Extracorporeal Membrane Oxygenation for Repair of Tracheal Injury during Transhiatal Esophagectomy

Introduction
Tracheal injury is a known complication of esophagectomies. We describe a case of tracheal injury recognized in the operative period of an open transhiatal esophagectomy for squamous cell carcinoma of the mid to distal esophagus. When injury was discovered, attempts to improve oxygenation and ventilation by conventional methods were unsuccessful. Therefore, peripheral ECMO was used to support oxygenation during the tracheal defect repair.

Case Report
A 60-year-old male presented with squamous cell carcinoma of the middle to distal esophagus (T3N1M0) for open transhiatal esophagectomy in a tertiary center. The patient underwent standard chemotherapy (carboplatin and paclitaxel) and radiation before surgery as described in the chemoradiotherapy for esophageal cancer followed by surgery (neoadjuvant chemoradiotherapy plus surgery versus surgery alone for esophageal or junctional cancer) trial.[2] General anesthesia was induced in usual fashion with a single-lumen endotracheal tube (SLETT), two 16-gauge peripheral intravenous catheters, and a radial arterial catheter. The procedure started in the supine position with mobilization of the stomach and lower half of the thoracic esophagus through the hiatus. During the dissection of the esophagus at the cervical level, the surgeon noticed air leaking into the neck and tracheal injury was suspected. At that point, the ventilator was unable to deliver the preset tidal volumes. The surgeon controlled the leak with manual compression while the SLETT was advanced past the injury with restoration of tidal volumes. A bronchoscopy was performed and revealed a 3.5 cm longitudinal laceration in the membranous portion of the trachea extending to the carina. Lung isolation and left lung ventilation were attempted with the SLETT; however, it was not long enough to allow the balloon to seat properly in the left main stem bronchus. Therefore, the SLETT was exchanged for a 35 French left double-lumen tube (DLT). The DLT position was verified with fiberoptic bronchoscopy.

The surgeons decided to perform a right posterolateral thoracotomy to repair the tracheal injury. Oxygenation and ventilation became very difficult after placing the patient in the left lateral decubitus position. The oxygen saturation decreased to...
approximately 77%, despite compression of the injury. The patient was positioned supine again, but ventilation and oxygenation did not improve. High peak pressures were noticed and raised the suspicion of pneumothorax. The surgeon placed bilateral chest tubes in the pleural space in an attempt to treat pneumothorax as a possible cause of the hypoxemia. Nevertheless, the patient’s arterial blood gas (ABG) showed severe hypoxemia [ABGs in Table 1].

At this point, it was decided to place the patient on venovenous ECMO to oxygenate patient appropriately while proceeding with tracheal repair. ECMO team was immediately available. The perfusionist prepared the ECMO circuit while the cardiac surgeon placed the cannulas in the femoral veins (19 French in the right for inflow and 23 French in the left for outflow). The ECMO flows are shown in Table 2. By our ECMO protocol, the activated clotting time was maintained around 200. The patient remained on ECMO for 289 min while the thoracic surgeon performed a repair of the tracheal injury with the assistance of an intercostal muscle flap. Then, the surgical oncologist completed the esophagectomy. Upon completion of the surgery, the DLT was exchanged for an 8.0 SLETT, and ECMO was successfully weaned with adequate ventilation and oxygenation. The patient was transported to the Intensive Care Unit where he was extubated the following day.

Discussion

The incidence of tracheal injury during transhiatal esophagectomy is estimated at 0.4% in high volume centers. However, they carry a burden in terms of morbidity and mortality.[3]

A recent retrospective review of tracheobronchial injury in the setting of esophageal cancer at our institution revealed that 1.6% of patients suffered an airway injury. Malignancy as well as chemoradiation preceding the surgery is potential risk factors.[4,5]

The outcomes are usually better if these injuries are discovered and treated during the surgery. In our case, the injury was promptly discovered and repaired during the intraoperative period. The unique aspect of this case can be summarized in the proactive maximal use of available resources including specialized anesthesia care and invasive ECMO, to complete the repair while integrating multidisciplinary surgical teams.

There are different approaches to oxygenation and ventilation depending on the location of the injury. The major concern of delivering positive pressure ventilation is worsening of the injury or damaging the anastomosis. While conservative management is described, in which the patient is spontaneously breathing while the injury is allowed time to heal, this was not an option in the middle of surgery and with already poor oxygenation. A common approach in this situation is to advance an endotracheal tube past the injury, allowing oxygenation, and ventilation while minimizing the risk of positive pressure. In the case presented, the SLETT was not long enough to sit below the injury and maintain one-lung ventilation. A DLT was placed at this point. Venovenous ECMO was started when one-lung ventilation failed to resolve the patient’s oxygenation and ventilation problems. This was felt to be the best option given the immediate availability of ECMO at the operating theater. The operating room ventilator was only capable of providing volume or pressure control modes of ventilation. It was not felt that obtaining a different ventilator and using advanced modes such as airway pressure release ventilation or high-frequency oscillation would avoid the potential risk of worsening the tracheal injury.

Traditionally, peripheral cannulation is used for venovenous ECMO. One long cannula with the tip in the right atrium is placed for inflow, and a short cannula ending in the inferior vena cava is placed for outflow.[6] Cannulas may be placed in the jugular or femoral veins; however, in this case, jugular vein cannulation was not an option as it would have been in the surgical field.

The main indication for venovenous ECMO is severe acute ventilatory and/or oxygenation failure that is potentially reversible and is not associated with cardiac failure.[6] ECMO has been used mostly for infants in cases involving meconium aspiration syndrome, congenital diaphragmatic hernia, or persistent pulmonary hypertension of the newborn.[7] in adult patients experiencing acute respiratory distress syndrome (ARDS), and in cases of traumatic lung injury.[8]

| Hours on ECMO | Oxygen saturation percentage | MAP (L/min) | ECMO flow (L/min) | ECMO RPM | ECMO sweep (L/min) | ECMO FiO₂ |
|---------------|-----------------------------|------------|------------------|----------|-------------------|-----------|
| 0.5           | 94                          | 94         | 4                | 2100     | 4                 | 100       |
| 1             | 100                         | 100        | 1.5              | 1705     | 2                 | 100       |
| 2             | 94                          | 90         | 1.5              | 2065     | 2.5               | 100       |
| 3             | 100                         | 84         | 1.5              | 2143     | 1.5               | 80        |
| 4             | 100                         | 94         | 1.0              | 2500     | 0.8               | 50        |

MAP: Mean arterial pressure, FiO₂: Oxygen inspired fraction, RPM: Revolutions per minute, ECMO: Extracorporeal membrane oxygenation
The risks and benefits of venovenous ECMO must be carefully evaluated before proceeding with it. The most common complication associated with ECMO is hemorrhage, due to the need for heparinization. Other complications include heparin-induced thrombocytopenia, neurological complications, ECMO circuit clots, and resultant oxygenator failure.

The temporary use of ECMO in this case allowed the physicians to perform the tracheal repair without a time constraint while avoiding anoxic sequelae. Although this may not be possible in all institutions, when it is immediately available, the use of venovenous ECMO may be considered to support primary surgical repair in cases of tracheal rupture.

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Conflicts of interest
There are no conflicts of interest.

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