

Research Article

Traumatic diaphragmatic ruptures: A 10-year retrospective study

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Introduction

Traumatic rupture of the diaphragm is a relatively uncommon but potentially serious condition present in patients suffering both blunt and penetrating trauma. In the absence of intra-abdominal organs herniating into the affected hemi-thorax through the diaphragmatic rupture, or a similar unequivocal sign, a definite diagnosis is hard to make based on a chest x-ray (CXR) [1].

Despite the wide adoption of computer tomography (CT) in trauma care as the primary imaging method in recent years reliably diagnosing diaphragmatic ruptures radiologically remains challenging and a large percentage of diaphragmatic ruptures are still discovered during operations performed based on other indications [2].

Traumatic diaphragm injuries (TDI) are typically categorised based on the mechanism of injury (MOI) and divided into blunt (BTDI) and penetrating TDIs (PTDI). PTDI will typically be caused by firearms or edged weapons, blunt trauma by motor vehicle accidents (MVA), falls, crush injuries etc. Blunt trauma in most studies causes BTDI in the left hemi-diaphragm in between 75% and 80% of patients [3,4].

There are several reasons for this. The liver and its ligaments are believed to provide some degree of protection for the right hemi-diaphragm that is absent on the left. It has been postulated that the left hemi-diaphragm is also physically weaker as a result of the embryogenesis of the diaphragm, making it further more susceptible to injury when there is a drastic rise in intra-abdominal pressure [5].

Blunt trauma causing BTDI to the left hemi-diaphragm also frequently causes injury to the spleen and occasionally herniation of ventricle, spleen or gut into the left pleural space [4]. The ruptured spleen may cause life threatening intra-abdominal bleeding and the herniated organs risk strangulation. If the herniation affects the mediastinum it can also affect circulation by inhibiting ventricular filling and lowering cardiac output.

TDI do not seem to be able to heal if left untreated and an undiagnosed TDI can therefore also cause a variety of late complications, sometimes many years later, with herniation, persistent pain from the diaphragm, respiratory distress or strangulation of intra-abdominal organs [6]. The intra-abdominal pressure will be higher than the thoracic pressure which during expiration will be negative, making organ herniation highly probable over time. Untreated TDIs also cause atrophy in the surrounding tissue in the diaphragm making a late repair significantly more complex than early repair.

Method

We reviewed the patient notes, operative notes and radiologic findings of every patient diagnosed with a TDI at Sahlgrenska University Hospital in Gothenburg Sweden, a regional trauma centre serving a population of approximately 1400 000 people, from 2005 to 2015. We reviewed patient charts for age, gender, mechanism of action, operating notes etc.

To study the ability of radiologic imaging to diagnose TDI in the trauma patient we first established if the patient had CT/CXR before or after their initial operation. We defined a late diagnosis as a diagnosis during a second operation or during a second CT/CXR. We separated TDIs diagnosed during initial imaging into definite, where a clear diagnosis was made, and suspected where the radiologist suggested TDI either based on findings or MOI *i.e.*, penetrating trauma with injuries below and above the diaphragm where the bullet/blade etc. would have to have penetrated the diaphragm even if the diaphragm itself appears intact when visualized. We also reviewed the surgeons notes from the operations to establish localisation of injury, if any abdominal organs adjacent to the diaphragm where injured in conjunction with the TDI.

We also noted what type of operation was performed, what type of suture was used and if a mesh was required to close the rupture. To compare means between groups we used an independent t-test. To compare percentages Pearson chi-square was used. Statistics were performed in SPSS.

Results

A total of 53 patients were identified, 64% suffered blunt trauma while 36% suffered some form of penetrating trauma. Of the total number of patients 83% were male and the average age was 47,8 years. Patients suffering TDI from penetrating trauma were younger with an average age of 41,4 while those suffering TDI from blunt trauma had an average age of 50,7 years. All patients presented with some form of associated injury with the most common being injury to the lung or thoracic cage (94%) followed by injury to the spleen (42%) and liver (38%).

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CT was the imaging modality used in all but one case where CXR was utilised, 38 patients had CT/CXR performed before surgery, 11 patients were taken directly to the operating theatre and in 4 cases we were unable to obtain radiologic findings where patients were transferred to us from another hospital. A definitive diagnosis of TDI based on initial CT was made in 31% of cases, all of these patients either had abdominal viscera herniating through diaphragmatic rupture, very large ruptures or damage in both thorax and abdomen in patients suffering penetrating trauma. All patients were diagnosed either within 24 hours or in the case of a late diagnosis within a week of injury.

The majority of patients (53%) were diagnosed during the initial operation but 23% of patients were diagnosed first during the second operation or in a few cases when patients had a second CT after the first operation.

All patients presented with some form of associated injury with the most common being injury to the lung or thoracic cage (94%) followed

by injury to the spleen (42%) and liver (38%). Mortality was 6% with 3 patients dead. One patient died in the ER, one during operation due to massive injuries and haemorrhage and one several weeks after discharge in cardiac arrest. The diaphragm was repaired with a laparoscopy in one case, otherwise repair was performed during either laparotomy or thoracotomy.

The vast majority of ruptures were repaired using non-absorbable sutures, with some penetrating ruptures being repaired using absorbable sutures. Two patients needed the application of a mesh to enable the suturing of the rupture. Statistically significant differences between groups are displayed in table 1.

Discussion

Patient characteristics

As in previous studies our patients were predominantly male with penetrating trauma patients being younger than blunt trauma patients.

Table 1. Overview

Patients	All Patients	Blunt Trauma TDI	With simultaneous rib fracture	Penetrating Trauma
Number of patients	53	34	18	19
Male gender	83%	76%	83%	95%
Female gender	17%	24%	17%	5%
Mean Age \pm SD	48 \pm 17.3 years	51 \pm 16.7 years	57 \pm 14.2**	41 \pm 17.6*
Mean ISS score \pm SD	23.7 \pm 13.4	25.9 \pm 14.8	17.9 \pm 10*	21.7 \pm 10
Mean ISS score right side TDI \pm SD	-	24.4 \pm 16.5	-	-
Mean ISS score left side \pm SD	-	26.9 \pm 15.3	-	-
Injury localisation				
- Right	43%	47%	61%	37%
- Left	57%	53%	39%	63%
Blunt trauma MOI				
MVA	-	53%	44%	-
Fall	-	35%	39%	-
Other	-	12%	17%	-
- Penetrating trauma	-	-	-	21%
- Firearm	-	-	-	79%
Edged weapon	-	-	-	-
Diagnosis				
TDI diagnosed on initial CXR/CT	34%	48%	22%	13%*
TDI suspected on initial CT	28%	17%	11%	40%
Operation before CT/CXR	53%	35%	67%*	79%*
TDI diagnosed during initial operation	53%	35%	67%	79%
TDI diagnosed during second operation/CT	23%	32%	0%	10%
CT-results unavailable	7%	9%	0%	5%
Mortality	6%	3%	0%	10%
Associated injuries				
Liver	38%	29%	16%	47%
Spleen	38%	34%	11%	42%
Spleen injury in left side TDI only	-	78%*	-	-
Pelvic fracture	-	8%	0%	0%
Management				
Thoracotomy	38%	53%	94%	10%
Laparotomy	60%	47%	6%*	90%*
Laparoscopy	2%	3%	0%	0%
Absorbable sutures	9%	0%	6%	26%
Unknown suture material	19%	15%	11%	26%
Gore-tex mesh	4%	6%	0%	0%

**p* value \leq 0.05 compared to blunt TDI

***p* value \leq 0.05 compared to all TDI

Blunt trauma

As previously noted in most studies blunt trauma mainly affects the left hemi-diaphragm. The generally accepted mechanism in these patients is that blunt trauma to the thoraco-abdominal area increases intra-abdominal pressure causing a rupture in the weaker and unprotected left hemi-diaphragm [7].

But this is only one of three possible mechanisms by which blunt trauma can cause TDI. Blunt trauma to the area of the lower ribs that results in a deformation of the thoracic wall has been hypothesised cause TDI in the affected hemi-thorax irrespective of intra-abdominal pressure [8].

The third mechanism is also caused by trauma to the lower rib area where a dislocated rib following a rib fracture punctures the diaphragm these TDIs will be smaller and located close to the rib fractures. In our material this was MOI for one patient.

Of the patients having a CT scan prior to operation 50% were diagnosed and in a further 18% TDI was suspected. During the initial operation a further 35% were diagnosed but 32% were missed and found first during a second CT scan or a second-look.

The reasons that even an experienced surgeon sometimes may miss a TDI are manifold. As TDI is hard to diagnose based on radiological findings the indication for performing an operation on a patient with TDI frequently the surgeon will be unaware of the TDI and perform the operation based on other indications. These "other indications" will often be ruptured spleens, injured lungs, bleeding livers etc. that can distract the surgeon. The injury load may also force the surgeon to close the wound after performing "damage control" before performing a thorough examination of the diaphragm to lessen the surgical burden in an already critical patient.

In patients suffering trauma that is primarily abdominal the spleen, ventricle or intestine will often be pushed through the rupture into the most, commonly the left, pleural space. The close association of the spleen to the left hemi-diaphragm results in the spleen often being injured at the same time. In our material 78% of blunt left side TDI also suffered some form of splenic injury, the splenic injury often being the indication for laparotomy in these patients.

Patients were almost evenly divided between thoracotomy and laparotomy. Although both approaches to the TDI have their proponents generally the associated injuries will dictate if the repair is performed via thorax or abdomen.

All blunt TDIs repaired by thoracotomy were patients with simultaneous multiple rib fractures where a thoracoplasty was also needed. In our left side blunt TDI patients due to the frequency of simultaneous injury to spleen, liver and ventricle there was often a need to control haemorrhage, repair or remove an intra-abdominal organ making a laparotomy the obvious choice. One patient with a blunt rupture visible on CT and no associated injuries was repaired using laparoscopy.

In 85% of cases a non absorbable suture was used, in the remaining cases we were unable to ascertain suture material. In two cases the ruptures were large enough to demand the application of Gore-Tex mesh to the injury to repair it.

Thoracic vs. abdominal blunt trauma

As previously noted one area where our findings differ from previously published studies is the high percentage of blunt TDI

compared to others. One possible reason for this is that thoracoplasty is performed at a greater rate in patients with multiple rib fractures and an unstable rib cages following trauma in recent years. During this operation the diaphragm is examined and as is the case in other forms of TDI a significant number of ruptures not visible on radiologic examination are found.

As previously mentioned Kim *et al.* [8] have postulated that trauma to the thorax resulting in a low rib fracture can either cause a diaphragmatic rupture due to temporary deformation of the chest wall or a fractured rib might penetrate the diaphragm. We believe that in patients with lower rib fractures with a simultaneous TDI the former mechanism is often to blame. Compared to all patients suffering blunt trauma TDI they are older, have a lower ISS score, the spleen or liver is damaged in only a minority of cases and in our material most TDIs affect the right diaphragm in this group.

The conclusion we draw from this is that the surgeon treating a flail chest, multiple lower rib fracture or similar condition where the MOI has produced significant deformation of the lower chest wall should have a low threshold for suspecting TDI in patients even when radiology is unable to confirm TDI. This also goes for patients with a history of lower rib fracture who present late with abdominal pain, respiratory distress or persistent pain from the diaphragm.

Penetrating trauma

In our material the majority of penetrating patients (79%) were victims of edged weapons attacks and minority (21%) suffered gunshot wounds (GSW). The ratio between penetrating and blunt trauma TDIs and the ratio among edged weapons vs GSW as MOI among penetrating trauma patients will both depend on local factors such as levels of violent crime, access to firearms and a variety of other factors.

CT was able to diagnose (13%) or give strong indications (40%) of a TDI in 53% of patients having a CT before an operation was performed. The reason for the better ability of CT to find suspected TDIs caused by penetrating trauma when compared to blunt trauma (18%) is mainly due to the linear nature of injury in penetrating trauma where a bullet or stabbing implement will create injuries in a linear wound canal where injuries on both sides of the diaphragm on CT strongly suggests TDI where the TDI itself is not visible. The majority (79%) of patients were still diagnosed during operation itself. 2 TDIs were diagnosed late, one during a second CT after the initial operation and the second during a second-look laparotomy.

All patients suffered some degree of damage to the lung in addition to the TDI. Many patients also suffered simultaneous damage to either the spleen (42%) or liver (47%). Most injuries were to the left hemi-diaphragm (63%) presumably because most assailants are right handed and therefore tend to stab to the left side of the victim. The majority of reparations were performed during laparotomy (90%) and of the TDIs where we were able to ascertain suture material 26% were repaired using absorbable sutures. Absorbable sutures can be used in penetrating TDI due to the frequently very small ruptures when compared to blunt TDIs.

Diagnosing TDI

As many others have previously noted one of the primary challenges TDI presents to the surgeon is the difficulty in diagnosing TDI radiologically and sometimes even during operation. Before the

advent of CT-scans the radiological findings of a TDI on a CXR where often either nonspecific like pneumothorax, hemothorax or abnormal differences in the level between the diaphragms unless the nasogastric tube or herniating abdominal organs could be visualized in the affected hemi-thorax [1].

With the wide adoption of CT in trauma care the quality of imaging has increased but as we show in this study a CT-scan is still lacks the sensitivity to be reliably used to exclude TDI in the trauma patient. MR has been suggested for diagnosing TDI, but the longer time required for and examination and the usually limited access to MR in most hospitals makes is less than optimal for diagnosing TDI in the acute phase.

Diagnostic peritoneal lavage (DPL) has been suggested but its low specificity and low sensitivity for TDI in the absence of major blood loss has made it controversial [9].

Given that FAST ultrasound is gradually replacing DPL in ATLS for diagnosing intraperitoneal haemorrhage it is unlikely that DPL will be used for diagnosis in the future. Ultrasound examinations such as FAST have the advantage of being able to visualize TDI but like DPL they cannot be relied upon to exclude TDI.

The modality with the best sensitivity and the least invasiveness is at present laparoscopy as shown in several studies [10]. Even during laparotomy there where some ruptures that where missed in our material.

This underscores the importance of the surgeon properly mobilising intra-abdominal organs so that a thorough examination of the diaphragm can be performed.

Management

Repair was performed either during laparotomy, thoracotomy or in one case laparoscopy. Which approach was used depended on other injuries and in the majority of cases the surgeon was unaware of the TDI before the operation. Two patients needed the applications of Gore-Tex mesh to the diaphragm in order to repair it, both suffered major blunt trauma in MVA with large herniations of viscera into the pleural space.

Weaknesses and limitations

Weaknesses in this study where that is, was a retrospective study and only has 53 patients.

Conclusions

TDI is frequently occult and hard to diagnose. The high risk of herniation or other complications over time taken with the increasing complexity of a late repair compared to an early repair underscore the need for better diagnostic tools enabling the clinician to diagnose and repair TDI in a timely fashion.

Patients suffering blunt thoracic trauma and low rib fractures may have TDI despite lacking the indications for laparotomy or thoracotomy and not having any radiologic findings.

Disclosure

The authors declare no conflicts of interest.

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