A narrative review of traumatic mediastinal injuries and their management: the thoracic surgeon perspective

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Objective: Mediastinal injuries are uncommon, rarely encountered and depending on the institution, can be managed by various sub-specialties. The purpose of this narrative review is to present an overview of traumatic mediastinal injuries, their presentation, and management options from the perspective of a thoracic surgeon.

Background: Although infrequent, traumatic mediastinal injuries can pose significant morbidity and mortality. The infrequency of these injuries limits operative exposure for thoracic surgeons and trainees. A concise overview of common presentations and management options is warranted to further solidify important concepts.

Methods: A search of the literature was conducted using MEDLINE, PubMed, and Embase for relevant articles pertaining to anatomic injuries of the mediastinum. The presentation of mediastinal injuries along with indications for non-operative versus operative management in cardiac injuries, thoracic esophageal injuries, tracheobronchial injuries, and injuries to the lungs and pleura was conducted and literature summarized.

Conclusions: In providing this review it is hopeful to enhance knowledge and comfort in recognition and management of these uncommon yet potentially lethal injuries. Early involvement of thoracic surgery is recommended to ensure effective and efficient treatment.

Keywords: Mediastinum; trauma; injury

Introduction

The anatomical borders of the mediastinum contain the pleural spaces laterally, the sternum anteriorly, the thoracic inlet superiorly, the spine posteriorly and the diaphragm inferiorly (1,2). The three-compartment model for the mediastinum is clinically relevant, dividing it into the anterior, middle and posterior mediastinum, each containing vital structures. The anterior mediastinum contains adipose, mesenchymal tissues and the thymus, the middle contains the heart, pericardium, aorta, and main bronchi with the posterior mediastinum encompassing the esophagus and descending aorta (2). The exact incidence of mediastinal injuries remains largely unknown, with overall chest trauma thought to account for approximately 25% of traumatic deaths in the United States from blunt and penetrating mechanisms (3). Given the high potential mortality from injury to important mediastinal structures, it is thought that a large portion of patients do not make it to the hospital alive and are therefore less likely to receive definitive treatment or

operative management as indicated (3).

While we recognize that different surgical specialties may play a role in the management of mediastinal injuries, the unique approach of the thoracic surgeon must be highlighted. While basic management principles exist regardless of specialty, the invaluable experience and comfort of the thoracic surgeon performing procedures in the mediastinum cannot be discounted. We present the following article in accordance with the Narrative Review reporting checklist (available at https://dx.doi.org/10.21037/med-21-13).

Methods

A comprehensive review of the literature was conducted in MEDLINE, PubMed and Embase examining current literature pertaining to the presentation and management of mediastinal injuries. Only articles published after the year 2000 in the English language were included, with some select older references in the case of landmark papers or if secondarily referenced in studies of interest. Search topics included injury to the cardiac box, thoracic esophageal injury, tracheobronchial injury and traumatic lung injury.

Discussion

Cardiac box

The classical description of an injury to the cardiac box is defined by the borders of the sternal notch superiorly, xiphoid process inferiorly and the nipples or mid-clavicular line laterally (4,5). Injury to this area is still considered to be anatomically significant for predicting cardiac injury where survival largely depends on minimizing the time from injury to operative repair (4,6). Injury severity may range from simple cardiac contusion to complete myocardial rupture where the various injuries are explored below (3).

Blunt and penetrating cardiac injuries

Blunt cardiac injury is thought to be one of the main causes of death in trauma, with autopsy reports suggesting a pre-hospital mortality as high as 95% (7,8). A recent retrospective cohort study reviewing blunt cardiac injury over a fifteen-year period at a level 1 trauma centre, examined 348 patients with blunt cardiac injury where only 43 (12.4%) underwent operative treatment (9). Motor vehicle accidents accounted for 21 (48.8%) of blunt cardiac injuries and were predominantly secondary to steering wheel impact (9). The most frequent area of injury found intraoperatively was the right ventricle, shown to be the most common involved chamber in both blunt and penetrating injuries (9,10). Other intraoperative findings were described and included pericardial herniation, heart rotation and significant intracardiac injury.

Penetrating cardiac injuries are also burdened with significant mortality, with estimates of only 10–20% of victims reaching the hospital alive (5,10,11). In hemodynamically unstable patients with penetrating cardiac injury, typical presentation includes cardiac tamponade and obstructive shock (5). Benign penetrating cardiac injury can also occur, defined as those who are hemodynamically stable, neurologically intact and exhibit no signs of cardiac tamponade or active bleeding (5). In any cardiac injury prompt diagnosis is essential, and the importance of eliciting a high clinical index of suspicion cannot be de-emphasized (8,10-12). Any delay in recognition or time to operative intervention can significantly increase morbidity and mortality.

Cardiac tamponade

Positive focused assessment with sonography (FAST) exam on pericardial view accompanied by signs of obstructive shock (hypotension and tachycardia), is significant for cardiac tamponade. Blood in the pericardial sac (hemopericardium), can also be present in a stable patient, therefore the choice of intervention for this clinical finding is largely based on the stability of the patient. In hemodynamically stable patients with suspicion of hemopericardium, pericardiocentesis can be performed. The patient is placed in the semi-upright position and the mid-anterior chest is prepared and draped. A parasternal placement of a catheter is performed in the 4th or 5th intercostal space, or in the subxiphoid space 2 cm inferior to the xiphoid to the left of the midline (13). A 21-gauge needle is directed at 45 degrees aimed at the left shoulder and is continuously aspirated as it is advanced (13). Once fluid or blood is encountered it can then be changed for a guidewire or flexible silastic catheter (13). This procedure can be both diagnostic and therapeutic in the hemodynamically stable patient. A pericardial window should also be considered, which is ideally performed under general anesthesia in the operating room. In this procedure, the midline over the xiphoid is incised and the distal sternum is elevated with a retractor and blunt dissection is carried out identifying the diaphragm and pericardium (13). The pericardium is then grasped and incised with scissors. If

there is significant active bleeding or significant clot burden, median sternotomy should then be carried out, extending the previous incision superiorly to enhance exposure and definitively identify the source of bleeding (11).

Median sternotomy is the definitive incision and intervention of choice for the management of patients with suspicion of cardiac injuries, allowing for access to the right and left hemithoraces (9,10,12,13). When clinical suspicion is high in the presence of hemodynamic instability, this intervention should not be deferred by first performing pericardiocentesis or pericardial window (12). If there is concern for other injuries, cardiac access can be adequately managed through a left anterolateral thoracotomy at the inframammary fold (9,10-13). If previous emergency department thoracotomy has been performed, decision to carry this incision toward the right pleural space into a clamshell thoracotomy provides adequate exposure to the heart and mediastinum (11). Once the mediastinum is exposed the pericardial sac must be opened, taking care to avoid the phrenic nerve while evacuating blood and clot (11).

Myocardial rupture

Myocardial rupture is defined as the development of a laceration or tear in the walls of the atria, ventricles or papillary muscles secondary to blunt trauma (8). Similar to those suffering from penetrating injuries, the right ventricle and atrium are most commonly affected (9,10). Typically, only those with small rupture will survive long enough to make it to the operating room.

In those with significant bleeding, temporary control of the injury can be obtained by applying digital pressure, placement of foley catheter balloon to tamponade the injury, or the use of skin staples for temporary closure of the laceration (8,9,11). Cardiac lacerations are repaired primarily using 3-0 or 4-0 Prolene sutures in a simple running fashion or with interrupted horizontal mattresses to re-approximate the defect (9,11,14). Repairing the atria requires precision as its thin walls are prone to tearing (11). The use of Teflon pledgets could also be considered if the walls are friable, more evenly distributing the suture tension (9,11). In posterior cardiac injuries, the heart needs to be lifted from its mediastinal position which can lead to significant hemodynamic instability and even cardiac arrest. The same technique of suture placement is utilized, but often the sutures need to be placed and the heart returned to the normal anatomical position prior to tying and securing the knots (11). Any injuries in close proximity to

the coronary arteries risk damaging cardiac inflow during repair and sutures need to be placed deep to the arteries to ensure they are not occluded (11).

There is controversy regarding the use of extracorporeal circulation, where advocating against its use highlights the significant time required for preparation and setup as well as the necessity for heparinization that could potentially exacerbate bleeding (9). For most cardiac repairs, this is not necessary and can be performed on the beating heart (9). If there is significant injury to the coronary arteries, cardiopulmonary bypass and the involvement of a cardiac surgeon should be encouraged (11).

Individuals can also present hemodynamically stable with myocardial laceration if their injury is potentially sealed off or partial thickness in nature. The literature supports that in this select population, close observation and monitoring rather than immediate sternotomy may be warranted (5). A single center randomized control trial was conducted in a level 1 trauma center in South Africa, where adult patients sustaining penetrating chest injuries who were hemodynamically stable with evidence of fluid in the pericardial sac on ultrasound underwent 24 hours of close observation followed by sub-xiphoid pericardial window (SPW) (5). SPW was carried out under general anesthesia where a 5 cm incision was made below the sternum and the pericardial sac was opened and irrigated. At the time of subxiphoid window, if there was active bleeding a median sternotomy was performed and if no bleeding was identified, patients were randomized into either sternotomy or drainage of the pericardial sac. During the study period 111 patients were stable on arrival and were selected for inclusion. Of the 55 patients randomized to sternotomy, 51 (93%) had either no cardiac injury or partial thickness injuries, with 4 patients exhibiting sealed wounds to the endocardium. While there was no significant difference in complications between the two groups, the severity of complications in the sternotomy group including cardiac arrest and sternal sepsis are considered to be more significant (5). During the observation period only 6 (5.4%) of patients became hemodynamically unstable and required urgent surgery (5). This study highlights that in stable patients presenting with penetrating chest wounds and clinical suspicion for hemopericardium, where close observation in an ICU setting is possible, median sternotomy is not always warranted. We advocate that in this very specific subset of patients, intensive observation with a low threshold for operative intervention is

appropriate.

Pericardial injury

Injury to the pericardium includes pericardial laceration, rupture, or pneumopericardium (8). Most commonly these are a sequela of penetrating injuries, rarely occurring in isolation. A spectrum of patients may present from those stable with hemopericardium to those who die prior to being treated, succumbing to co-injuries or significant cardiac tamponade (15). When pericardial laceration occurs, one must be aware of risk of cardiac herniation, with potential sudden death from strangulation secondary to inflow and outflow occlusion (5). Pericardial laceration can be repaired primarily using absorbable suture after the pericardial injury has been identified through median sternotomy (11).

Myocardial contusion

Myocardial contusion is often given as a diagnosis, yet its definition can be challenging to delineate. Most injuries are secondary to the heart's location in the mediastinum commonly secondary to direct impact to the anterior chest, acceleration/deceleration forces and blast force (8). Contusion can present with cardiac biomarker elevation and ECG changes (8). These injuries are managed conservatively, while the patient is closely observed in either a telemetry monitored bed or ICU setting dependent on hospital specific policies and the hemodynamic stability of the patient. Cardiac function can then be assessed using echocardiogram based on the degree of clinical suspicion.

Thoracic esophageal injuries

The esophagus begins in the neck and then courses through the thoracic inlet into the chest where it lies in the posterior mediastinum (16). The esophagus is relatively protected, surrounded by the vertebral column posteriorly, the lungs laterally and the heart anteriorly, making isolated esophageal injuries rare (16). Esophageal injuries are only estimated to account for 0.02–1% of all traumatic injuries, with many individuals dying on scene from exsanguination secondary to co-injury of the great vessels (16,17-23). If present these injuries pose significant morbidity (upwards of 70%) and mortality (40–53%) (17,21,24). Esophageal trauma can be categorized based on location (cervical, thoracic or abdominal), as well as mechanism (blunt or penetrating) (24). Esophageal injury in trauma is thought to be upwards of 16 times more common in penetrating injuries where the

cervical esophagus is most commonly affected (23-25).

The decision on management of esophageal trauma depends on the clinical status of the patient, location of the injury and whether or not the perforation is contained (16). There is new emerging evidence to suggest that small, contained thoracic esophageal perforations with no clinical signs of sepsis, could be considered for non-operative management involving broad spectrum antibiotics, nothing by mouth (NPO) and placement of nasogastric tube for proximal decompression (26). Non-operative management should be approached with caution, where most literature examining this method does not encompass patients with traumatic mechanisms that could have the potential to disrupt tissue plains and make a contained perforation less likely (23,27-29). Evolving literature also lends support to the use of esophageal stents to close small esophageal perforations in stable patients. In a review of the literature by Dasari *et al.* [2014] evaluating 27 case series, it was noted that esophageal stenting appeared safe and effective in controlling small esophageal perforations (29). Again, these series did not include trauma patients and there was no comparison between stenting and operative management to accurately answer this important clinical question, therefore this approach should be considered with caution (3,23,29).

While there continues to be debate regarding non-operative management for stable patients, unstable patients are taken to the operating room for exploration. Timing to the operating room is advocated to be essential in decreasing the significant morbidity associated with traumatic esophageal perforation, suggesting that both morbidity and mortality increase after 24 hours and could limit options for repair (26). Patient positioning is dependent on location of the perforation where a right posterolateral thoracotomy is performed for a proximal perforation and a left posterolateral thoracotomy for more distal perforations (3,4,16,26). Proximal cervical esophageal injuries should be approached through a left neck incision where the recurrent laryngeal nerve is more readily visualized and preserved (26).

The most commonly performed surgical management for esophageal perforation is a primary repair when closure of healthy tissue without tension is possible (3,16,21,23,26,30,31). Prior to performing repair, the chest should be thoroughly irrigated and debrided of any debris (3,26). Once the perforation is localized, the muscular layer of the esophagus should be incised vertically to expose the entirety of the mucosal defect and trimmed to healthy tissue (3,16,26). The defect is then closed in two layers, where the use of absorbable and non-absorbable sutures remains

controversial. Separate closure of the mucosal and muscular layers with interrupted silk sutures are described while a technique utilizing a running 4-0 monofilament to close the mucosa and 3-0 interrupted silk sutures for the muscular layer could also be considered (3,16,26). A buttress should then be performed, with pedicled intercostal muscle flap being the most common method described, while other entities such as pericardium could be considered (3,23,26). After repair of the defect and closure of the chest, consideration should then be made to placing a feeding jejunostomy tube and potentially a venting gastrostomy tube depending on the clinical status of the patient and the extent of the injury (26). Another option for nutritional feeding is the insertion of a percutaneous endoscopic gastrostomy (PEG) tube prior to esophageal repair, to ensure the repair is not compromised by endoscopic intraluminal examination. The PEG can later be exchanged for a gastro-jejunostomy tube and eliminates the morbidity of laparoscopy or laparotomy for select patients.

Esophageal exclusion can be considered in patients who have a significant esophageal injury where primary repair is not achievable (3). This management strategy involves proximal diversion with a cervical esophagostomy, venting gastrostomy and feeding jejunostomy tube (3,26). Other options include placing a T-tube in the perforated segment and externalizing it through the chest wall, with wide local drainage at the site of perforation (3,26). Given that this procedure can be associated with significant complications and morbidity for patients, it is performed rarely and in only severe cases, with numbers estimated to be low in 1–4% of esophageal injuries (30,32). Reconstruction is generally not advocated for in the unstable patient, where the increased operative time may further compromise patient hemodynamics posing a greater risk of conduit ischemia and anastomotic leak (31,33). Most of the literature surrounding urgent esophagectomy and reconstruction for esophageal injury stems from iatrogenic endoscopic injury in the setting of benign esophageal disorders and are not necessarily translatable to the trauma population (26,33).

Tracheobronchial injury

The trachea is an elastic structure composed of approximately 16–22 incomplete cartilaginous rings covering the anterior two thirds of its surface, remaining well protected in the thorax behind the sternum and rib cage (34,35). It comprises a cervical component in the neck that then becomes the thoracic trachea as it descends into the mediastinum through the thoracic inlet, lying posterior to both the innominate artery and vein (35,36). Further distally, it passes underneath the aortic arch, posterior and left to the superior vena cava (35,36). The heart lies anterior to the trachea, the pleura and lungs laterally, and the esophagus posteriorly (35). Approximately 50% of the trachea lies in the neck and 50% in the chest, with these numbers fluctuating based on body habitus (36).

All encompassing, tracheobronchial tree injuries are rare and are estimated to occur in 0.5–2.8% of patients often in conjunction with co-injuries to the lungs with pneumothorax or hemothorax, chest wall injury, esophageal, cardiac, spinal cord or intra-abdominal injuries (3,34-38). The relative protection of the thoracic trachea leaves the exposed cervical trachea more commonly injured. Penetrating injury more commonly effects the cervical trachea, where blunt injury can cause injury to either the cervical or thoracic trachea (3,34,36,38). In blunt injury, sheer force can cause separation of the bronchi from the carina with lateral displacement of the lungs often occurring within 2 cm of the carina (3,35,38). Those with injury to the lower third of the trachea often suffer fatal injuries to the heart or great vessels and die prior to receiving medical care (38,39). The most common location for tracheobronchial injury overall is thought to be the right mainstem bronchus (35-37,39).

Tracheobronchial injuries from iatrogenic injury post intubation have been classified by Cardillo *et al.* [2010] and can be applied to guide management in the trauma setting. A Level I injury contains mucosal or submuscosal injury without mediastinal emphysema or esophageal injury (39). Level II is a lesion extending to the muscular wall with subcutaneous or mediastinal emphysema in absence of esophageal injury or mediastinitis (39). Level III A involves a complete laceration with esophageal or mediastinal soft tissue herniation without esophageal injury or mediastinitis where level IIIB is characterized by any laceration with esophageal injury or mediastinitis (37,39) (*Table 1*). Diagnosis and level of injury relies on high clinical suspicion with bronchoscopy as the gold standard diagnostic procedure (35-37).

The first daunting task in tracheobronchial injury is intubating and ventilating the patient. All patients should be intubated using bronchoscope or fiberoptic technique which can be performed without cervical extension in the awake patient and can act as a bougie for the placement of the endotracheal tube (36). Anesthetic management requires constant communication between the thoracic surgeon and

Table 1 Summary of Cardillo classification for tracheobronchial injury (40)

Level of tracheobronchial injury	Cardillo classification
Level 1	Mucosal or submucosal injury; no mediastinal emphysema or esophageal injury
Level 2	Lesion extends into the muscular wall; presence of subcutaneous or mediastinal emphysema; no esophageal injury
Level 3A	Complete laceration through all layers; esophageal or mediastinal soft tissue herniation; no esophageal injury; no mediastinitis
Level 3B	Any laceration; presence of esophageal injury or mediastinitis

the anesthesiologist to ensure an effective operative strategy. If bronchoscopy has not been completed for intubation, it is essential to perform to identify the location and extent of the injury (36). A long single-lumen endotracheal tube is often preferred as it can easily traverse and extend distal to the injury without extending it (36). However, in cases of main stem bronchial or carinal injuries, a double lumen tube with possibility for single lung ventilation is advocated (36). Even with single lumen tubes, the capacity to isolate the lung with the use of a bronchial blocker should be available.

For exposure to the proximal one half to two thirds of the trachea, injuries are accessed by a low collar incision which can be carried down into a T shaped incision over the manubrium to allow for adequate exposure to the adjacent vasculature (3,35-38). The lower third of the trachea, carina, right mainstem and proximal left mainstem bronchus are best exposed through a right posterolateral thoracotomy incision, entering the chest through the 4th intercostal space over the 5th rib (3,35-38). The distal left mainstem bronchus is best exposed through a left posterolateral thoracotomy incision where visualization can prove challenging when in close proximity to the aorta (3,35-38). If these injuries are found in conjunction with cardiac injuries, and a median sternotomy is performed, airway access can be challenging. In this circumstance, the superior vena cava must be mobilized and reflected to the right, retracting the ascending aorta to the left, and dividing the posterior pericardium longitudinally while still only providing visualization of the anterior airway (37,39).

Primary repair of tracheobronchial injuries is often indicated, however minor injuries (Cardillo levels I and II) who are clinically stable with tears <2 cm or less than one-third of the circumference of the airway, could be considered for non-operative management (34-36,39). Other important considerations for non-operative management include absence of esophageal injury, minimal mediastinal air and non-progressive pneumomediastinum

or subcutaneous emphysema (40). These minor injuries can be treated with close monitoring of clinical status (stability of subcutaneous emphysema and respiratory status) with recommendations for follow up bronchoscopy and course of antibiotics (36,39,41).

Once the injury is identified and exposed, de-vitalized tissue is debrided to ensure the closure of healthy membranous tissue (35-37,41). For simple, clean lacerations repair can be carried out primarily with simple interrupted absorbable sutures such as a 4-0 vicryl with consideration of buttressing the repair with an intercostal muscle flap (35-37,41). All surgical knots should be tied to the outside in hopes of decreasing granulation tissue formation. If there is significant tracheobronchial disruption, a circumferential resection and primary anastomosis may be required, with possibility for up to 50% tracheal resection being successful in most patients (36,37). Both mainstem bronchi can be typically completely resected and reconstructed without tension in most cases (36). If there is tension present, tracheobronchial release maneuvers have been described. In limited resections often blunt development of the anterior avascular pre-tracheal plane combined with neck flexion when possible can provide adequate length (36). In proximal cervical resections, a suprahyoid laryngeal release may provide an additional 1–2 cm of length, where in mainstem bronchi or carinal resections division of the pericardium around the hilum can provide similar mobilization (36).

In rare cases where repair is un-manageable, lobectomy or pneumonectomy is performed with closure of the bronchial stump, yet this is reserved for severe cases due to significant morbidity and mortality (35). Carinal injuries are more challenging, where repair is favored over reconstruction in those cases (36).

Temporary placement of covered self-expanding metal stents has been utilized in tracheobronchial trauma where surgery is not feasible or the patient was not an optimal surgical candidate (34,38). The stent is thought to obstruct

the tracheal defect and expediate the inflammatory response with granulation tissue formation causing closure of the defect (38). The stents are then typically removed in 4-6 weeks after an endoscopic re-evaluation of the injury (34,38,39,40).

Rib fractures

While controversy exists regarding timing of surgical fixation for flail segments, those with severe pulmonary contusion who are unable to be weaned from the ventilator should be considered for repair (14). A Bayesian meta-analysis was conducted by Choi *et al.* [2020] examining the implementation of surgical stabilization for rib fractures (SSRF) in improving clinical outcomes compared with non-operative management. Thirty-nine studies (5 randomized control trials) were analyzed and it was found with 95% probability that SSRF was associated with 2–7 fewer ventilator days, 5–7 fewer days in ICU, 8–12 fewer days hospitalized, 25–80% lower odds of pneumonia, 15–85% lower odds of undergoing tracheostomy, and 35–85% lower odds of mortality compared with non-operative management" (53:212). This accounted for a near 100% probability that SSRF was associated with better outcomes (42). Another systematic review conducted by Ingoe *et al.* [2019] examined internal surgical fixation compared with any external fixation or non-surgical management. They included 12 studies in their systematic review and for those with a flail chest segment, were noted to have decreased length of mechanical ventilation, length of stay, pneumonia and tracheostomy rates with surgery compared with non-surgical management (43). Therefore, there is increasing support to consider early rib fixation, particularly in those with flail chest.

Thoracic surgery involvement

While an emphasis on early recognition and prompt intervention for mediastinal injuries has been highlighted, a dichotomy in management remains. Depending on the centre, mediastinal injuries may be managed by trauma or thoracic surgeons. While the vast skill set of the trauma surgeon cannot be discounted, early involvement of thoracic surgery upon initial recognition for any unstable patient with thoracic mediastinal injury is advocated. While stable patients with pneumothorax, hemothorax and pulmonary contusion are often self-resolving with appropriate chest tube placement and pulmonary toileting, any prolonged air leak, challenges weaning from ventilation or un-drained

hemothorax should be referred to thoracic surgery. We advocate that all esophageal, tracheobronchial injuries as well as pulmonary lacerations requiring anatomical resection are best managed by thoracic surgery. While injuries of the cardiac box are under the scope of practice of the thoracic surgeon, involvement of cardiac surgery may also be warranted.

Conclusions

A review of mediastinal injuries as well as operative and non-operative management strategies from the perspective of a thoracic surgeon has been outlined. The hemodynamic status of the patient as well as the mechanism of injury should be the main considerations driving treatment decisions. While these injuries are rare, they can be lethal and prompt recognition and intervention is essential. We advocate that all esophageal, tracheobronchial injuries as well as pulmonary lacerations requiring anatomic resection are best managed by thoracic surgery.

Footnote

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