"A Stab in the Dark" - Review of multidetector CT imaging findings in penetrating diaphragmatic injury and correlation with clinical outcome. A UK Level 1 Trauma Centre Perspective.

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Learning objectives

"A Stab in the Dark"
Review of multidetector CT imaging findings in penetrating diaphragmatic injury and correlation with clinical outcome.
A UK Level 1 Trauma Centre Perspective.

S. Javed, M. Akhtar, S. West, T. Campion, S. Cross

To understand the key role the Radiologist plays in diagnosing penetrating diaphragmatic injury.

To illustrate the importance of multidetector CT in delineation of diaphragmatic rupture in Penetrating Trauma The CT signs in penetrating diaphragmatic injury can be subtle.

We will demonstrate key findings along with potential pitfalls.
Background

Introduction:

• The Royal London Hospital is a Level 1 Trauma Centre in central London.

• The number of stabbing related admissions to our Emergency Department has increased steadily year on year.

• Penetrating trauma to the torso in the haemodynamically stable patient can cause damage that is clinically and radiologically subtle.

• Left sided traumatic diaphragmatic injury is almost universally surgically repaired regardless of the mechanism. The CT imaging signs of penetrating diaphragmatic injury are not as well documented in the literature as those secondary to blunt trauma.

Background:

• Penetrating trauma is defined as injury incurred when an object such as a knife or bullet penetrates the body.

• Official statistics from Jan-Sep 2011 highlighted 32,500 stabbing offences involving knives or sharp instruments in the UK. [1]

• It is penetrating trauma rather than blunt trauma that causes the majority of diaphragmatic injuries [2].

• As the majority of diaphragmatic perforations are relatively small (usually varying from 1 to 4 cm in length), patients with isolated penetrating diaphragmatic injuries are relatively asymptomatic, and do not show any radiographic abnormalities. [2] [3]

  • Influencing factors with regards to the incidence of diaphragmatic injuries include:
    • entry site - taken as between nipple and umbilicus
    • trajectory of the wound
    • presence of associated injuries in the abdomen and chest [3]
The culture of surgery has changed over the past decade, with more surgeons preferring to manage conservatively patients who do not have major visceral organ injuries.

Diaphragmatic injury can be easily missed in the acute phase as it may be clinically quiescent. Mortality can be as high as 23% and if gone unnoticed without surgical intervention, complications can include:
- bowel obstruction
- perforation,
- intra-thoracic sepsis [6]
- Diaphragmatic injuries can remain clinically silent and re-present at a later stage with life threatening complications; thus emphasizing the importance of picking up the pathology on the pre-operative imaging.

Pathophysiology:

- In penetrating trauma, the injury to the diaphragm is caused by the knife or bullet penetrating through the diaphragm physically. In comparison, blunt trauma to the diaphragm is brought about by an increase in intraabdominal pressure from an impact directly to the left hemidiaphragm à leading to avulsion of the diaphragm. [5]
- As for the random nature of gun shots, there is no predisposition for one site or side being targeted more than any other side. However, the majority of stab wounds do tend to be on the left side, as majority of people, and thus the majority of stabbers are right handed. [6]
- The pressure differences in the abdominal and thoracic cavity can cause herniation of abdominal contents into the chest despite the injuries to the diaphragm in penetrating trauma tending to be more relatively small in size (1-4cm). [2]

Clinical Signs and Symptoms:

- The diaphragmatic lacerations can temporarily be closed either due to omental plugging, or by muscular contractions of the diaphragm
- Small tears if untreated, will eventually enlarge over a period of time and delayed symptoms may then present once there is herniation of abdominal contents into the thoracic cavity.
- With such a variable clinical presentation - from asymptomatic in the acute phase, to bowel obstruction, perforation or sepsis in the delayed phase - one should always have a high degree of suspicion with any case of penetrating thoraco-abdominal trauma.
- Severity of clinical signs or symptoms will depend on: [10]

The extent of lung collapse, associated with mediastinal shift, causing: (reduced air entry)
• Hypoxia
• Desaturation
• Cyanosis

The extent of herniation of bowel contents (reduced bowel sounds / bowel sounds in thoracic cavity)

• Pain
• Vomiting
• sepsis

Investigations:

• There is no single investigation that can reliably identify diaphragmatic injury
• **CHEST RADIOGRAPH (haemodynamically stable patients):**
  • frequently unreliable
  • If there is herniation of bowel contents into the thoracic cavity in the acute setting, then sensitivity of plain chest radiograph is 94%
  • If there is a simple diaphragmatic tear (which is most likely post stab or gun shot - as the tears are typically quite small), the sensitivity is as low as 30% for simple tears [11]
  • Haemopneumothorax can also mask findings and make image interpretation more difficult. If this is seen, then one should be concerned of the high possibility of diaphragmatic injury.
• **ULTRASOUND:**
  • In the trauma setting, if there is reduced movement of the diaphragm seen on FAST scan, suspicion of diaphragmatic injury should be raised.
  • Ultrasound is useful in identifying diaphragmatic flap present in the pleural cavity or splenic herniation into the thoracic cavity [14]
  • Findings suggestive of diaphragmatic injury:
    • inability to visualize the diaphragm
    • structural discontinuity of the diaphragm
    • herniated abdominal viscera [15]
    • We do not advocate the use of ultrasound to diagnose diaphragmatic injury
• **MULTIDETECTOR CT**
  • Surveys have been carried out retrospectively in assessing the sensitivity of CT in establishing diaphragmatic injury à which have shown a sensitivity between 42 and 90% [12]
  • Should CT findings be inconclusive, Coronal and sagittal T1 weighted MRI has been demonstrated to be useful [13]. However with modern 64 slice CT scanners with reformatting capabilities the need for MRI is low.
Despite this, a study which carried out systematic CT reporting by Consultant radiologists asked to specifically look out for signs associated with diaphragmatic injury demonstrated a sensitivity of 100% and specificity of 94.6% [12]

Management and Prognosis:

- MANAGEMENT:
  - Patients with established diaphragmatic injury can not be managed conservatively, as patients can become symptomatic shortly, or years after the initial injury has taken place.
  - Surgical management and correction of the repair is necessary.
- PROGNOSIS
  - associated mortality up to 23%
  - Usually due to associated injuries, or complications as a result of the diaphragmatic injury.

Trauma Reporting:

- Penetrating diaphragmatic injuries are often missed
- Small lacerations can be difficult to directly visualise on imaging, especially to the untrained eye.
- Studies have shown that up to 42% of all penetrating trauma with an entry site between the nipple line superiorly, the costal margin inferiorly, and the sternum and spine as media margins have diaphragmatic injuries.[7]
- The largely low sensitivity of imaging in diaphragmatic injury in penetrating trauma is due to the small size of laceration caused, in comparison to the large posterolateral defects in the diaphragm allowing for abdominal viscera herniation into the thoracic cavity. [8]

CT signs for diaphragmatic injury in penetrating trauma:

- Thickening of the diaphragm:
  - this could represent oedema or haematoma from the laceration of the diaphragm
  - Thickening may be localised to the site of the laceration, but can also involve the whole diaphragm to a larger extent if the laceration is significant
  - It is important to note that thickening can also be due to haematoma from injury to adjacent organs like liver or spleen, bowel, adrenal glands, or kidneys, tracking along the diaphragm à and thus rendering this sign not very specific.
• If diaphragmatic thickening is present, and there is strong clinical suspicion - close monitoring and a follow up CT is recommended.

• **The "collar" sign**
  - Band like constriction of a herniating viscous through the diaphragmatic laceration

• **The dependent viscera sign**
  - Right sided injury: Upper third of liver in direct contact with posterior lower ribs on right
  - Left sided injury: abdominal content (stomach/bowel) directly in contact with posterior lower ribs. [9]

• **Contiguous injury on either side of the diaphragm**
  - contiguous organ injury seen on either side of the diaphragm à which implies diaphragmatic injury on that side
  - e.g. injury to the left lower lobe of the lung and the spleen
  - The actual defect within the diaphragm may not be seen
  - This sign however can only be applied to those trauma cases where a single stab wound/gun shot wound was present
  - However the wound track should be looked for. It can be outlined by:
    - haematoma
    - soft tissue emphysema
    - Bullet / bone fragments

**Accuracy of signs:**

See table 1.

**MDCT diagnosis of penetrating diaphragm injury.**

Table 4: Sensitivity, specificity, and accuracy of individual MDCT signs in diagnosing diaphragmatic injury

<table>
<thead>
<tr>
<th>MDCT signs</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Accuracy</th>
<th>Pearson’s P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herniation of viscera</td>
<td>17% (8/47)</td>
<td>97% (96/98)</td>
<td>71%</td>
<td>0.0008</td>
</tr>
<tr>
<td>“Collar” sign</td>
<td>4% (2/47)</td>
<td>100% (98/98)</td>
<td>68%</td>
<td>0.03</td>
</tr>
<tr>
<td>Dependent viscera</td>
<td>0% (0/47)</td>
<td>100% (98/98)</td>
<td>66%</td>
<td>NaN</td>
</tr>
<tr>
<td>Contiguous injury</td>
<td>88% (24/27)</td>
<td>82% (41/50)</td>
<td>84%</td>
<td>0</td>
</tr>
<tr>
<td>Discontinuous diaphragm</td>
<td>40% (19/47)</td>
<td>90% (89/98)</td>
<td>74%</td>
<td>0</td>
</tr>
<tr>
<td>Thickening of diaphragm</td>
<td>48% (23/47)</td>
<td>70% (69/98)</td>
<td>63%</td>
<td>0.023</td>
</tr>
</tbody>
</table>

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Fig. 1: Table 1:

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Findings and procedure details

Methods:

- Level 1 UK Trauma centre
- Manual search through trauma database since April 2007 to Nov 2013
- All CT's were reported by a Senior Radiology registrar and approved by a Consultant.
- 66 patients admitted with penetrating abdominal injury and subsequently taken to theatre during this time
- Of the 65 patients, 20 patients did not have pre-operative CT, 4 died before they could have a CT, and 8 did not have surgery post injury (other form of treatment, conservative, endoscopy etc.),
- 33 patient had a pre-operative CT, 19 of which did not pick up a diaphragmatic injury. Of these 19 patients, 16 subsequently had surgery which confirmed diaphragmatic injury which was missed on CT.
- 14 patients of the 33 who had a pre-operative CT picked up a diaphragmatic injury, all of which were accurately confirmed in surgery.

Results:

<table>
<thead>
<tr>
<th>Surgical confirmation</th>
<th>CT did not report diaphragm injury</th>
<th>CT reported diaphragm injury</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diaphragmatic injury present</td>
<td>16</td>
<td>14</td>
<td>30</td>
</tr>
<tr>
<td>Diaphragmatic injury not present</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>14</td>
<td>33</td>
</tr>
</tbody>
</table>

- The results indicate that when there is a diaphragmatic injury seen by the radiologists, there is 100% correlation with the findings at post-CT surgery.
- However, if a post trauma CT reports no diaphragmatic injury, there is only 15.8% correlation with the findings at surgery, and thus nearly 85% of all diaphragmatic injuries are being missed on CT scans.

Imaging Examples:

Case 1:
• See figure 2
• 28 year old man stabbed left upper quadrant
• Defect seen in the left hemi diaphragm demonstrated by the discontinuation

Case 2:

• See figure 3
• 25 year old, stabbed on the left side
• Haemothorax
• Splenic laceration
• Injury on both sides of the diaphragm implies diaphragmatic injury

Case 3:

• See figure 4
• 18 year old with gunshot wound to the right side of the chest
• Shattered rib adjacent to liver
• Liver laceration
• Implied injury to diaphragm over the liver in the area of the entry wound

Case 4:

• See figure 5
• Trajectory of stabbing can be seen through subcutaneous fat, under posterior left rib and into spleen
• Splenic laceration with associated peri-splenic fluid
• Localised thickening of diaphragm with diaphragmatic defect

Case 5:

• See figure 6
• 31 year old, Stabbing
• Haematoma seen within the subcutaneous tissue within anterior abdominal wall
• Intraperitoneal haematoma with implied injury to the central diaphragm was surgically confirmed

Case 6:
• See figure 7
• Haemathorax with splenic laceration post stabbing
• Injury above and below the diaphragm knife implies the knife must have traversed the left hemi-diaphragm causing injury

Case 7:
• See figure 8
• Herniation of loop of large bowel and omental fat through diaphragmatic defect

Case 8:
• See figure 9
• Hour glass appearance of the stomach in keeping with traumatic diaphragmatic rupture and gastric herniation
Fig. 2: 28 year old man stabbed left upper quadrant Defect seen in the left hemi diaphragm demonstrated by the discontinuation

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**Fig. 3:** 25 year old, stabbed on the left side Haemothorax Splenic laceration Injury on both sides of the diaphragm implies diaphragmatic injury

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**Fig. 4:** 18 year old with gunshot wound to the right side of the chest. Shattered rib adjacent to liver. Liver laceration. Implied injury to diaphragm over the liver in the area of the entry wound.

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**Fig. 5:** Trajectory of stabbing can be seen through subcutaneous fat, under posterior left rib and into spleen splenic laceration with associated peri-splenic fluid. Localised thickening of diaphragm with diaphragmatic defect.

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Fig. 6: 31 year old, Stabbing Haematoma seen within the subcutaneous tissue within anterior abdominal wall Intraperitoneal haematoma with implied injury to the central diaphragm was surgically confirmed

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**Fig. 7:** Haemathorax with splenic laceration post stabbing Injury above and below the diaphragm knife implies the knife must have traversed the left hemi-diaphragm causing injury

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**Fig. 8:** Herniation of loop of large bowel and omental fat through diaphragmatic defect

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Fig. 9: Hour glass appearance of the stomach in keeping with traumatic diaphragmatic rupture and gastric herniation

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Conclusion

• Left sided penetrating diaphragmatic injury is a surgical emergency and requires prompt diagnosis. • With multidetector CT, the Radiologist plays a key role in diagnosing this, often subtle, injury. • By keeping diaphragmatic injury in mind particularly when reporting trauma involving penetrating injury - the radiologist is likely to improve their pick up of this difficult pathology. • Appropriate educations, investigations, and awareness will lead to more accurate diagnosis, and make reports more useful to the clinicians. • Being aware of the CT signs will aid in the diagnosis.
Personal information

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References


