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Review Article

Tracheobronchial Trauma

Andrew Jennings[1], Morgan Joe[2], and Karmy-Jones R[1,2]*

[1]*Division of Trauma, Peacehealth Southwest Washington Medical Center, USA*
[2]*Division of Trauma, Legacy Emanuel Medical Center, USA*

***Corresponding author**
Karmy-Jones R, Division of Trauma, Legacy Emanuel Medical Center, 2801 N. Gantabein Ave., Suite 130, Portland OR 97227, USA, Tel: 503-413-2100; Email: rkarmy@lhs.org

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Abstract

Tracheobronchial injuries are uncommon, occurring in less than 1% of all patients following injury. However, the incidence is higher in specific subsets, notably up to 8% following penetrating neck injury and up to 2% following high energy blunt chest and/or focal cervical injury. In the majority of cases tracheobronchial injury presents as immediately life threatening injuries, but in up to 1/5 of cases they manifest in a more occult fashion with late onset of hemoptysis, recurrent pneumonia and/or "asthma." Diagnosis often requires a high degree of clinical suspicion. Initial management is based on immediate securing of the airway, which often requires bronchoscopic assistance. Subsequent repair must take into account the severity of associated injuries and exact location and degree of airway disruption. Repair strategy must include a coordinated plan with anesthesia, including possible cross field ventilation. The majorities of patients who survive to undergo treatment do well, but must be followed for late complications, notably stricture formation.

INTRODUCTION

Traumatic tracheobronchial injuries include those that involve the airway between the cricoid cartilage and the right and left main stem bronchial bifurcations. Laryngotracheal injuries are sometimes classified with tracheobronchial injuries, but tend to have different etiology, pathophysiology and management issues. More distal airway injuries are essentially primary parenchymal injuries. Tracheobronchial injuries are most commonly encountered in the setting of penetrating neck trauma. Blunt injuries can be due to direct trauma (usually to the neck) or by indirect mechanisms, such as shear or barometric insults. Disruption and/or narrowing of the airway present as an immediately life threatening airway emergency. However, injuries can also present in a delayed fashion, presenting as an airway stricture, with attendant complications.

INCIDENCE

The true incidence of traumatic tracheobronchial rupture is difficult to establish because the majority of published studies are case series in which mechanisms are combined, and do not publish the overall volume of cases to provide a denominator from which an incidence can be calculated. An accepted estimate is that the overall incidence among patients with multiple injuries is as low as 0.5% [1-4].

Penetrating trauma overall has the highest incidence, primarily because of the predominance of tracheobronchial injury following penetrating neck injury (3 - 6%). Less than 1% of patients with penetrating chest injuries suffer tracheobronchial injury [5,6]. Overall, the incidence of penetrating tracheobronchial trauma constitutes 1% to 2% of thoracic trauma admissions in major trauma centers [5-8].

Blunt tracheobronchial injuries more commonly involve the distal trachea and/or main bronchi. Large autopsy studies suggest an incidence of 1-3% with a third to fourth-fifths of victims dying at the scene, and the remainder within 2 hours [9,10].

Based on collective reviews, we can estimate that tracheobronchial injury occurs in 0.5% to 2% of individuals sustaining blunt trauma, including blunt trauma to the neck. 60-80% of tracheobronchial injuries from blunt trauma are located within 2.5 cm of the carina, with less than 10% involving the cervical trachea [10-13]. In the review published by Symbas, 22% of the blunt airway injuries involved the distal thoracic trachea; 27%the right main stem bronchus; and 17%the left proximal main stem bronchus. Eight percent were complex injuries involving the trachea and main stem bronchi, and 16% involved the lobar orifices [11].

MECHANISM

Knife injuries produce a tearing or shearing effect, resulting in perforation, linear laceration, through and through injuries, or transection [5]. Gunshot wounds are a more common cause of penetrating airway injury and can affect any portion of the cervical or intra thoracic airways. However, cervical injuries are still predominate, because more distal penetrating injuries of the trachea often have associated fatal injuries of the heart or great vessels resulting early demise [13,14]. A variety of mechanisms have been proposed to explain how blunt trauma results in tracheobronchial injury, with the majority within 2-3 cm of the carina (Table 1) [1,12-19]. Knife wounds result in clean lacerations, predominantly affecting the cartilaginous rings which are anterior. Gunshot wounds create various degrees of cartilage and mucosal disruption depending on the caliber and

Table 1: Mechanisms of blunt tracheobronchial injury.	
Cervical	• Direct blow with crush against vertebra (includes dash board and clothes line injury) • Compression and rotation (high riding shoulder harness) • Rapid hyperextension leading to traction and disruption • Acute compression with glottis closed, resulting in acute increase of intratracheal pressure, leading to membrane disruption
Thoracic	• Antero posterior compression leading to lateral traction injury at carina • Acute compression with glottis closed, resulting in acute increase of intratracheal pressure, leading to membrane disruption • Rapid deceleration leading to shear force at carina

path of the bullet. "Blow out" injuries due to rapid compression may present with the membrane torn away from one or both sides of its attachment to the cartilaginous rings. Direct blows or torsion injuries result in ragged injuries to both components, with associated crush necrosis. The defect or zone of injury is usually 1-4 cm in length and partial, but complete separation is possible [13].

ASSOCIATED INJURIES

Because of the adjacent cervical and intra thoracic structures, penetrating airway trauma frequently is associated with other major injuries in the affected body region. Blunt trauma is often associated with multiple extra thoracic injuries [14,18]. In one series of penetrating cervical tracheobronchial injuries, 28% of the patients had an associated esophageal injury, 13% a major vascular injury, 8% had a recurrent laryngeal nerve injury, and 3% had a spinal cord injury. Of penetrating intrathoracic injuries, associated injuries included esophageal (11%); major vascular injury (18%); cardiac injury (5%); spinal cord injury (7%); and intra-abdominal injuries (18%) [20]. Several other series have shown an overall incidence of associated major injuries with penetrating tracheobronchial trauma to be in the range of 50% to 80%, most of these being esophageal and vascular injuries, followed by spinal cord, pulmonary, and intra-abdominal injuries [6,7,11,18,21,22]. The majority of associated injuries in the cervical area can be managed concurrently with repair of the airway, while intrathoracic injuries often require a combined approach, with the most immediately lethal injuries taking precedence.

DIAGNOSIS IN THE ACUTE SETTING

The initial assessment of the patient with potential airway trauma involves the traditional ABCs of resuscitation, with particular emphasis on airway stability. Initial management should proceed simultaneously with making the diagnosis. The most common symptoms are dyspnea and respiratory distress (76-100%) and half of those with cervical injuries present with hoarseness and/or dysphonia, often with anterior neck swelling and bruising (Figure 1) [20-24]. Air escaping from a neck wound occurs in approximately 60% of patients with cervical penetrating trauma to the trachea [1,7]. If the cervical air leak ceases after intubation, this confirms the diagnosis. The most common signs of intrathoracic airway injury are subcutaneous emphysema (35%–85%), pneumothorax (20%–50%), and hemoptysis (14%–25%) [22-26].

Chest radiography is the most useful initial imaging study. Deep cervical emphysema and pneumomediastinum will be seen in 60% and pneumothorax occurs in 70% of patients with tracheobronchial injuries (Figures 2 & 3). [14,24,26,27].

Figure 1 This patient suffered a clothes line injury while riding an all-terrain vehicle. She immediately developed hoarseness and stridor. She underwent urgent oral intubation. The picture demonstrates the red mark of the injury site, edema and subcutaneous emphysema. The blue line marks the planned incision.

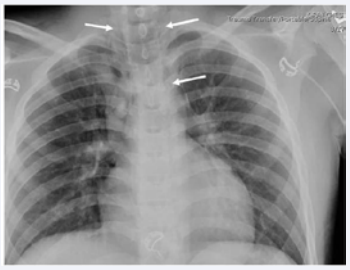

Figure 2 Chest radiograph in a youth who presented after hitting his throat on handle bars. The patient has cervical subcutaneous emphysema (arrows) and mediastinal fullness. Workup identified a cervical tracheal membrane iinjury.

Additional findings can include disruption of the tracheal or bronchial air column, over-distention of the endotracheal tube balloon cuff (as balloon expands within the injury) and/or the "falling lung sign of Kumpe" which occurs when complete bronchial separation results in the lung collapsing towards the diaphragm. [27-30]. A persistent pneumothorax from a well-placed chest tube should increase the suspicion of intrathoracic tracheal or bronchial injury. Complete transection can lead to mediastinal tissue plugging the airway lumen leading to recalcitrant collapse without pneumothorax. More commonly, there is a significant air leak and the patient experiences more respiratory difficulties with the chest tube on suction (as tidal volume is "stolen") [31]. In the stable (or stabilized) patient, CT scan can delineate the injury, and help distinguish between leaks emanating from parenchymal as opposed to tracheobronchial injuries, identify associated injuries and help plan and prioritize management (Figures 4 & 5) [13,32]. A negative CT scan does not obviate the need for bronchoscopy or other diagnostic studies.

Direct or fiberoptic laryngoscopy is an important part of the endoscopic study in patients with cervical trauma and should be

Figure 3 Chest radiograph following motor vehicle crash. The patient has extensive subcutaneous emphysema (stippled arrows) pneumothorax (arrow), and clinically had a moderate air leak. Workup identified a distal intrathoracic tracheal membrane injury.

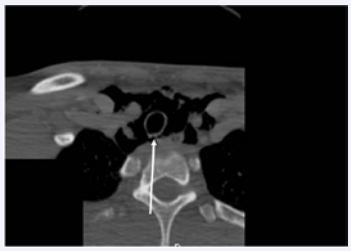

Figure 4 Same patient as in Figure 2. There is a small membranous defect (arrow) with marked subcutaneous air but no pneumothorax. This patient was managed non-operatively.

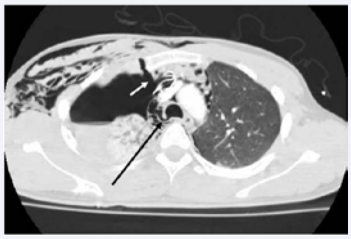

Figure 5 Same patient as in Figure 3. A membranous disruption from the cartilage rings of the distal trachea is noted (black arrow) in conjunction with persistent pneumothorax and collapse of the right upper lobe. In addition a traumatic chest wall defect is identified (white arrow). This patient underwent operative repair.

Figure 6 Operative findings of patient in Figure 1. Despite near complete transection of the trachea the patient was successfully intubated using judicious paralytics and careful gentle technique.

performed with the assistance of an experienced otolaryngologist when laryngeal injuries are suggested. Bronchoscopy is both diagnostic, and can play a critical role in airway management. Careful examination of the tracheobronchial tree with the fiberoptic bronchoscope will allow determination of the site and extent of injury. Bronchoscopy is the only study that can reliably exclude central airway trauma, although minor lacerations may occasionally be missed. The advantages of fiberoptic bronchoscopy are that it can be performed quickly and easily, even in the setting of concomitant head and neck injuries or cervical spine trauma. If bronchoscopy is being performed for a suspected airway injury in an intubated patient, it is important to carefully withdraw the endotracheal tube during endoscopy to avoid missing proximal tracheal injuries.

INITIAL AIRWAY MANAGEMENT

Maintaining a stable airway is the cornerstone of management. The incidence of need for urgent airway control ranges from 36-60% with a surgical airway needed5-40% of the time. In some series, intubation of the cervical trachea through an open wound was performed in 10-25% cases. Bronchoscopic guidance has been felt necessary in 10% of cases. Sudden and unexpected loss of a previously stable airway in patients being evaluated for other injuries has been described in up to 15% of patients. [2,22,26,33]. Depending on the setting, flexible bronchoscopy may be inadequate and/or precipitate airway occlusion. In this setting rigid bronchoscopy can be lifesaving, although in setting of blunt trauma does require neck flexion which may not be possible if an unstable cervical spine is suspected [1].

Patients with cervical tracheal injuries who require an airway urgently are generally best managed by oral intubation (Figure 6). As noted above, anywhere from 5-40% of the time this is not possible. If a bronchoscope is immediately available, this can be used to direct intubation. However, whenever intubating a patient with suspected tracheal injury, preparation for immediate tracheostomy must be made at the same time. Unfortunately, cricothyroidotomy is less useful in tracheobronchial trauma because the injury lies distal to the insertion point of the airway, which is placed blindly and with no additional accuracy over oral intubation alone. Again, utilizing a bronchoscope can facilitate securing the airway through this route. If a tracheostomy is performed, the tracheostomy tube should ideally be placed through the area of injury if possible to prevent extension of the tracheal injury by the tracheal stoma. A transected cervical trachea may retract into the mediastinum; in these cases it is best found by inserting a finger into the mediastinum anterior to the esophagus, locating the distal trachea by palpation, and grasping it with a clamp to allow controlled retraction back into the cervical wound and distal intubation [33,34].

Management of the airway for injuries of the distal trachea, the carina, and the proximal mainstem bronchi present slightly different challenges. Patients do not face the same anatomic challenges with intubation that those with cervical injuries present with. While malposition through the injury site is possible, the major difficulty is air leak and loss of functional ability to oxygenate and ventilate the patient. We prefer to avoid double-lumen tubes because of their rigidity and size, which increases the possibility of injury extension. In addition,

the smaller lumens make suctioning more problematic. In these cases, a long endotracheal tube can be positioned beyond the injury or into the appropriate mainstem bronchus to provide single-lung ventilation. This can best be performed with the aid of the flexible bronchoscope serving as a guide and to confirm the final position. In almost all cases, standard ventilation can be initiated once distal airway control is ensured. In cases of distal injuries of the left mainstem bronchus, the bronchus intermedius, or lobar orifices, a bronchial blocker placed proximal to the injury under endoscopic guidance provides another alternative for stabilizing the airway and allowing ventilation. However, if the patient is stable and using bronchoscopic guidance, a double-lumen tube is acceptable for those surgeons who prefer it. Direct surgical access of the intrathoracic airways in the setting of massive air leak and inability to ventilate has been reported, usually performed through emergent right thoracotomy [35].

NON OPERATIVE MANAGEMENT

While stressing the importance of securing the airway, anecdotally as many or more patients present with injuries that do not require repair. Non-operative management is appropriate in patients who are stable, do not have other injuries requiring repair in the area, which do not show evidence of ongoing air leak (increasing crepitance, pneumothorax, and/or pneumomediastinum) and/or ongoing hemoptysis. Generally, lesions less than 2 cm in length, and predominantly involving membranous injuries are candidates for non-operative approaches (Figures 2 & 4) [1,13]. Adjuncts include humidified oxygen, bronchodilators, Heliox, racemic epinephrine and/or short course steroids if edema is a prominent feature.

OPERATIVE MANAGEMENT

In patients with significant defects, prompt definitive repair provides the most reliable short and long term result and should be performed whenever possible when the injury is recognized. In rare circumstances, it may be appropriate to perform a delayed repair if operative correction is not immediately possible because of the instability of the patient with multiple injuries. Bronchoscopy, if not already performed, defines the location and extent of injury and serves to guide the surgeon regarding the operative approach and intended repair.

As discussed previously, our preference is to use a generous single lumen endotracheal tube, which permits easier bronchoscopy, has a lower risk of extending the injury, and because it is smaller and less rigid than double lumen tubes facilitates repair. Specifically, intrathoracic distal tracheal or right mainstem injuries (which are the most common pattern) can be managed by passing a single lumen tube into the left mainstem. End bronchial blockade is also an option, while double lumen tubes (placed carefully under bronchoscopic guidance) can be used if surgeon preference, particularly with distal mainstem injuries.

In the cervical area, and occasionally intrathoracic, exposure and repair is facilitated by planning for cross field ventilation (Figure 7) [35,36]. High-frequency jet ventilation provides an effective option for ventilation with relatively low airway pressures. It may be most useful in the setting of complex carinal injuries. Cardiopulmonary bypass or Extra Corporeal Membrane Oxygenation is virtually never necessary for the intraoperative management of isolated airway injuries but have been used to permit repair of complex carinal injuries [35].

Figure 7 Cross field ventilation using an "armored" tube. The distal trachea is secured with heavy sutures. The esophagus and pre vertebral space are clearly seen. This exposure allows repair of any associated esophageal injuries, permits interposition of muscle between the repair and esophagus and/or carotid sheath, and allows careful reconstruction of the posterior membranous wall. When the posterior repair is complete, the tube is removed and under directs guidance the oral endotracheal tube is gently advanced through the anastomosis and the anterior repair completed.

The proximal one half to two thirds of the trachea is best approached through a low cervical collar incision that also provides excellent exposure to vascular or esophageal injuries in the neck (Figures 1,6 & 7). Creating a "T" incision over the manubrium and splitting the manubrium down to the second interspace opens the thoracic inlet and provides a broader exposure to the middle third of the trachea as well as proximal control of the innominate artery or veins. The distal third of the trachea, the carina, the right mainstem bronchus and proximal left mainstem are most easily approached through a high (4th intercostal space) right postero-lateral thoracotomy, which also provides good exposure to the azygous vein, superior vena cava, and right atrium, as well as the entire intrathoracic esophagus (Figure 8).

Injuries of the left mainstem bronchus distal to its origin at the carina, are most easily approached through a left thoracotomy, which also provides good exposure to the distal portion of the aortic arch, the descending thoracic aorta, and the proximal left subclavian artery. However, exposure to the proximal left mainstem, the carina, the distal trachea, or the right mainstem is extremely difficult through a left thoracotomy, owing to the overlying aortic arch. Adequate proximal exposure may be gained by mobilization of the arch with retraction cephalad and laterally and division of the ligamentum arteriosum.

Sternotomy or "clam-shell" incisions may be required based on patient stability and/or associated injuries (Figure 9). The carina can be exposed by dividing the posterior pericardium between the superior vena cava and ascending aorta, and

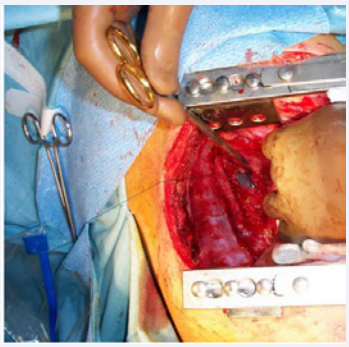

Figure 8 Same patient as in Figure 3 and 5; the membranous defect extended into the origin of the right main stem and was repaired by reattaching the membrane to the cartilage. Note that the patient is ventilated via a single lumen tube advanced into the left mainstem.

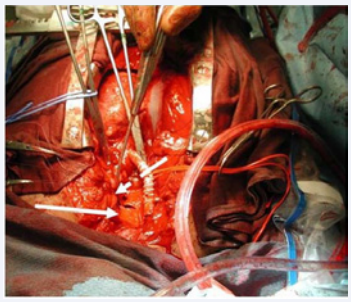

Figure 9 This patient presented with rupture of the innominate artery at the origin (stippled arrow) and a tracheal tear (arrow). The innominate was closed and bypass performed and the aortic arch then retracted to the left allowing direct access to the tracheal injury.

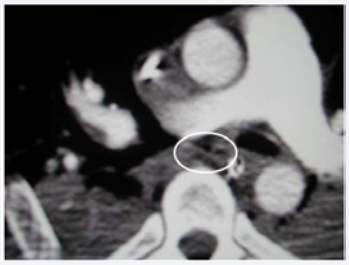

Figure 10 Patient who underwent left thoracotomy for hemothorax following motor vehicle crash. Three days postoperatively she was noted to have persistent hypoxia and hypercarbia, thick secretions, and atelectasis on the right. There was no air leak from the right sided chest tube. CT was obtained demonstrating an "occlusion" of the right main stem just at or distal to origin of right upper lobe origin. In fact, it shows complete disruption with mediastinal soft tissue filling the gap (circle) hence explaining the persistent collapse of the lung in the absence of air leak. The patient underwent sleeve resection and reconstruction with salvage of the lung.

mobilizing the crossing right main pulmonary artery.

Simple, clean lacerations without airway devascularization can be repaired primarily with simple interrupted sutures. Where the membrane has been sheared away from its cartilaginous attachments, it can be re-suspended with horizontal mattress sutures. Generally 4-0 or occasionally 3-0 sutures are used, and absorbable multi- or monofilament as well as non-absorbable monofilament sutures have all been used. In cases in which there is significant tracheobronchial damage, all devitalized tissue should be debrided, with care taken to preserve as much viable airway as possible. In these cases, a circumferential resection and end-to-end anastomosis is almost always preferable to partial wedge resections of traumatized airway with attempted primary repair. If significant membrane damage has occurred, patch repair with autologous material is a reasonable option. Dissection of the airway is limited to the region to be resected to preserve tracheobronchial blood supply to the area of anastomosis. The principles of airway resection and reconstruction are similar for tracheal, carinal, or bronchial injuries, although the anatomy of reconstruction is unique to the surgical exposure, the location, and the extent of resection. This is particularly true when a portion of the carina must be resected or reconstructed, because a large variety of techniques may be necessary to achieve reconstruction in this area [37].

In most patients, up to half of the trachea can be resected and primarily reconstructed. Both mainstem bronchi can be completely resected and primarily reconstructed without tension. Extensive injuries of the carina are more problematic and should be repaired rather than resected if at all possible.

Repair of associated injuries should be accompanied by interposing tissue between the tracheal injury and the repaired structure (most commonly in neck, and most commonly esophagous and/or carotid artery). When working through an anterior cervical exposure, the esophagus may be best exposed by complete tracheal transection through the area of planned tracheal repair. A vascularized flap of muscle or soft tissue should be interposed between the tracheal and esophageal repairs to minimize the risk of postoperative tracheoesophageal fistula. Intrathoracic tracheobronchial suture lines are also preferably wrapped with pedicle pericardial fat, or pleura to separate the airway anastomosis from overlying blood vessels [1,22]. An intercostal muscle pedicle can be used as an on lay patch, but preferably should not be used to circumferentially wrap a repair because of the concern of late calcific stricture. Intercostal muscle flaps can also be useful to repair extensive mucosal defects [35].

Only 3 to 4 cm of airway involving the carina can be resected and allow for primary reconstruction. A variety of tracheobronchial release maneuvers have been used to allow a tension-free anastomosis. For most limited cervical tracheal resections, blunt development of the anterior avascular pretracheal plane combined with neck flexion is all that is necessary. For more extensive proximal tracheal resections, a suprahyoid laryngeal release can provide 1 to 2 cm of additional proximal mobilization. For resections of the mainstem bronchi or carina, division of the pericardium around the inferior aspect of the hilum in addition to dividing the inferior pulmonary ligament provides an additional 1 to 2 cm of distal airway mobilization [38]. In cases in which a portion of the trachea or carina has been resected and reconstructed, much of the airway mobility is provided by neck flexion. This position is maintained in the postoperative period by placement of a "guardian suture" between the chin and the sternum.

POSTOPERATIVE MANAGEMENT

Most patients with isolated tracheobronchial injuries can be easily extubated at the end of the operative procedure and should be managed by the anesthesiologist with this in mind. Patients who require postoperative ventilation because of their associated injuries should finish the procedure with a large-bore, single-lumen endotracheal tube to allow good pulmonary toilet and fiberoptic bronchoscopy if necessary. Major laryngeal or maxillofacial injuries with the anticipated need for prolonged ventilation are indications for placement of a tracheostomy at the completion of the tracheobronchial repair. This tracheostomy ideally should not be placed through the tracheal repair, which will lead to a contamination of the suture line with subsequent dehiscence or stenosis [34].

Careful airway observation is maintained in the early postoperative period. Aggressive pulmonary toilet, including the liberal use of bedside bronchoscopy, is important because these patients may have difficulty clearing secretions past their anastomosis or area of airway repair. Patients who have an associated vocal cord paralysis may have even more difficulty with pulmonary toilet owing to their inability to produce an effective cough. Some patients with tracheal resection may have problems with postoperative aspiration because of difficulty in elevating the larynx during deglutition. This is more profound in the patients with associated recurrent nerve injuries or in those who have had a suprahyoid laryngeal release. The remainder of the postoperative management is similar to the routine care after other neck operations or thoracotomy for pulmonary resection. Noninvasive positive pressure ventilation is relatively contraindicated in the first week after surgery, but can be tried if needed. In the trauma setting, management of the associated injuries and their complications may dominate the care of the patient. For the ventilated patient, care should be taken to position the endotracheal balloon distal or proximal to the tracheal suture line and minimize airway pressures in cases where the endotracheal tube lies above the airway anastomosis by necessity. These patients should be managed at the lowest possible airway pressures that provide satisfactory oxygenation and ventilation and extubated as soon as their other injuries will allow. Bronchoscopy should usually be performed 7 to 10 days after tracheobronchial repair or before discharge to ensure satisfactory healing without granulation tissue or the early development of anastomotic stenosis.

OUTCOMES

Injury to the trachea and proximalbronchi is a lethal injury, with 30-80% of patients with blunt tracheobronchial trauma dying before arrival to the emergency department, although whether primarily due to airway injury or associated injuries is not entirely clear [1,9]. On the other hand, collected reviews suggest that with new techniques mortality in those who survive to admission has significantly decreased from approximately 36% in the 1950's to 9% in 2001 [1].

In patients operated on for penetrating injuries, the mortality is 6% to 18% [7,8]. Of 17 survivors of penetrating tracheal trauma in one series, 15recovered completely [8]. One of 17 patients had permanent hoarseness from concomitant recurrent laryngeal nerve injury and a second patient required a permanent tracheostomy because of complications and failed reconstruction of a combined tracheal and esophageal injury. In Rossbach's series of 32 patients with penetrating (59%) and blunt (41%) tracheobronchial trauma, 25 patients required postoperative mechanical ventilation. In patients with a penetrating injury, this ranged from 1 to 3 days with a mean of 2 days, and in patients with blunt injury, intubation ranged from 3 to 9 days with a mean of 5 days. The average length of intensive care unit stay was 4 days for patients with penetrating trauma and 9 days for patients with blunt injury, whereas the mean hospitalization was 15 days and 17 days for penetrating and blunt injuries, respectively [22]. Nineteen percent of patients in this series sustained postoperative complications but 93% of patients were ultimately asymptomatic and returned to pre injury function. Only 1 of 32 patients (3%) had a symptomatic late stenosis after repair of complex avulsion injury. The mortality rate in this series was 6% and was related to multiple injuries in the setting of blunt trauma. Results from other series show a mortality of 0 to 25% for patients undergoing repair of tracheobronchial injury in the setting of penetrating or blunt trauma with associated injuries. [13,14,24,26,33].

Patients with early definitive airway repair had a long-term good result in over 90% of patients, with poor airway–related outcomes generally being due to associated recurrent nerve injury or failed initial tracheobronchial repair [2,23]. In the series by Reece and Shatney, complications resulting in need for re-intervention arouse in a third of patients who had tracheal repair over a stent or with a tracheostomy, leaving the authors to conclude that primary early repair, rather than staged, resulted in a reduction of later complications of stricture and anastomotic breakdown [23]. In many series, the ultimate prognosis after airway injury is dependent on the associated injuries, particularly closed-head injuries. In a series published by Angood and associates, 13% percent of the patients were left in a vegetative state in spite of excellent functional airways after definitive tracheobronchial repair [3].

MANAGEMENT OF COMPLICATIONS AND LATE PRESENTATION

Anastomotic dehiscence or restenosis occurs in 5% to 6% of patients after tracheal reconstruction for all causes, but may be higher in the trauma setting [39]. Alassal and colleagues described a 25% incidence of stricture among patients managed both conservatively and by repair, although those who underwent operative repair had shorter length of stays [13]. Initial management of a critical cervical stenosis involves securing the airway, usually with an endoluminal or tracheal T tube until healing is complete and the perioperative inflammation has subsided. Most of these patients can be managed with subsequent airway resection and reconstruction 3 to 6 months after the original repair if necessary. Other options may include serial dilation and stenting [39,40]. Anastomotic dehiscence is life threatening if this results in fistula formation to the innominate artery or esophagus. Tracheal/innominate artery fistula is rare but frequently fatal and requires immediate operation for division of the innominate artery and interposition of healthy tissue between the airway and great vessels. Tracheoesophageal fistula can usually be managed initially by establishing gastric

drainage, enteral nutrition, and treatment of pneumonia. When the patient is stable and no longer requires ventilatory support, the tracheoesophageal fistula can be divided, with the esophageal and tracheal defects resected or repaired and healthy soft tissue interposed between the adjacent suture lines. If vocal cord paralysis is permanent, it can usually be palliated by vocal cord procedures.

Patients may incur delayed treatment after tracheobronchial trauma for three reasons. First, the initial injury may have been subtle and initially missed in the early or intermediate trauma management [13]. Second, severe associated injuries may have prevented early definitive management of recognized airway injury. Third, initial attempts at repair may fail, resulting in dehiscence or late stenosis.

The majority of patients with "missed" injuries manifest symptoms within 1-4 weeks. The injury can be missed in the first 48 hours from between 5-80% of patients for a variety of reasons including partial injuries that do not affect ventilation immediately or obscuring by major associated injuries [1]. In any of these scenarios, the sequelae are similar. Although the airway may be partially or completely disrupted at the time of initial injury, it may be held together by strong peri-tracheal connective tissue, allowing an airway to be established and ventilation to be maintained. In the setting of right main stem injury, mediastinal tissue can occlude the defect, preventing air leak but also preventing distal ventilation (Figure 10). However, as the primary injury or secondary dehiscence heals, granulation tissue and scar contracture result, with subsequent stricture formation. In the cervical area patients' exhibit stridor. Patients with more distal intrathoracic injuries may present with post obstructive potentially progressing to lung necrosis. Task in and associates reported nine patients with blunt tracheobronchial rupture, five of whom had operations purposely delayed from 9 to 89 days because of complete lung expansion with suction drainage [41]. However, in all five patients, dyspnea later developed, with bronchoscopy revealing obstruction and granulation tissue at the site of airway injury. Each of these patients required subsequent airway resection with primary reconstruction.

Patients occasionally present months or years after the event with dyspnea on exertion, wheezing, stridor, cough, difficulty in clearing secretions, and/or recurrent respiratory infections. In a patient with a history of trauma or prolonged intubation, any of these symptoms should raise the suspicion of a late airway stenosis, which should be diagnosed or excluded by bronchoscopy. A 50% reduction in the cross-sectional area of the trachea usually results in dyspnea only with significant exertion, whereas narrowing of the lumen to less than 25% usually produces dyspnea and stridor at rest. Patients may reasonably compensate in spite of significant stenosis but can have acute life-threatening deterioration with a minor amount of airway edema or secretions. A high index of suspicion in these patients helps subsequent workup and timely diagnosis [12].

Once recognized, critical airway stenosis can be evaluated and initially stabilized by bronchoscopy and dilatation [42]. However, the appropriate, definitive management of most of these patients is subsequent tracheal or bronchial resection with primary reconstruction as for benign airway strictures from other causes. Except in cases of distal lung destruction by chronic infection, re-establishment of ventilation to lung parenchyma can be expected to restore significant function, even years after the injury. While there may be little or no apparent function by preoperative perfusion scanning, this is likely due to reflexive pulmonary vasoconstriction and is reversible on resumption of ventilation to the lung parenchyma. In these instances, airway reconstruction should always be considered first with pulmonary resection reserved for patients with lesions that are not reconstructable or for those with destroyed parenchyma from chronic infection or bronchiectasis.

CONCLUSION

Although tracheobronchial injury is relatively uncommon, it generally presents in a dramatic fashion, requiring immediate airway control. CT scan is a valuable but ultimately bronchoscopy is the most definitive assessment tool, while also potentially having a therapeutic import. Airway and ventilation strategies should take into account the risk of aggravating the injury as well as being part of the operative plan. Surgery is generally recommended but, small injuries not associated with significant clinical findings may be managed non-operatively. Commonly, penetrating injuries involving the cervical trachea are generally relatively easy to correct while blunt mechanisms require more complex intrathoracic repair (usually from a right thoracotomy approach). Complications of repair or missed injuries typically involve narrowing of the airway resulting in delayed stricture, difficulty breathing and/or persistent post obstructive pneumonia. In patients requiring operative repair, the majority can be managed with direct repair or resection and reconstruction. Most patients do well, with outcomes determined by associated injuries.

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