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Use of VV ECMO for Perioperative Support in Repair of Tracheal Injury Secondary to Emergent Cricothyroidotomy

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Background	Iatrogenic tracheal injury is an uncommon complication from airway intervention, most commonly seen in emergent airway procedures and complex intubations. Management may vary from conservative to surgical, and in very severe cases, cardiopulmonary support may be necessary during repair and or healing.
Summary	We present a case of tracheal injury secondary to prehospital cricothyroidotomy, which, to our knowledge, is the first case of this etiology reported in the literature. Due to the severity of the injury, the patient required respiratory support with venovenous extracorporeal membrane oxygenation (VV ECMO), which was initiated soon after her presentation to our facility. She subsequently underwent successful surgical repair and was weaned from ECMO six days postoperatively. The patient had a good recovery and, at the time of writing, is back to her baseline functional status.
Conclusion	Perioperative VV ECMO can aid the management of severe iatrogenic tracheal injury with the potential for excellent outcomes. Cricothyroidotomy as an etiology for an injury of this severity requiring VV ECMO support has not previously been reported.
Key Words	tracheal injury; cricothyroidotomy; ECMO
Abbreviations	VV ECMO: venovenous extracorporeal membrane oxygenation RSI: rapid sequence intubation ETT: endotracheal tube

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Case Description

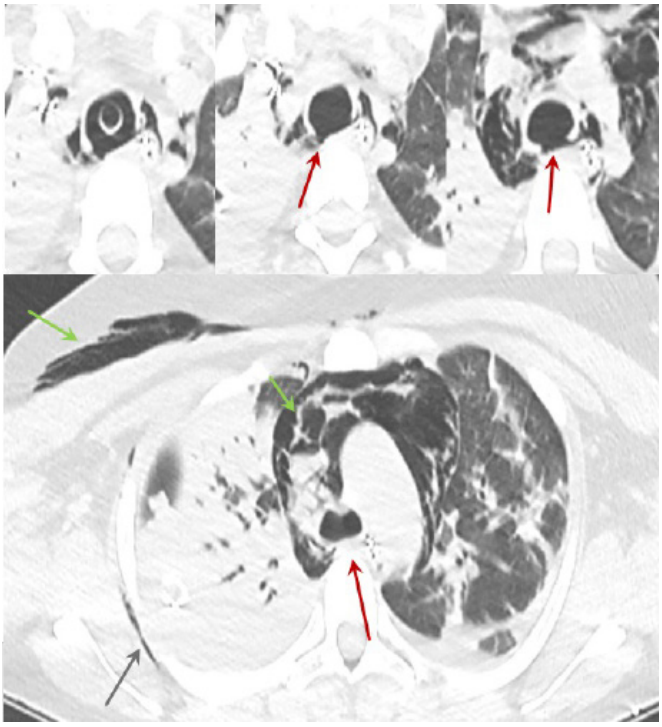
A 33-year-old female with a history of depression presented to a Level II Trauma Center with a gunshot wound to the left side of her face. On scene, her mental status was reported as normal but worsened en route. An unsuccessful attempt at rapid sequence intubation (RSI) by EMS was followed by a cricothyroidotomy with a size six endotracheal tube (ETT) was performed in the ambulance. Upon examination in the ED, a defect was seen on the left face, through the cheek and parotid gland. Dark venous oozing was seen coming from the cricothyroidotomy site. Blast injuries to the left second and third fingers were also noted. Her breath sounds were clear and equal bilaterally. She was hemodynamically stable, and vascular access was obtained. Shortly after arrival, she began to desaturate. Given concerns about the airway, she was taken to the OR for conversion to tracheostomy.

First, fiber optic oral tracheal intubation was attempted. The ETT was seen to be within the airway, but the anatomy was unclear. A vertical midline incision was made and carried down to the trachea, which was incised. The ETT was removed from the cricothyroidotomy site, and a #6 cuffed Shiley tracheostomy tube was placed in the surgical tracheotomy. A bronchoscopy was then performed, which showed bloody secretions without endobronchial lesions or visible airway trauma.

After tracheostomy, the patient remained difficult to ventilate and oxygenate. A chest X ray was done, which showed bilateral pneumothoraces (right greater than left) and subcutaneous emphysema. A right chest tube was placed. Given her worsening clinical picture, she was transferred to our Level I Trauma Center with ECMO capabilities for further management.

On arrival, the patient remained hypoxic and difficult to ventilate. Bronchoscopy was repeated, which showed a partially collapsed trachea with suspicion for a poorly visualized posterior tracheal injury. CT was obtained, which showed extensive pneumomediastinum, pneumothoraces, subcutaneous emphysema, and a defect in the posterior trachea (Figure 1). The position of the defect was consistent with a likely source for the bilateral pneumothoraces and pneumomediastinum. Thoracic surgery was consulted for evaluation for repair, which they felt would be possible if the patient could be stabilized. VV ECMO was initiated for hypoxia and failure to ventilate adequately. Right 21Fr internal jugular and left 25Fr femoral catheters were placed. Initial settings included a flow of 4.9L/min, 3600 RPM, sweep gas flow of 6L/min, and sweep gas FiO2 100%. The patient was successfully oxygenated with oxygen saturations greater than 88%. To avoid further airway trauma, she was sedated to prevent respiration, and ventilation was discontinued.

Figure 1. Initial Imaging. Published with Permission



Top: Sequential axial images in lung windows show that immediately inferior to the ET tube, there is apparent discontinuity of the posterior trachea (red). Bottom: Origin of the mainstem bronchi appears intact (red). Mediastinal and soft tissue emphysema (green) are noted as well as atelectasis (blue).

After she had been stable on VV ECMO for 24 hours, she was taken to the OR. A right posterolateral thoracotomy was performed. When the posterior trachea was exposed, a large defect with tissue loss was seen extending from the cervical trachea to approximately 2 cm above the carina. Part of this was easily approximated and repaired primarily, but in the area of tissue loss, a bovine pericardial patch was used for repair (Figure 2). An intercostal muscle flap was used to buttress the repair. The #6 Shiley tracheostomy tube was replaced with a flexible #8 Bivona silicone tracheostomy tube. It was not possible to land the cuffed portion on the uninjured distal trachea as this segment was too short. The cuff was left deflated, and the patient was kept on sole ECMO support postoperatively. She underwent daily bronchoscopy to evaluate the repair, which remained intact and perfused. On postoperative day 3, the cuff was

partially inflated, and gentle pressure support was started and slowly increased. ECMO was weaned as tolerated. By postoperative day 6, the patient was able to be effectively ventilated and oxygenated on pressure support. She passed an ECMO trial off and was decannulated. Her recovery was complicated by difficulties with sedation and psychiatric medication management as well as an episode of tracheostomy occlusion by thick secretions requiring emergent replacement of the tube. After this was addressed, her respiratory recovery proceeded smoothly. The tracheostomy was downsized postoperative day 24, and she was discharged to outpatient psychiatric care on postoperative day 32.

Figure 2. Surgical Repair. Published with Permission

The patch was parachuted down onto the defect visible at the bottom of the image with the suction tip in the center of the defect.

Discussion

Significant iatrogenic tracheal injuries are uncommon but potentially life-threatening. Injury may occur from the inside or the outside of the airway, the latter usually being from surgical dissection in the area, such as that required for esophagectomy.[1] Injuries from blunt trauma are usually to the membranous portion and commonly within 2 cm of the carina.[2] Internal injury is most commonly from emergent single-lumen endotracheal intubation but may also occur in elective double-lumen endotracheal intubations, tracheostomies, and other airway instrumentation.[3-5] The incidence of internal iatrogenic tracheal injury is difficult to discern, with only a handful of case series in the literature. The greatest risk factor is emergent airway procedure, with additional risk factors including higher grade cord view, large body habitus, and female gender (likely due to shorter tracheas).[3,6]

In terms of cricothyroidotomy, we were unable to find specific examples of tracheal injury as a result of this procedure. This was somewhat surprising given that they are always emergent and usually in patients who have difficult airways. It seems likely that the relative infrequency of this procedure, compared to intubations and tracheostomies, bears some responsibility. Injuries may be smaller and of less clinical consequence or may be missed in the context of other acute issues. Additionally, despite the settings in which cricothyroidotomy is usually performed, they are often successful and may not have as frequent or severe complications as previously thought; compared to tracheostomy (creation and conversion from cricothyroidotomy), major and minor complications are similar, and long-term complications are lower.[7,8] The success rate of surgical cricothyroidotomy is about 90% in the prehospital setting and up to 97% when performed by surgeons.[9] Needle cricothyroidotomy success is lower at 66% to 77%, again with slightly higher rates when performed by physicians.[9] The experience and comfort of physicians likely influences the difference in success. Still, it is also important to remember that prehospital providers work under much less controlled conditions.[8] The risk of injury and failure of the procedure, as any other, needs to be weighed against the risk of losing the airway; cricothyroidotomy, by its nature, is a life-saving salvage procedure.[10]

There are multiple ways to approach an iatrogenic tracheal injury. Given the typical pattern of posterior membranous tears and defects with iatrogenic injuries, these injuries are frequently approached through a right thoracotomy, usually in the fourth intercostal space.[11-13] Along with tracheal exposure, the esophagus should also be inspected visually and with endoscopy to rule out an injury, even in the case of partial thickness tracheal injuries, as blunt force may still be transferred.[14] Once the tracheal injury is exposed, the amount of tissue disruption determines whether the injury can be repaired primarily[11,12] or with a pericardial patch that may be autologous or xenograft.[12,14] Absorbable monofilament polydioxanone sutures are most commonly used.[14]. After repair, buttresses with intercostal flaps are commonly used,[12,15] although in some cases the esophagus may be used as a buttress.[11]

Keeping the airway patent while protecting the repair can be difficult. If the injury is proximal enough, the endotracheal balloon would ideally be placed below the repair and inflated to isolate the repair from the pressure generated by the ventilator circuit and lungs. If isolation of the injury is possible, conventional therapy may be used. If not, ECMO support should be considered.[6] Many airway management options exist if ECMO is used for oxygenation and ventilation. A conventional endotracheal tube may be used, in which case the placement should avoid the tip and or cuff at the level of the injury if possible. The cuff is generally left down or only partially inflated to avoid pressure on the repair. Tracheostomy may or may not be needed depending on the size of the defect and the anticipated duration of mechanical ventilation required. It may also already be an etiology for the injury, obviating the choice.[4] Ventilation is also more flexible; ultra-lung protective settings with low tidal volumes and low pressures that do not provide adequate gas movement and exchange on their own but prevent injury to a fresh repair may be used with ECMO support.[12,16] Even apnea may be used for short periods.

The length of time required in ultra-lung protective settings varies by the extent of injury, the quality of repair, individual variations in healing, and surgeon comfort. Smaller injuries with primary repair may require less healing time than larger ones with more surrounding tissue disruption and potentially compromised blood supply. It is useful to assess the repair by bronchoscopy (done by an experienced operator) prior to increasing ventilator support.[11,17] Daily bronchoscopies may also be done to assess healing and ensure that secretions do not build up in the airways and around the repair. Although aggressive suctioning should be avoided, gentle inline suctioning with care not to advance if any resistance is met is helpful. Hesitancy to blind suctioning likely contributed to the obstruction of the tracheostomy in our case. We could not find any report of damage to a repair by inline suctioning in the literature. There is support for serial bronchoscopy to prevent mucous accumulation at the repair and in the rest of the airway.[6]

There are some situations where surgery may not be necessary. Conservative management may be reasonable in small tracheobronchial injuries (generally less than 2 cm tear)—where normal respiration is not affected or where conventional mechanical ventilation is effective without a large air leak.[3,4,18] Conservative management may also be attempted by necessity in patients who may benefit from surgical repair but are not operative candidates because of concurrent injuries, infections, or comorbidities.[6,19] Bronchoscopic interventions such as stenting, suturing, and glue application have been increasingly explored in tracheal injuries,[20,21] commonly based on previous experience in tracheoesophageal fistula management.[22] This type of management is not yet well established and would not be considered standard of care, but may be considered on a case-by-case basis where expertise is available.

VV ECMO is an invaluable tool in severe tracheal injuries. The ability to exchange oxygen and carbon dioxide without the need for air to go through the damaged airway allows many more options for management.[2] ECMO can be used for extended periods with ultra-lung protective ventilation to allow healing over time in patients who are not operative candidates.[19] In cases requiring surgery, ECMO removes the need to maintain a patent airway during repair, allowing steady gas exchange throughout the case without compromising mobility or space intraoperatively. This strategy can be limited to the immediate perioperative period.[1,17,23] Conversely, in cases where damage is extensive and or other healing barriers/complications are expected, it can be continued until any air leak has resolved and the repair appears to be healthy and healing by bronchoscopic visualization.[12,24-26] Bronchoscopy is also a lower risk when the airway the scope is passed through is not the primary route of gas exchange and can allow more complex bronchoscopic procedures to be done.[19,23]

There are potential drawbacks to ECMO use: at least two large central venous catheters must be placed; additionally, when compared with traditional cardiopulmonary bypass, while ECMO is much less invasive and usually faster, hemodynamic instability and significant blood loss are still not uncommon.[27] With the large surface area of the circuit, there is also a risk for thrombosis; as such, anticoagulation is generally indicated. However, this is not absolutely required with heparin-coated circuits, particularly when higher flows are maintained.[15] The option of avoiding anticoagulation is desirable in the intraoperative setting or in trauma patients for whom anticoagulation would cause worsening of hemorrhagic injuries.

Conclusion

Iatrogenic tracheal injury is a complex scenario with potentially life-threatening consequences. Early recognition is vital to mobilize the resources required to treat severe injuries. VV ECMO provides a way to stabilize the patient by obviating the need to use the airway to provide oxygenation and ventilation so the injury can be assessed and treated appropriately. Surgical repair, when indicated, can be done in a controlled fashion with multiple options for airway management both intraoperatively and postoperatively with the aid of VV ECMO.

Lessons Learned

VV ECMO can safely and effectively be used for perioperative support in the case of traumatic tracheal injuries. Gentle but thorough and frequent suctioning is vital to prevent airway obstruction; the risks of these complications far outweigh the small risk of disrupting the repair.

Authors Contributions

Dr. Arvin Gee was the admitting and primary attending for this case and provided edits to the manuscript. Dr. Alexandra Brito was the fellow on the case and wrote the initial and subsequent drafts of the manuscript.

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