaches.

Materials and Methods

Ethical approval and consent to participate

This study was approved by the ethics committee of Sichuan provincial people's hospital. The subject had given written informed consent to participate and publish. The study was registered at the Chinese Clinical Trial Registry (ChiCTR1800018945). Conduct and reporting adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Guideline.

Study population

All adult patients with traumatic PTTS who underwent tracheal reconstruction surgery with ECMO from 2015 to 2019 were included in this study.

Tracheal reconstruction

The size and location of the stenotic tracheal and the degree of stenosis were diagnosed by bronchoscopy or computed tomography (CT). Bronchoscopy was performed by an interventional pulmonologist using a rigid bronchoscope (BF-260, OLYMPUS, Tokyo, Japan).

General anesthesia was achieved using intravenous propofol or opioids based on attending anesthetists' preferences and patients' needs. Tracheal reconstruction surgery was performed by thoracic surgeons or otolaryngologists.

Within 24 hours of the initial ECMO-supported surgery, a rigid bronchoscope or chest CT was used to evaluate intervention success which was defined as a post-intervention endoluminal diameter of at least 50% of the original normal airway. No additional procedures were undertaken after the surgery. Then, these patients were transferred to the oncology department for further chemotherapy or radiotherapy.

ECMO

A multidisciplinary consultation involving pulmonologists, surgeons, intensive care specialists, and anesthetists was held to address the potential use of ECMO and to individualize each patient's treatment strategy.

ECMO was applied using the CardioHelp auxiliary system (Maquet AG, Germany), which was set and managed by intensive care specialists. The drainage and reinfusion cannula were both heparin-coated. Immediately before cannulation, a single dose of 3000–5000 IU sodium–heparin was administered intravenously. Then, under the guidance of vascular ultrasound, cannulas were percutaneously inserted under local lidocaine analgesia. Heparin was not continuously infused since the duration of ECMO was expected to be relatively short. ECMO flow was set at 50%–80% of the patient's estimated cardiac output, with mean arterial pressure maintained above 60 mmHg. The PaO_2 target range was set between 100 and 150 mmHg, with a $PaCO_2$ target range of 35–45 mmHg. Normothermia management was applied, and the blood temperature was maintained at 36–37°C.

Statistical analysis

The primary outcome of the study was intervention success, while survival, ECMO characteristics, complications, intensive care unit (ICU), and hospital stay were secondary outcome parameters.

Continuous variables are described using means and ranges. Count data are described using percentages. Statistical analyses was performed using SPSS (version 23; SPSS, Chicago, IL, USA).

Results

Study population

Between 2015 and 2019, four patients underwent tracheal reconstruction surgery with the support of ECMO to treat critical traumatic PTTS arising from removal of tracheotomy tube. They all had traumatic brain injury following car accidents and had undergone tracheotomy. The mean age was 28 years old (range: 17–48 years), and 75% (3/4) of patients were men. The mean time from removal of tracheotomy tube to admission was 3.2 months (range: 1–9 months). The mean diameter of the stenotic segment was 5 mm (range: 4–6 mm). Additional characteristics are presented in **Table 1**.

Table 1 Demographic, clinical, and surgical characteristics of the patients

Case	Age	Gender	Time from removal of TT to admission (m)	Diameter of stenosis	ECMO type	Vascular access	Duration of ECMO (h)	Surgery	Time of surgery (h)	ICU stay (d)	Hospital stay (d)
1	17	M	9	4 mm	VA	Femoral vein–Femoral artery	53	Tracheoplasty + semi-tracheostomy	4	3	21
2	27	M	1	5 mm	VV	Jugular vein–Femoral vein	16	TRE	3	2	13
3	21	F	2	6 mm	VV	Jugular vein–Femoral vein	48	TRE	3	3	13
4	48	M	1	5 mm	VV	Jugular vein–Femoral vein	24	TRE	2	3	7

ECMO: extracorporeal membrane oxygenation; TRE: tracheal resection and end-to-end anastomosis; TT: tracheotomy tube; VA: venoarterial; VV: venovenous

Tracheal reconstruction surgery

One patient had obvious dyspnea, in semi-supine position, with cyanosis of lips, and obvious trident sign which required emergency tracheotomy. However, he developed critical airway obstruction leading to cardiac arrest and pneumothorax during the surgery. Although jet ventilation was applied and thoracic drainage tube was placed, his oxygenation could not be maintained. Emergency bronchoscopy suggested there was a kind of valve close to carina, which disappeared when inhaling, expanded and blocked the main trachea when exhaling. And a length of 6.5 mm longitudinal fistula was located at the posterior wall of the trachea, without connection with the esophagus, and the depth was about 4 cm. Venoarterial (femoral venous–femoral arterial) ECMO therefore was urgently used due to the intolerance of supine position caused by his extreme dyspnea. Tracheoplasty and semi-tracheostomy were performed immediately after ECMO establishment while intraoperative saturation was maintained at 80–100%. A no. 8 lengthened tracheotomy tube was inserted into the semi-tracheostomy incision to connect the ventilator.

Severe tracheal stenoses were indicated by CT (**Fig. 1**) in the remaining three patients who underwent tracheal resection and end-to-end anastomosis (TRE) with the support of venovenous (jugular venous–femoral venous) ECMO empirically (**Figs. 2** and **3**). Prior to ECMO, none of the three patients required invasive

Fig. 1 Three-dimensional reconstruction image of the stenotic trachea.

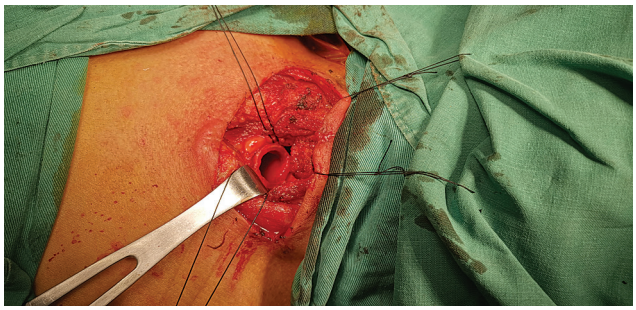

Fig. 2 Surgical field following resection of the stenotic trachea with the support of extracorporeal membrane oxygenation.

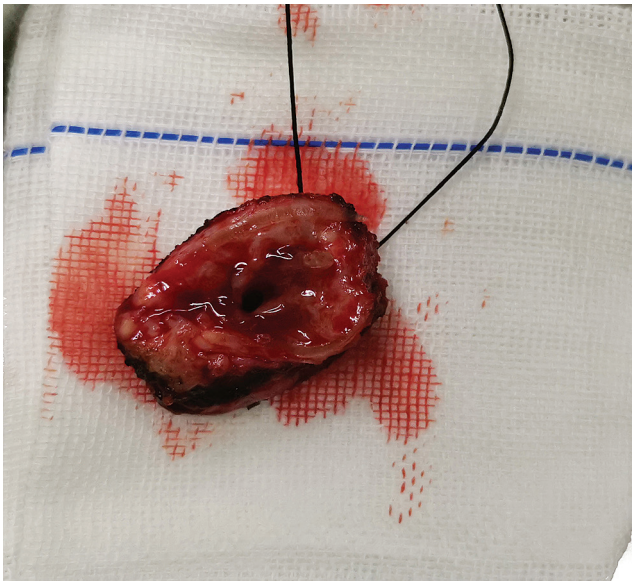

Fig. 3 Excised specimen of the stenotic trachea.

mechanical ventilation. Oral endotracheal tubes were inserted in all three patients after successful completion of the surgery. The mandible was sutured to the anterior chest wall to avoid cervical flexion at the end of surgery.

The mean surgical time was 3 hours (range: 2–4 hours) in the four patients. After the surgery, all the patients were sent to ICU.

ECMO support

ECMO support was gradually decreased until patients were breathing spontaneously and the ECMO cannulas could be removed. The mean duration of mechanical ventilation was 14.8 hours (range: 12–18 hours). The mean flow rate used was 3.0 L/min with a range from 1.9 to 4.0 L/min. Weaning off ECMO support was successful in 100% (4/4) of patients. The mean duration of ECMO was 35.3 hours (range: 16–53 hours).

Outcomes and complications

Procedure success was defined as a post-intervention endoluminal diameter of at least 50% of the original normal airway. Procedure success was achieved in 100% (4/4) of patients which was indicated by the CT or bronchoscopy. No blood product was administered and no other complications occurred.

The mean duration of ICU stay was 2.7 days (range: 2–3 days), with a median hospital stay of 13.5 days (range: 7–21 days). All patients were discharged alive from the hospital. After a mean follow-up of 26 months (range: 7–57 months), the overall survival rate was 100% (4/4).

Discussion

We present the results of four patients with critical trauma PTTS who received tracheal reconstruction surgery supported by ECMO. We document successful hospital discharge for all of these patients, with a mean duration of survival of approximately 2 years. In our professional judgment, we do not believe we would have been able to achieve adequate oxygenation in these patients using conventional airway management techniques and thus may not have been able to provide these life-saving tracheal reconstruction surgery.

Maintaining adequate oxygenation during the tracheal reconstruction surgery in patients with PTTS is very challenging for anesthesia management.[6] If tracheal intubation or tracheotomy can be achieved, invasive mechanical ventilation, or occasionally jet ventilation, may also support reconstruction.[10] However, severe PTTS often make the conventional ventilation approaches difficult, impossible, or even life threatening.

In patients with anticipated difficult airways, ECMO has been demonstrated to be a useful method for maintaining oxygenation prior to achieving a definitive airway under general anaesthesia.[11] In patients with benign tracheal stenosis, ECMO was more likely to be used in pediatric patients with congenital tracheal stenosis in the previous studies.[12] Venovenous ECMO was successfully used in four adult patients with post-intubation or post-tracheotomy tracheal stenosis during the airway surgery reported by Ahn et al.[13] However, the cause of stenosis and the number of patients with PTTS were not specified. In 2017, Kim et al.[14] reported nine patients underwent airway operation with the support of venovenous ECMO, of which only one traumatic patient with PTTS. The status quo is few reports further described the use of ECMO in such patient population.

Complications

In our current study, heparin-coated cannula without continuous anticoagulants was the main contributor of less bleeding and minimized complications associated with arterial cannulation. The development of cannula with better histocompatibility, impregnated with novel anticoagulants, may significantly improve the safety of ECMO.

Strengths and Limitations

As with any case series, we cannot provide comparisons to appropriate control patients. Since the technique under study is usually applied to patients in whom conventional techniques have been deemed "dangerous or impossible,"[15] we cannot find published outcomes for patients with critical PTTS who have been judged too risky and therefore have not been offered reconstructive surgery.

Furthermore, our study reports outcomes from a single center. Establishing a rigorous multicenter registry that also includes patients who present with critical PTTS but are not offered reconstructive surgery is imperative to begin understanding the safety and effectiveness of interventions that are offered.

Conclusions

In our study, we described ECMO was successfully applied in patients with critical PTTS during life-threatening tracheal reconstructive surgery without any complications. Although venovenous ECMO can be considered gold standard if extracorporeal life support is needed during airway surgery,[15] venoarterial ECMO is still an option in cases of extremely dangerous breath leading to the difficulty in establishing the internal jugular vein access. Further large-scale studies are required to promote guidelines integrating ECMO into difficult airway management.

Acknowledgments

The authors thank Professor Gordon S. Doig from Northern Clinical School Intensive Care Research Unit of Sydney University for editing the manuscript, Dr Xiaobo Huang from Critical Care Department of Sichuan Provincial Peoples' Hospital for technical support of ECMO and Dr Gang Feng from Thoracic Surgery Department of Sichuan Provincial Peoples' Hospital for surgical consultation and images.

Disclosure Statement

There is no conflicts of interest.

References

1) Özgül MA, Gül Ş, Çetinkaya E, et al. Our eight years experience in postintubation/posttracheostomy tracheal stenosis. Tuberk Toraks 2019; **67**: 55-62.
2) Fokin AA, Wycech J, Chin Shue K, et al. Early versus late tracheostomy in trauma patients with rib fractures. J Surg Res 2020; **245**: 72-80.
3) Ezemba N, Echieh CP, Chime EN, et al. Postintubation tracheal stenosis: surgical management. Niger J Clin Pract 2019; **22**: 134-7.
4) Li M, Yiu Y, Merrill T, et al. Risk factors for posttracheostomy tracheal stenosis. Otolaryngol Head Neck Surg 2018; **159**: 698-704.
5) Ulusan A, Sanli M, Isik AF, et al. Surgical treatment of postintubation tracheal stenosis: a retrospective 22-patient series from a single center. Asian J Surg 2018; **41**: 356-62.
6) Doyle DJ, Hantzakos AG. Anesthetic management of the narrowed airway. Otolaryngol Clin North Am 2019; **52**: 1127-39.
7) 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 Anaesth 2018; **65**: 685-97.
8) Wang L, Xu XP, Zhan H, et al. Application of ECMO to the treatment of benign double tracheoesophageal fistula: report of a case. Ann Thorac Cardiovasc Surg 2014; **20**: 423-6.
9) Frerk C, Mitchell VS, McNarry AF, et al. Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. Br J Anaesth 2015; **115**: 827-48.
10) Ost DE, Ernst A, Grosu HB, et al. Therapeutic bronchoscopy for malignant central airway obstruction: success rates and impact on dyspnea and quality of life. Chest 2015; **147**: 1282-98.
11) Willms DC, Mendez R, Norman V, et al. Emergency bedside extracorporeal membrane oxygenation for rescue of acute tracheal obstruction. Respir Care 2012; **57**: 646-9.
12) Huang SC, Wu ET, Chi NH, et al. Perioperative extracorporeal membrane oxygenation support for critical pediatric airway surgery. Eur J Pediatr 2007; **166**: 1129-33.
13) Ahn HY, Su Cho J, Kim YD, et al. Surgical outcomes of post intubational or post tracheostomy tracheal stenosis: report of 18 cases in single institution. Ann Thorac Cardiovasc Surg 2015; **21**: 14-7.
14) Kim SH, Song S, Kim YD, et al. Outcomes of extracorporeal life support during surgery for the critical airway stenosis. ASAIO J 2017; **63**: 99-103.
15) Hong Y, Jo KW, Lyu J, et al. Use of venovenous extracorporeal membrane oxygenation in central airway obstruction to facilitate interventions leading to definitive airway security. J Crit Care 2013; **28**: 669-74.