Case Presentation

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Management of Diaphragmatic Injury in Penetrating Trauma
History

- Diaphragmatic rupture first described by Sennertus in 1541
- Ambrose Paré (1579) describes four patients with delayed presentation, e.g.:
  - French artillery captain sustains a chest wound
  - 8 months later suffers colonic obstruction
  - Autopsy: diaphragmatic rent “no larger than the tip of the finger”
- Bowdich (1853) – First ante-mortem diagnosis
- Riolfi (1886) – First successful repair
Embryology

- Develops between 4\textsuperscript{th} and 10\textsuperscript{th} weeks of gestation from:
  - Septum transversum
  - Pleuroperitoneal membrane
  - Dorsal mesentery of the esophagus
  - Lateral body walls
Anatomy

- **Lumbar part:**
  - Crura arise from the anterior surface of the lumbar vertebrae; other fibers originate from lumbocostal arches; insertion at central tendon

- **Costal part:**
  - Originates from the six caudal ribs, inserts in central tendon
  - Lumbocostal trigone (Bochdalek’s gap)

- **Tendinous part**

- **Location:**
  - Depends on extent of inhalation or exhalation, age, sex, momentary posture, extent that intestines are filled, and general body structure
  - At rest, right dome is at ICS 4 and left dome is approximately 1 to 2 cm lower; at maximal inhalation at ICS 6 on right and ICS 7 on left
Anatomy

- **Blood supply:**
  - Pericardiophrenic artery and aortic branches

- **Innervation:**
  - Phrenic nerve (originates from C3, C4, C5); predominantly motor on the right; sensory innervation shared with peritoneum, gallbladder, liver

- **Lymphatic drainage:**
  - To parasternal, lateral aortic, and posterior mediastinal lymph nodes
Penetrating injury of diaphragm most commonly secondary to stab and gunshot wounds

Less commonly caused by operative misadventure, incorrect chest tube placement, impalement injuries

Must be suspected in any stab wound in which the trajectory reaches the fourth and fifth intercostal spaces superiorly and the level of the twelfth rib inferiorly¹

Gunshot wounds can perforate the diaphragm from virtually any entry site in the chest, abdomen, or pelvis

Incidence after stab wounds to the left lower chest as high as 35% in some series

In clinical reports, left-sided injuries are reported to be more common than those on the right; autopsy series, however, reveal the incidence to be nearly equal.

Delay in diagnosis until the time of visceral herniation and strangulation can have a mortality rate as high as 40%.

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Natural history

- Diaphragmatic hernias are not believed to close spontaneously\(^1\)
  - A pressure gradient exists between the thoracic and abdominal cavities
  - The diaphragm is thin and in constant motion
- In animal models, however, some spontaneous healing is noted, particularly when injury is “protected”:
  - 56 rats with 5-mm trocar injuries to diaphragm. At 150 days, 100% of right-sided and 83% of left-sided punctures had healed\(^2\)
  - 8 pigs with 1.5- to 2-cm lacerations to each diaphragm. At 6 weeks, 15/16 lacerations had healed\(^3\)

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\(^3\) Shatney CH, Sensaki K, Morgan L. The natural history of stab wounds of the diaphragm: implications for a new management scheme for patients with penetrating thoracoabdominal trauma
Expectant Management?

- Leppäniemi et al: 100 high-risk patients randomized to exploration or observation\(^1\)

<table>
<thead>
<tr>
<th></th>
<th>Total (%)</th>
<th>Exploration (%)</th>
<th>Observation (%)</th>
<th>(p) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of patients</td>
<td>97</td>
<td>47</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>61 (84)</td>
<td>39 (83)</td>
<td>42 (84)</td>
<td>0.999</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>37 ± 11</td>
<td>36 ± 12</td>
<td>35 ± 11</td>
<td>0.281</td>
</tr>
<tr>
<td>Intoxicated at admission</td>
<td>60 (82)</td>
<td>37 (79)</td>
<td>43 (86)</td>
<td>0.427</td>
</tr>
<tr>
<td>Self-inflicted wounds</td>
<td>27 (28)</td>
<td>12 (25)</td>
<td>15 (30)</td>
<td>0.633</td>
</tr>
<tr>
<td>Multiple stab wounds</td>
<td>15 (15)</td>
<td>10 (21)</td>
<td>5 (10)</td>
<td>0.163</td>
</tr>
<tr>
<td>Left-sided stab wound</td>
<td>71 (73)</td>
<td>35 (74)</td>
<td>36 (72)</td>
<td>0.822</td>
</tr>
<tr>
<td>ISS</td>
<td>4 ± 4</td>
<td>5 ± 4</td>
<td>3 ± 3</td>
<td>0.001</td>
</tr>
<tr>
<td>NISS</td>
<td>4 ± 5</td>
<td>6 ± 5</td>
<td>3 ± 3</td>
<td>0.001</td>
</tr>
<tr>
<td>ATI score</td>
<td>3 ± 5</td>
<td>5 ± 5</td>
<td>1 ± 4</td>
<td>0.000</td>
</tr>
<tr>
<td>Associated hemo- or pneumothorax</td>
<td>12 (12)</td>
<td>5 (11)</td>
<td>7 (14)</td>
<td>0.761</td>
</tr>
<tr>
<td>Significant nondiaphragmatic abdominal organ injury</td>
<td>7 (7)</td>
<td>4 (9)</td>
<td>3 (6)</td>
<td>0.709</td>
</tr>
<tr>
<td>Diaphragmatic injury detected during initial hospitalization</td>
<td>4 (4)</td>
<td>4 (9)</td>
<td>0 (0)</td>
<td>0.052</td>
</tr>
</tbody>
</table>

\(\text{ISS, Injury Severity Score; NISS, New Injury Severity Score; ATI, Abdominal Trauma Index.}\)

- 2 patients in nonoperative group presented later with strangulation of hollow viscus and perforation (follow up of 0.5 to 5 years)

\(^1\) Leppaniemi A, Haapiainen R. Occult diaphragmatic injuries caused by stab wounds. J Trauma 2003;55:646-650
Diagnosis

- Clinical acumen
  - Clinical correlates to diaphragmatic rupture include:
    - chest and abdominal pain
    - dyspnea
    - reduced breath sounds in the lower lung fields
    - respiratory failure
    - bowel sounds heard in the chest
    - peritonitis
    - palpation of abdominal viscera during insertion of chest tube
    - drainage of DPL fluid or bile from a chest tube
    - hemodynamic instability and/or respiratory decompensation with use of MAST
  - Clinical history, knowledge of mechanism, and physical exam all lack sufficient sensitivity
Diagnosis

- Radiography:
  - CXR alone allows diagnosis of 27-60% of left-sided injuries but only 17% of right-sided injuries
    - Diagnostic findings include intrathoracic herniation of a hollow viscus and visualization of NGT above the diaphragm
    - Can be mimicked or masked by pleural effusion, pulmonary contusion, atelectasis, phrenic nerve palsy
  - Helical CT allows diagnosis of 78% of left-sided injuries and 50% of right-sided injuries
    - Diagnostic findings include direct visualization of discontinuity of the diaphragm, herniation of abdominal contents, “collar sign”
  - MRI can be useful; it provides direct coronal and sagittal images and delineation of the diaphragm
    - It is, however, too impractical to use routinely

Diagnosis

- Diagnostic peritoneal lavage

  - Sensitivity and specificity depend on criteria used\(^1\)

<table>
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<tr>
<th>Threshold (RBC/mm(^3))</th>
<th>False negative</th>
<th>False positive</th>
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<tbody>
<tr>
<td>10,000</td>
<td>1.0%</td>
<td>13.6%</td>
</tr>
<tr>
<td>100,000</td>
<td>11.1%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

  - 5000 red cells/mm\(^3\): DPL had a sensitivity of 91%, a specificity of 94%, an accuracy of 93%, a PPV of 80%, and a NPV of 98% in predicting intra-abdominal injury requiring surgical repair\(^2\)

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Diagnosis

- **Laparoscopy**
  - Safe and effective\(^1,2\) with a specificity of 100% in some series\(^3\)
  - Can be therapeutic as well as diagnostic
  - Complications are minor and include atelectasis, pneumothorax, and transient hypoxia or hemodynamic instability during insufflation of abdomen
  - Expensive: addition to protocol increases costs by $1000 per patient

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Management

- Acute injuries are best approached through laparotomy
  - Single layer closure with nonabsorbable suture
- Chronic diaphragmatic hernias are best repaired through the chest
Conclusions

- Diaphragmatic injury after penetrating thoracoabdominal trauma can be clinically silent. However, the results of a missed injury can be catastrophic. Clinical suspicion must be high.
- Penetrating injuries with a trajectory below the mammary line and above the costal margin – particularly on the left – should arouse suspicion of a diaphragmatic injury.
- DPL is superior to imaging modalities in diagnosing diaphragmatic trauma is nonetheless imperfect.
- Laparoscopy should be considered whenever diaphragmatic injury is suspected, even if the remainder of the workup is negative.