Tips and tricks in the operative management of esophageal, trachea, and bronchial injuries: What you need to know

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ABSTRACT: Tracheal injuries can be immediately life-threatening. Fiberoptic bronchoscopy in the operating room can make the diagnosis and satisfy the principle of achieving an airway distal to the injury. Repair is performed with a single layer of absorbable suture. Esophageal injuries are diagnosed with imaging, endoscopy, or intraoperatively. In the chest, esophageal injuries are best repaired through posterolateral incisions. Repairs are performed in one or two layers, and drains are routinely used. For a damage-control approach to esophageal injuries, wide drainage can be considered. For both tracheal and esophageal injuries, the operative approach is based on the anatomic location of the injury and muscle flap buttressing of the repairs is routinely employed. (*J Trauma Acute Care Surg.* 2024;00: 00–00.

KEY WORDS: Trachea; esophagus; injury; trauma; operative.

Tracheal and esophageal injuries are rare.[1,2] They are central structures, deep in the mediastinum, with an extension into the neck and for the esophagus, the abdomen. While uncommon, tracheal injuries can be immediately life-threatening and require critical intervention.[3] Esophageal injuries may not have immediate mortality but can have significant sequela because of mediastinal sepsis. Thus, an index of suspicion for these injuries is important.

TRACHEA

Mechanism

Overall, tracheobronchial injuries are uncommon, occurring in as few as 0.5% of injured patients.[1,4,5] Tracheal injuries can present from blunt, penetrating, and iatrogenic etiologies.[5–7] Blunt injuries to the cervical trachea can occur from direct impact. In the cervical region, one of the classic injuries is the "clothesline injury" that can occur when the victim is riding a bicycle or motorcycle and the neck impacts upon a rope or cable stretching across their path. These can result in crushing or disruption of the trachea. Penetrating injuries in the neck can occur from stab wounds or gunshot wounds. Associated injuries to the esophagus occur in 20% of patients.[8] Blunt injuries to the intrathoracic trachea can occur from hyperextension and compression injuries. These commonly occur at the distal trachea.[9–11] Because of the trachea being deep in the mediastinum, penetrating injuries to the thoracic trachea are most common from gunshot wounds.[12] Iatrogenic injuries can also occur during vascular access and airway interventions.

Presentation

It is remarkable how during spontaneous breathing even significant tracheal injuries may be well tolerated. However, the patient may present with stridor or difficulty breathing. The patients are often extremely anxious, sitting up, and reticent to lie supine. One of the most common physical examination findings is subcutaneous emphysema. This is usually seen in the neck but can track to the chest wall and into the face.[8,13,14]

Prehospital Considerations

The most important prehospital consideration for prehospital care of a patient with a possible tracheal injury is suspicion and rapid transport to an appropriate facility. Findings such as shortness of breath and subcutaneous emphysema create an index of suspicion. Patients are transported, if possible, in a sitting position. The usual reflex for early endotracheal intubation may not be the best course. While an airway may be able to be passed beyond the vocal cords, it may not communicate and ventilate the distal trachea if there is a tracheal injury in the neck or in the chest. One exception may be the large gaping wound in the neck where the distal trachea can be identified. Intubation of this distal segment, while challenging, may be lifesaving.[15]

Emergency Department Considerations

The patient is rapidly assessed for considerations of an airway injury. Dyspnea, a falsetto voice, anxiety, and subcutaneous emphysema with a pattern of injury or missile trajectory may be suggestive. Again, the usual reaction of early endotracheal intubation in the emergency center may not be advisable. For these patients, the principle is to achieve an airway distal to the anticipated injury. This is sometimes difficult to achieve in the emergency center. The safest course is often rapid evacuation to the operating room where the full team of surgeons, anesthesiologists, and nursing with special airway equipment and maneuvers is available. An awake fiberoptic intubation has both diagnostic and therapeutic efficacy.[2,16] The surgeon and the anesthesiologist coordinate their efforts, and this is often performed with the patient in a sitting position. An appropriate size, perhaps

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reinforced, endotracheal tube is preloaded on the fiberoptic bronchoscope. Topical local anesthesia can be obtained in the back of the pharynx. Local laryngeal nerve blocks may be performed. The flexible bronchoscope is introduced, and further local anesthetic can be injected through the bronchoscope onto the vocal cords. The bronchoscope can then be passed through the cords, and direct inspection of the trachea can be achieved. Again, the priority in the operator's mind is to identify an injury and to achieve an airway distal to the injury. The tracheal tube is then positioned under direct vision past the injury. Partial circumferential injuries can thus be temporized. For patients with high suspicion for injury, a negative bronchoscopy can be repeated later.[17]

This satisfies the airway component of the primary survey, and the remainder of the patient's evaluation may then be completed. Distal tracheal injuries may require that the endotracheal tube be passed preferentially into a bronchus to at least achieve one lung ventilation. For distal tracheal or bronchial injuries, it has been suggested that an airway bougie can be used to place a double lumen endotracheal tube into the bronchus for additional length. However, the stiffness of the tube and the required manipulations can cause extension of the injury. Sometimes, the operator will place the bronchoscope through the cords and then not see tracheal rings. The sensation the operator will have is that they are lost. This suggests that the bronchoscope is in the mediastinum and is seen when the trachea has a large injury or is completely transected. Sometimes, the operator will be able to visualize the distal trachea deep in the mediastinum. If possible, the bronchoscope can be directed into the distal trachea and the endotracheal tube passed, achieving ventilation and oxygenation.

Again, the principle is to achieve an airway distal to the injury, and sometimes, this cannot be done even with the bronchoscope. This is an advantage of rapid movement to the operating room. With these massive injuries, the patient may not survive even a brief attempt at intubation. An airway may need to be achieved operatively. If there is high suspicion that the injury is to the cervical trachea, a generous cervical incision followed by midline division of the strap muscles may allow exposure and intubation of the distal trachea. It is common, however, that these patients develop cardiac arrest and require a resuscitative thoracotomy for an intrathoracic tracheal injury. While not optimal for tracheal injuries, an emergent clamshell thoracotomy is often performed for a patient in extremis for resuscitation. The trachea is exposed through the posterior right mediastinum. One of the key maneuvers to access the intrathoracic trachea via thoracotomy is division of the azygous vein. The azygous vein loops around the right main stem bronchus before joining the superior vena cava. Division of the azygous vein gets the operator in the plane of the trachea so that it can be exposed and explored. The mediastinum will often be extremely distorted with hematoma, making the anatomy difficult. When the trachea is identified, the goal is to achieve an airway distal to the injury. This involves identifying the injury and directly intubating the trachea or one of the mainstem bronchi with an endotracheal tube on the field, so the patient can be resuscitated. As an example, the authors were involved in a case where the distal trachea was avulsed off the carina and the patient arrested en route to the operating room. Following a clamshell thoracotomy, the surgeon remembered to divide the azygous vein and was able to identify and directly intubate the left mainstem bronchus. This allowed the patient to be resuscitated, and thoracic consultants were called in to perform the complex reconstruction. Achievement of this temporary intrathoracic airway was the key maneuver that resulted in the patient's survival.

Many patients with penetrating injuries to the intrathoracic trachea that are partial circumferential are sometimes surprisingly stable, and the injury is noticed on a screening computed tomography (CT) scan. Pneumomediastinum may be noted on chest roentgenogram or CT. Periodically, one can see disruption of the trachea along the trajectory of the missile or loss of the contour of the tracheal air column on chest roentgenogram. Overdistention of the endotracheal tube cuff may suggest the cuff is bridging an injury. These presentations are unusual but do allow operative planning. These injuries are also sometimes identified during an exploratory cervical or thoracic procedure. After exposing the injury, the endotracheal tube can be directly manipulated beyond the injury. This may be assisted with a tracheal bougie to guide the tube.

In summary, the diagnostic and initial approach to tracheal injuries is most commonly managed by emergent fiberoptic bronchoscopy and intubation.[18] These injuries sometimes require operative intervention including thoracotomy to satisfy the principle of achieving an airway distal to the injury. These can be extremely daunting injuries to address and often require rapid decision-making. Keeping in mind the primary goal of achieving an airway distal to the injury is the most important consideration. Once this is obtained, there is time to reevaluate the exposure and potentially create a different incision for repair.

Operative Approach/Incisions

The trachea can be approached through a variety of cervical and thoracic incisions. Known injuries to the cervical trachea are commonly approached through a large U-shaped apron incision that permits access to the vascular structures, the trachea, and the esophagus. Sometimes, a tracheal injury is noted during a unilateral neck exploration for penetrating trauma. If the unilateral incision is not adequate, it can be extended to a bilateral incision to access the contralateral/anterior trachea if needed (Fig. 1). Thoracic incisions are often based on the acuity of the patient. As noted earlier, the patients may present near cardiac arrest and require a rapid intrathoracic airway to be obtained. As the patient is supine, they are best managed via clamshell thoracotomy, recognizing that the trachea is a posterior structure. Known mid to distal tracheal and carinal injuries, in a patient where one has secured a fiberoptic airway, are managed through a right fourth or fifth interspace posterolateral thoracotomy. In a stable patient, a rib resection and an intercostal muscle flap are developed during the thoracotomy and prepared. Dividing the azygous vein allows access to the plane of the trachea. This incision provides exposure of the mid to distal trachea, right main stem bronchus, and proximal 1 to 3 cm of the left main stem bronchus. Injuries high in the mediastinum can be problematic. If the injury primarily is in the neck with an extension into the mediastinum, the neck incision may be extended through partial sternotomy, recognizing that the trachea passes posteriorly into the mediastinum behind the innominate vessels. The authors have sometimes had to make a higher interspace posterolateral incision through the same skin incision, to get better access to

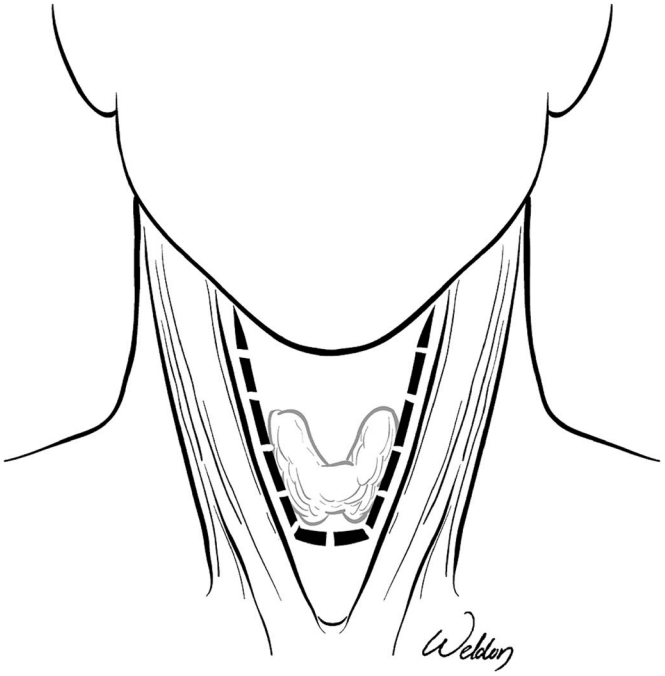

Figure 1. A unilateral neck exploration may be converted to a bilateral cervical exposure (copyright K.L. Mattox, used with permission).

a proximal thoracic tracheal injury. During the previously mentioned case where the trachea was avulsed from the carina, the superior trachea had retracted high into the neck and was unable to be visualized through the clamshell thoracotomy. A median sternotomy extension of the superior aspect of the clamshell thoracotomy allowed extension into the neck and localization of the trachea, so it could be brought down to the carina.

Bronchial Injuries

Bronchial injuries most commonly occur after penetrating trauma. There are isolated reports of hilar avulsions, but these are almost uniformly fatal. The patients usually present with a pneumothorax, which, after placement of a chest tube, exhibits a large air leak. The lung usually does not expand, and chest tube suction may evacuate the entire tidal volume, preventing air exchange. Recognizing this pattern of injury, removing suction, and placing the chest tube to water seal may be lifesaving. The patient is then rapidly evacuated to the operating room. After intubation, bronchoscopy makes the diagnosis, and an airway is achieved intubating the opposite bronchus. The operation can be strategized based on the anatomic location of the injury. A right mainstem bronchial injury is approached via a right posterolateral thoracotomy. Because of the aortic arch, proximal (within 2–3 cm of carina) left bronchial injuries are approached through a right posterolateral thoracotomy. Distal left bronchial injuries that are beyond the thoracic aorta can be approached via a left posterolateral thoracotomy in the fifth interspace.

Missed injuries may present late with wheezing, atelectasis, or recurrent pneumonias. While they may respond to dilatation and a stent, they may require resection/reanastomosis or pulmonary resection of involved lobe/segment.

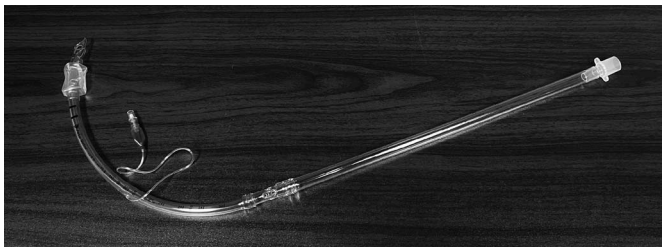

Figure 2. A chest tube and a cardiopulmonary bypass connector used to create a sterile extension for an endotracheal tube (copyright M.J. Wall, Jr., used with permission).

Instruments/Adjuncts

A sterile, reinforced, endotracheal tube with sterile tubing for ventilation is helpful to have on the field. In an emergent situation or if sterile tubing was not available, the authors have used a chest tube and a cardiopulmonary bypass tubing connector to extend the endotracheal tube (Fig. 2). This also permits distal intubation of the bronchus, avoiding the need for a stiff double lumen tube. When the trachea is explored via a cervical incision, the tracheostomy hook can be an incredibly useful instrument. The author's preference is to have two to three tracheostomy hooks on the field, which often requires opening multiple trays. With blunt disruption of the cervical trachea, once the trachea is exposed, it may retract into the mediastinum. The surgeon can palpate in the mediastinum for the tracheal rings, and this distal tracheal segment can be grasped with the tracheostomy hook. A second hook can be used to regrasp and gradually bring the distal trachea back up into the wound. An assistant can then hold the trachea in place while intubation of the distal trachea is obtained (Fig. 3). For the cervical approach, appropriate self-retaining retractors are helpful. For thoracic repairs, the rib set is useful to take a rib, as this allows the development of a significant intercostal muscle flap. Most repairs are performed with an absorbable suture.

Repair

The trachea is primarily cartilaginous, and its blood supply enters laterally from each side. Thus, mobilization of the

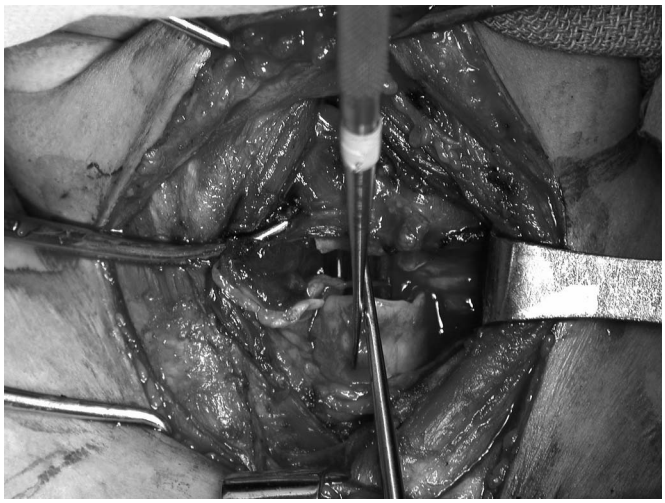

Figure 3. Multiple tracheostomy hooks can be useful to expose and mobilize the transected trachea (copyright M.J. Wall, Jr., used with permission).

trachea is performed anteriorly and posteriorly. When the injury is identified, the trachea is minimally debrided, removing only damaged rings. For trauma, usually at most two to three rings must be resected, so anterior and posterior mobilization will allow the trachea to be bought together primarily. To preserve blood supply, mobilization is only performed enough to bring the trachea together without tension. Maneuvers needed during significant tracheal resections for malignancy, such as Montgomery suprahyoid laryngeal release, or mobilization of the pulmonary hila, are not commonly needed.[19] For limited injuries, interrupted 4-0 absorbable sutures such as polyglycolic acid are placed around the tracheal rings. End-to-end repairs are performed with the same suture in an interrupted manner with the knots external to the trachea.[20,21] Some sew the membranous trachea with a continuous absorbable suture, with interrupted sutures for the cartilaginous trachea encircling the ring above and below. The endotracheal tube may need to be intermittently pulled back or removed to place distal sutures.[21] Long longitudinal tears of the membranous trachea sometimes seen with avulsions are closed with continuous absorbable suture. This may also be useful as a rapid damage-control approach. After reconstruction with reanastomosis, a stitch may be placed from the chin to the sternum to remind the patient to limit hyperextension.

Iatrogenic injuries of the trachea usually occur during difficult intubation or instrumentation of the trachea. They usually involve the membranous trachea.[22] If they are small, less than a third of the circumference of the trachea, with minimal pneumomediastinum and not on positive pressure ventilation, they can be observed.[23] Fiberoptic intubation distal to the injury may also allow them to heal. This approach has been applied to minimal traumatic injuries that are well opposed.[14,24] Larger injuries are approached operatively as previously mentioned depending on their location. Stenting with covered stents is being increasingly used to manage tracheal injuries, particularly for iatrogenic injuries where associated injuries are less common.[25]

Bronchial injuries can be particularly challenging. Many of these injuries are initially missed and may present later.[26] There may be associated pulmonary artery and vein injuries. The more distal the injury, the more intimately the pulmonary vasculature wraps around the bronchus. Hilar clamping may be required to control bleeding, and the anatomy may be significantly distorted. Following an emergency department thoracotomy, the hilar twist can be used as a temporizing measure.[27] Pulmonary tractotomy may be a diagnostic maneuver to identify a bronchial injury deep in the parenchyma.[28] Proximal bronchial injuries in a stable patient may allow careful mobilization of the thin-walled pulmonary vasculature and repair. The bronchus is repaired with interrupted absorbable suture in a manner similar to the trachea. Injuries distal to the main stem bronchi require a skillset similar to that needed for a bronchial sleeve resection. While this can be considered in the stable patient, an unstable patient may be better served with a nonanatomical resection of that lobe. Massive injuries of the mainstem bronchi may require a damage-control pneumonectomy as an attempt to save the patient.[29]

At the completion of the tracheal or bronchial repair, a muscle flap brings vascularized tissue to buttress the repair. This is secured to the cartilage and surrounding tissues. For cervical injuries, the sternocleidomastoid, omohyoid, or strap muscles can be detached and rotated to cover a repair. For intrathoracic injuries, the pedicled intercostal muscle flap is used. This is not placed circumferentially, as the periosteum of the rib is usually still present in the flap.[21] At the completion of the procedure, fiberoptic bronchoscopy is performed to clear the airways and reposition the endotracheal tube.

Tracheostomy is seldom performed, except for devastating injuries.[21] Early extubation, getting the patient off positive pressure is preferred, although not always possible in critical patients. Tracheostomy may be required if there are concomitant injury to the recurrent laryngeal nerves

In extreme cases, cardiopulmonary bypass or extracorporeal membrane oxygenation may be needed, although this is very uncommon. It carries the morbidity of heparization or at a minimum an extracorporeal membrane oxygenation run. For complicated cases, the authors have placed femoral arterial and venous access and positioned the patient in a thoracoabdominal position, so percutaneous cannulas can be placed if needed. This may be needed if a distal airway cannot be achieved. As extracorporeal membrane oxygenation is more commonly used, it may have increased use. The author's experience is that cardiopulmonary bypass was only needed for one case. This was when single lung ventilation was not adequate to sustain the patient.

Postoperative Care

The patient is extubated from positive pressure ventilation as soon as practical. If unable to extubate, frequent bronchoscopy to keep the airways clear can be helpful. Avoiding overresuscitation and pulmonary edema is important but can be difficult in multiply injured patients. Avoiding and addressing aspiration to the uninjured side with frequent bronchoscopy starting at the end of the case can be helpful.[30] Lung protective strategies, limiting airway pressures, are particularly important in these patients. Patients are counseled that stricture is a not uncommon late complication that may require future dilatation or resection.

Results

Tracheal stenosis is the most common long-term complication. This may require later dilatation, stenting, or surgical reconstruction.[21,25] Mortality for patients who reach the hospital is approximately 9%.[2,4] Richardson[31] reported a unique, single surgeon's, long-term experience of treating tracheobronchial injuries. He noted that midtracheal injuries treated with resection did better than proximal airway or distal bronchial injuries.[31]

ESOPHAGUS

Mechanism

The esophagus may be injured from blunt, penetrating, or iatrogenic mechanisms.[32,33] While uncommon, the esophagus may rupture from a blunt mechanism similar to the Boerhaave syndrome. This can occur from a compression injury or a severe deceleration. Philosophically, the esophagus is like the pancreas. It does not heal well, has noxious contents, does not hold sutures well, is intolerant of failure, and is treated with wide drainage.

The esophagus is a central organ passing from the neck through the mediastinum to the abdomen. Penetrating injuries to the esophagus are uncommon because of its central location but can occur. These are often suggested by the trajectory of

the wounding agents. In the abdomen, there is a short distance of distal esophagus terminating at the gastroesophageal junction. Iatrogenic injuries to the esophagus can occur during endoscopy, most commonly just distal to the cricopharyngeus muscle. It can also occur from a variety of intrathoracic devices that can erode into the esophagus. Because the esophagus traverses three anatomical compartments, the transition zones can be problematic. Often, an initial approach makes one realize that the injury may not be visualized. It is important to be flexible enough to change the operative course and make a different incision. For example, if the esophageal injury is higher in the chest than recognized when through an abdominal approach, a thoracotomy may be needed.

Presentation

Esophageal injuries may be suggested based on mechanism and injury patterns. A sensation of dysphagia or pain on swallowing may be elicited. Subcutaneous emphysema may be noted on physical examination. Imaging studies showing air in the tissues of the neck or the mediastinum may suggest esophageal injury. A pleural effusion may be present.[33,34] Assessing the potential trajectory of wounding agents may be suggestive but is not always reliable.[35] Screening CT may show extravasation of contrast and a suggestive trajectory.

Initial Management

In the prehospital phase, patients with difficulty swallowing and managing their secretions may be transported in a semisitting position to prevent aspiration. Esophageal injury seldom causes shock, suggesting the need for further investigation of the cause of hemodynamic instability. The primary cause for morbidity and mortality for esophageal injuries is leak of enteric contents into the mediastinum, sepsis, and death, and this typically does not manifest acutely. While time sensitive, concern for esophageal injury may parallel tracheal injury, but management of the airway is a higher priority. Once the patient has stabilized, the esophagus may be investigated. In a conscious, cooperative patient, a contrast swallow with barium can be obtained looking for extravasation in the neck or the mediastinum. This has a diagnostic accuracy of 85% to 90%.[36] Alternatively, endoscopy of the esophagus can be performed with the same diagnostic accuracy. The esophagus is systematically examined, being careful with insufflation.[37,38] Similar to the trachea, if one finds oneself lost in the mediastinum, it may be that the scope has passed through an injury. The endoscope is usually passed into the stomach and then carefully withdrawn examining the esophagus. It is important to look carefully at the mucosa, as small abnormalities may portend an injury. Iatrogenic injuries are often proximal. With routine use of CT, contrast can be instilled into the esophagus during the scan looking for extravasation. As the diagnostic accuracy for each of these examinations approaches 85%, it can be useful to combine modalities if an injury is not identified and an esophageal injury is highly suspected.[33] Treatment hinges on the location of the injury and its extent. Localized contusions to the esophagus without extravasation can be carefully followed with liberal use of repeat studies. The primary principle in dealing with esophageal injuries is preventing or managing mediastinal/cervical leak and sepsis. With significant leaks, achieving adequate drainage is important to prevent abscess formation and sepsis. Thus, drainage is a priority and repair is performed if possible.

Cervical Injuries

These injuries are often found during cervical exploration for penetrating trauma.[39] They may be noted as combined injuries associated with the trachea and vascular structures. In the neck, the esophagus lies to the left of midline. The neck is usually explored via a left-sided incision anterior to the sternocleidomastoid muscle. Alternatively, the neck may be explored using a U-shaped apron flap incision, which can be a much more versatile incision.

Operative Approach

The patient is positioned supine with a shoulder roll and the neck extended. The chin can be turned away from the operative side or if a bilateral approach is chosen left in the midline. After the vascular and tracheal injuries have been addressed, attention then turns toward the esophagus.

The esophagus is usually exposed going medial to the carotid sheath. It can also be approached by going posterior to the sheath depending on the anatomy (Fig. 4). A nasogastric tube can be placed, so it can be palpated in the esophagus. The omohyoid muscle is divided and may be used later to buttress a repair (Fig. 5). The esophagus can be mobilized by developing the tracheoesophageal space low in the neck. The recurrent nerves can be exceedingly difficult to identify in the injured neck and may already be injured. They are identified and

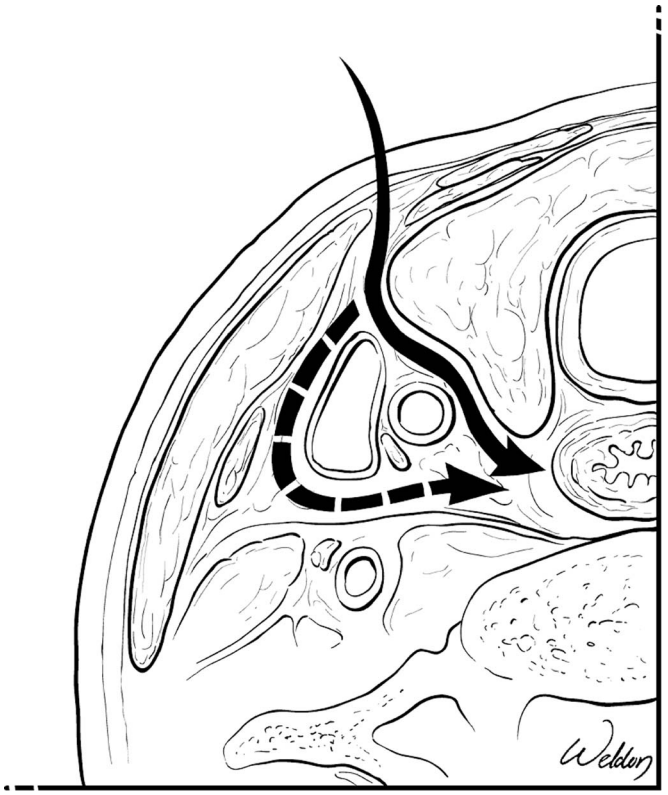

Figure 4. The cervical esophagus can be approached either medial or posterior to the carotid sheath (copyright K.L. Mattox, used with permission).

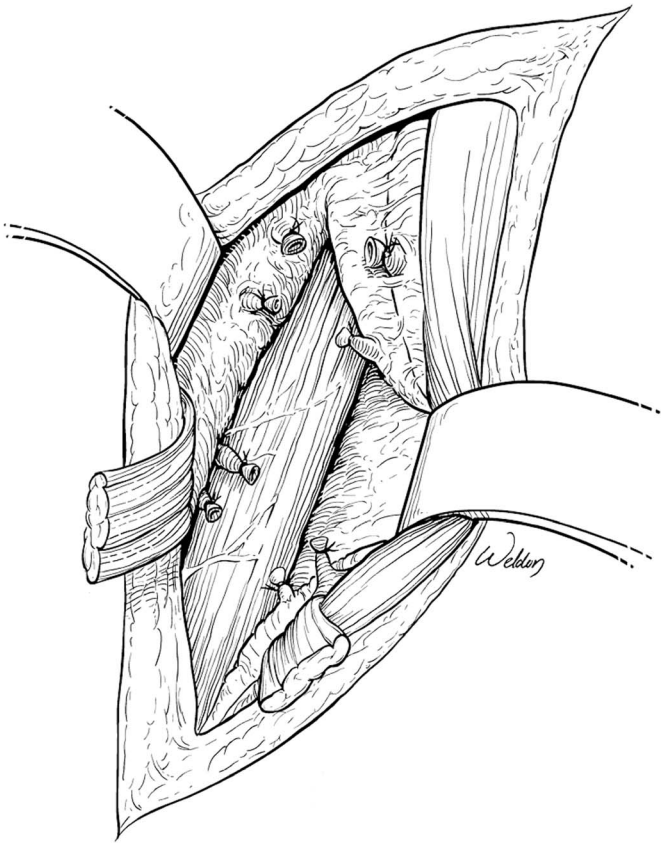

Figure 5. Dividing the omohyoid muscle and the middle thyroid vein to expose the esophagus low in the neck (copyright K.L. Mattox, used with permission).

preserved if possible. The space between the anterior spinal ligament and the esophagus can then be developed encircling the esophagus with a rubber drain. This allows it to be pulled into the operative field.

The esophagus may then be mobilized superiorly and inferiorly and while space is tight, rotated to identify the injury. The nasogastric tube can be pulled back, the field flooded with saline, and air injected to help identify an injury. Intraoperative endoscopy can be helpful. Limited injuries are primarily repaired. This is usually performed with an absorbable continuous layer such as polyglycolic acid suture on the mucosa/submucosa for hemostasis. This is followed by a second layer of interrupted nonabsorbable/silk suture, reapproximating the outer muscular layers. With difficult exposures, sometimes, only a single layer of nonabsorbable suture can be placed. At the conclusion of the repair, it is important to place an adjacent closed suction drain should the repair leak. If a concomitant vascular repair has been performed, the drain should be routed away from it potentially to the opposite side of the neck. As the esophagus has a marginal blood supply, muscle flap buttressing can be extremely helpful. It is also helpful to interpose muscle between the esophagus and a tracheal or vascular injury. Any of the muscles of the neck that are convenient such as the straps, omohyoid, or sternocleidomastoid can be rotated to cover the repair with vascularized tissue.[29,40] While repairs may leak, if they are covered by muscle and well drained, they will usually heal with time.

Sometimes, a high posterior injury to the esophagus can be difficult to visualize. After appropriate efforts have been attempted, wide drainage of this area potentially filling the posterior space with a muscle flap can be performed as a bailout procedure. Following repair, a nasogastric tube is usually passed into the stomach to decompress it in the postoperative period. A feeding tube can also be passed to provide postoperative nutrition.

More destructive injuries may require a creative approach. If a significant circumference of the esophagus remains, the esophagus may be mobilized and repaired primarily. Here, a muscle flap to reinforce the repair followed by wide drainage will be extremely helpful. Loss of a sizable portion of the esophagus may warrant a damage-control approach where the area is widely drained with significant size drains placed directly in the lumens of the proximal and distal esophagus. The proximal segment can also be brought out as an ostomy. Plans can then be made for a definitive reconstruction in the future. This may require gastric pull up or jejunal interposition with vascular augmentation.

Iatrogenic injuries can be particularly challenging, as they are often secondary to a primary obstructive pathology in the esophagus such as a malignant stricture. Their management is thus driven by the primary process. In patients with poor prognosis such as for an advanced malignancy, wide drainage with potentially endoluminal stenting may permit palliation.

Postoperatively, the nasogastric tube is removed when the ileus resolves and enteric feeding via the feeding tube is begun. A contrast swallow at 5 to 7 days to verify patency of repair can be performed. If the repair is intact, diet may be advanced. If there is evidence of leak, the patient is maintained nil per os, and the drains are maintained. The patient is observed to ensure that there are no retained fluid collections. The contrast study can be repeated in 5 to 7 days and usually will show healing of the leak.

Intrathoracic Esophagus

Anatomical Issues

The esophagus courses from slightly to the left of midline at the thoracic outlet, to the right of midline in the midthoracic portion and back toward the left side at the gastro-esophageal junction. As the esophagus is a posterior structure, a posterolateral thoracotomy on the appropriate side is usually the best approach. The choice of incision can also be influenced by which pleural space has an effusion. One caveat in the unstable patient is that these patients are routinely explored through anterior incisions. The vascular, tracheal, pulmonary, or cardiac issues causing instability are addressed via that incision, and esophageal injury may then be found. Because of the posterior nature of the esophagus, it is extremely difficult to achieve a good repair of the esophagus via an anterior incision. If the patient is hemodynamically unstable, the area should be widely drained, potentially by directly intubating the esophageal injury with an appropriate tube. The patient can then be closed, brought to the intensive care unit, and resuscitated with plans for the esophageal repair to be performed when the patient is more stable. If the patient's physiology will allow repair at an initial procedure done through an anterior incision, we routinely close the anterior incision, turn the patient, and approach the esophagus via an appropriate posterolateral thoracotomy. It is noted that 50% of the

esophageal repairs that are performed via an anterior incision break down and leak.[10]

Operative Approach

For the distal esophagus, a low left posterolateral thoracotomy in the seventh interspace provides good exposure. Muscle flap buttressing is also important for esophageal repairs, so we routinely take an intercostal muscle flap while opening. This is wrapped in a warm saline sponge and tucked away to later buttress the repair at the end of the procedure. For the mid and upper esophagus, a right posterolateral thoracotomy via a fourth or fifth interspace is performed. For either side, for the distal esophagus, the inferior pulmonary ligament is mobilized, and the pleura over the esophagus is opened. The esophagus is bluntly dissected, anteriorly and posteriorly, and encircled with a rubber drain. In the upper chest, the azygous vein may need to be divided to provide further exposure. For distal injuries, the esophageal hiatus/diaphragm may be opened to improve exposure and mobilization. The esophagus is then mobilized until the injury can be identified. Injuries to the opposite side of the esophagus may be difficult to visualize. The esophagus, when adequately mobilized, can often be rotated to visualize it. The injury should be carefully inspected. Sometimes, the mucosal defect is longer than the muscular one. The muscular layer at the injury should be opened until the mucosal defect is fully identified. Injuries are then repaired in two layers, with the mucosal/submucosal layer with a continuous polyglycolic acid suture, followed by interrupted silk sutures on the outer muscular layer. Through and through and more significant injuries can be repaired over an esophageal bougie to prevent narrowing. The repair is then buttressed with the intercostal muscle flap, anchored to the esophagus and surrounding tissues with interrupted silk sutures in a noncircumferential manner. While the intercostal flap is the most common muscle flap used to buttress esophageal injuries, Richardson and Tobin[41] described developing a flap from the diaphragm and rotating it on to the esophagus. They have also described closing significant defects with a muscle flap.[41]

The area is then widely drained, typically with a closed suction drain adjacent to the repair, followed by appropriate chest tube drainage of the pleural space. For significant intrathoracic esophageal injuries, proximal drainage is obtained with a nasogastric tube proximal to the injury. As these may take longer to heal, a jejunostomy feeding tube is placed for nutrition. A very tenuous repair may be augmented by a gastrostomy for gastric decompression and a spit fistula in the neck, although this is less commonly required. The lateral cervical esophagostomy was commonly described but is often technically challenging to perform. The esophagus in the neck can be difficult to mobilize up to the skin. When done, it is usually encircled with a drain, and the drain may be sewn to the skin edges. The esophagus is then opened, and the skin is brought down to the opening in the esophagus. Some have suggested as an alternative to place a tube pharyngostomy via the neck, to decrease the amount of swallowed saliva. Postoperatively, the patient is resuscitated to assure good tissue perfusion. The esophagus is assessed with a contrast study at day 5 to 7. When the repair is intact, advancement of diet can occur. If a leak is detected but is limited and well drained, the patient is maintained nil per os and restudied in 5 to 7 days. With wide drainage and muscle flap repair, most leaks will close. It is important to counsel the patient postoperatively that the repairs may stenose and require dilation in the future.

Re-exploration is reserved for patients who develop undrained fluid collections and signs of sepsis. These then usually require wide drainage, proximal diversion, and plans to reconstruct the esophagus when the sepsis resolves. Some have placed covered stents in this scenario.[42] For very devastating injuries, esophageal resection may be required, but it is often better to achieve wide drainage and resuscitation, so a formal plan can then be developed. The esophagus can be intubated directly with a closed suction drain to create a controlled fistula in this scenario (Fig. 6).

Injuries at the gastroesophageal junction are found during laparotomy. The esophagus may be mobilized via the hiatus up to the heart, allowing it to be brought further down into the abdomen. For difficult exposures, the laparotomy is closed, the patient is turned, and a low left posterolateral thoracotomy is performed. The injury is repaired with the same two-layer repair. In this case, the stomach may be used as a partial or full wrap to buttress the repair.[43] Postoperative management is similar to thoracic injuries. Massive gastro-esophageal junction injuries may be reconstructed using the stomach as a conduit pulled up into the chest through a low left posterolateral thoracotomy.

Chronic Injuries

Sometimes, a patient is encountered with an empyema from subacute esophageal injury. Decortication is performed to address the septic foci. The mediastinum is widely drained and debrided. In some cases, the esophagus may be repairable and reinforced with a muscle flap. Many times, this is not possible, and the goal is to achieve drainage and a controlled fistula by placing drains or a large T-tube directly into the esophagus. The area is widely drained, and the patient resuscitated from

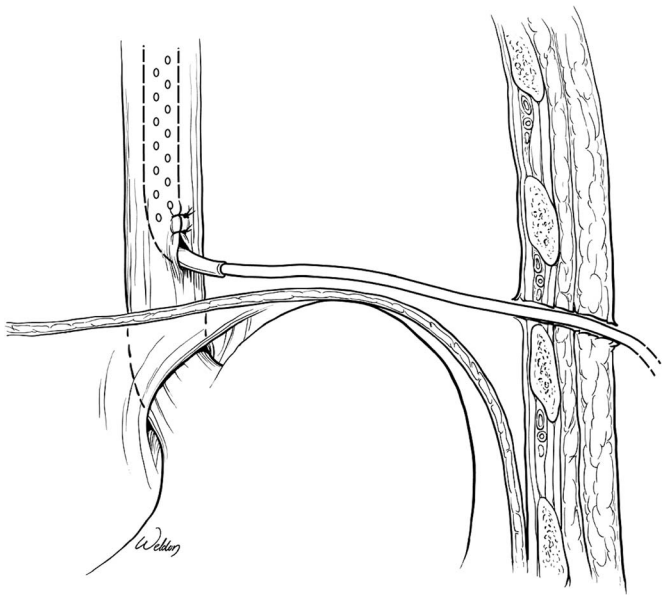

Figure 6. For a damage-control approach to massive or late recognized injuries, a closed suction drain can be placed directly into the esophageal lumen to create a controlled fistula (copyright K.L. Mattox, used with permission).

sepsis. If this can be accomplished, long-term plans for esophageal reconstruction can then be developed.

Evolving Treatments

Recently, endoluminal drainage of limited iatrogenic injuries of the esophagus has been used. A vacuum type sponge is anchored to a nasogastric tube and positioned adjacent to an injury. This allows suction to be applied, draining the cervical or thoracic esophagus through the injury. This technique is being carefully followed.[44] Small iatrogenic injuries in the neck are being treated with antibiotics and observation, monitoring for undrained collections and signs of sepsis. Some have suggested endoluminal clips to close esophageal tears.[45] Covered esophageal stents are being used, particularly for postoperative leaks where the mediastinum is already drained.[42] A recent multicenter study noted increased risk of leak for patients with esophageal injuries initially treated with covered stents compared with operative repair.[46] Experience is being gained with these techniques.

Results

Despite efforts to manage mediastinal sepsis, mortality can approach 19%.[47] Leak is a common early complication. Stricture is the most common late sequelae, and patients should be counseled that further intervention such as dilation may be anticipated.

SUMMARY

Tracheobronchial injuries are suggested by stridor, dyspnea, subcutaneous emphysema, pneumomediastinum, or pneumothorax. The initial priority is achieving an airway distal to the injury. This usually entails fiberoptic bronchoscopic intubation in the operating room, which is also the most useful diagnostic technique. Airway injuries are managed through incisions based on the anatomic location of the injury. Repairs are performed with interrupted absorbable sutures and buttressed with a muscle flap.

Esophageal injuries are suggested by dysphagia, pain, subcutaneous emphysema, pneumomediastinum, or pleural effusion in patients with a suggestive pattern of injury. Contrast esophagography and endoscopy are often combined to make the diagnosis. Incisions are chosen based on the location of the injury. Repairs are commonly performed in two layers and widely drained to prevent mediastinal sepsis. Repairs are reinforced with a muscle flap.

AUTHORSHIP

M.J.W. and K.L.M. participated in the design, writing, and editing of the manuscript.

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DISCLOSURE

Conflict of Interest: Author Disclosure forms have been supplied and are provided as Supplemental Digital Content (http://links.lww.com/TA/E60).

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