Diaphragm Injuries

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Injury Demographics

- Diaphragmatic injuries, whether secondary to blunt or penetrating trauma, are relatively rare with incidence of 0.8% to 8% after blunt trauma and 10% to 15% after penetrating trauma.
- Blunt ruptures of the diaphragm occur predominately on the left, in nearly two-thirds of reported cases.
- Blunt trauma:
    - produces large radial tears (5-10cm)
    - injuries occur posterolaterally at the pleuroperitoneal membrane which is a site of weakness
- Penetrating trauma:
    - creates small linear incisions or holes
    - if not recognized at the index admission, may have a delayed presentation (months to years) with gradual enlargement and herniation with possible incarceration of viscera as small diaphragmatic holes are the initial injury with progressive expansion secondary to pleuroperitoneal pressure gradients.

Clinical Presentation

- The clinical presentation of a diaphragm injury varies widely from asymptomatic to shock and respiratory failure.
- Signs and symptoms are typically related to concomitant injuries.
- Acute thoracic signs and symptoms relate to intra-abdominal contents from herniation into the pleural space and include chest pain, dyspnea, decreased breath sounds, bowel sounds on chest auscultation and crepitus.
- Acute abdominal symptoms include abdominal pain, vague and diffuse in characteristic, and dyspepsia.
- Delayed presentation can present with obstruction, incarceration, or strangulation of herniated intra-abdominal contents into the pleural cavity.

Evaluation/Diagnostics/Imaging

- Patients may be asymptomatic; therefore, a high index of suspicion is required, particularly in high-energy blunt mechanisms and in penetrating truncal trauma.
- Chest radiography should be the initial diagnostic study, and may show
    - elevation of a hemidiaphragm
    - nasogastric tube curling or gastric bubble in the left hemithorax
- Ultrasound may be diagnostic in select patients, with visualization of viscera within the thoracic cavity.
- The sensitivity of helical computed tomography (CT) is superior to chest radiographs. CT findings include visceral herniation, constriction of the diaphragm at the point of visceral herniation ("collar sign"), visualization of the defect, or non-visualization of the diaphragm.
- Thoracoscopy and laparoscopy may be considered a diagnostic, as well as a treatment option. It should be considered when the diagnosis is unconfirmed and laparotomy is not warranted by initial evaluation; this may be particularly true in penetrating left-sided thoracoabdominal injuries.
- Magnetic resonance imaging is a sensitive test, but is limited by time and location. It may be utilized when other diagnostics are equivocal as coronal and sagittal planes allow complete visualization of the diaphragm with high-quality images.

Role of Non-operative Management

- Diaphragm injuries are rarely life-threatening. Definitive repair can be delayed in damage control scenarios in which treating life threatening associated injuries takes precedent. Visceral herniation and respiratory compromise are potential complications if not addressed at the original damage control surgery.

Indications for Operative Intervention

- The majority of acute and chronic diaphragm injuries require surgical repair.
- Right sided injuries secondary to penetrating trauma may be observed as the liver provides protection from visceral herniation.
- Goals for acute repairs include preventing respiratory compromise while goals for chronic repairs include preventing herniation of contents into the chest cavity and potential obstruction, incarceration, strangulation, and possible rupture of the stomach and colon.

Impact of Associated Injuries

- Diaphragmatic injuries rarely occur in isolation.
    - Solid abdominal solid organ injuries are common after blunt trauma.
    - Pelvic fractures are associated in 40%
    - Splenic and liver injuries are present in 25% of cases.
    - Thoracic aortic injuries are seen in 5-10%
- Associated injuries are most commonly responsible for clinical signs and symptoms.
- Life threatening associated injuries have operative priority, diaphragm repair may be delayed.

Operative Techniques/Intraoperative Considerations

Acute Injury

- A midline laparotomy is the approach of choice for acute injury (rather than a thoracic approach) due to the high incidence of associated intraabdominal injuries. For isolated injuries, laparoscopic repair represents a viable alternative.
- The two basic goals of operative treatment include reduction of herniated structures followed by watertight repair.
- Appropriate retraction of the liver, stomach and spleen, with visualization of the injury is imperative.
- Non-viable edges of the diaphragm should be debrided to healthy tissue with an attempt to create a linear defect, especially with blast injury where transfer of energy released causing more extensive damage.
- The margins of the laceration can be grasped with Allis or Babcock clamps, to inspect both the extent of laceration and potential injury in the thoracic cavity.
- The edges should be everted to expose and evacuate the pleural space to confirm there is no bleeding from lung parenchyma or intercostal vessels, with subsequent placement of a thoracostomy tube under direct visualization.

- The chest should can be irrigated and drained prior to closure of the injury, particularly when there is contamination in the field to minimize subsequent empyema. Due to the pressure gradient across the diaphragm, blood and visceral contamination accumulate within the pleural space.
- Repair should be as tension free as possible, utilizing non-absorbable 1-0 or 0 non-absorbable monofilament suture. Some have described use of locking sutures while others perform a running locking buttress suture for any laceration >2cm.
- Upon completion of the repair, visualizing the repair during administration of a large tidal volume with optional saline instilled into the upper quadrants can be performed to test the integrity of the repair.

Chronic Injury

- Because chronic diaphragm lacerations often involve intrapleural adhesions, a thoracic approach is optimal.
- Many chronic injuries involve muscle atrophy with enlargement of the defect; this may preclude primary repair with inability to re-approximate the defect. Defects of 8 cm or less may be successfully repaired primarily.
- Although some advocate the use of prosthetics with a specific size of defect, surgeon discretion is the most important predictor of need for mesh; one should assess whether repair can be accomplished with acceptable tension and diaphragm functionality. Mesh can be used if a linear repair is unable to be performed or if too much tissue is lost.
- If prosthetic is required, a variety of meshes will suffice, including polypropylene or PTFE, which should be sutured into place with a 1-0 or 0 monofilament suture. Bioprosthetic meshes have been advocated and utilized in contaminated cases.
- Mesh should be considered when primary repair results in flattening of the diaphragm and loss of functionality.

Special Operative Considerations

- For both blunt and penetrating mechanism, it is not uncommon to encounter a diaphragm injury when performing a thoracotomy acutely for thoracic hemorrhage. A liver or splenic laceration, particularly with herniation, may hemorrhage predominately into the chest due to the negative pressure gradient that exists in the pleural space. Under these circumstances, diaphragm repair can occur via the thoracotomy, but a laparotomy should be performed to identify and treat abdominal injury.
- If the diaphragm is detached from the chest wall, typically in the left posterolateral region, it may be necessary to suture the diaphragm directly to ribs, by placing sutures circumferentially around the ribs.
- Diaphragm lacerations may extend into the pericardium, which may require careful suture apposition of the pericardium to the diaphragm.
- Laparoscopic repair is appropriate in select circumstances for acute injury, typically in the absence of concomitant injury, including left sided thoracoabdominal stab wounds.
- With appropriate surgeon expertise, thoracoscopic repair can be accomplished for select chronic lacerations.

Postoperative Management/Complications

- Postoperative morbidity is high with overall mortality 4.3 to 37% in a series of penetrating and blunt injuries, respectively. It is most commonly related to associated injuries, ranging from empyema to multisystem organ failure.
- Common post-operative complications include pulmonary atelectasis (11-68%), pneumonia and pleural effusions (10-23%) and empyema (2-10%).
- Diaphragm-related morbidity includes repair dehiscence (extremely rare) and paralysis. Hemidiaphragm paralysis can occur with iatrogenic phrenic nerve injuries; care should be taken to identify and preserve the phrenic nerve intraoperatively.

Selected Readings

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