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Descriptive Analysis of Right and Left-sided Traumatic Diaphragmatic Injuries; Case Series from a Single Institution

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ABSTRACT

Objective: To investigate the presentation, management and outcomes of left and right-sided traumatic diaphragmatic injury (TDI) in a single level I trauma center.
Methods: This cross-sectional study was conducted during a 7-year period from 2008 to 2015 in a level I trauma center in Qatar. We included all the patients who presented with TDIs during the study period. Data included demographics, mechanism of injury, associated injuries, initial vitals, emergency department disposition, length of ICU and hospital stay, ventilator days, management, and outcomes. The variables were analyzed and compared for patients with left (LTDI) and right (RTDI).
Results: A total of 52 TDI cases (79% LTDI and 21% RTDI) were identified with a mean age of 31±11. LTDI patients were more likely to have higher Injury severity scores (p=0.50) and greater AAST organ injury scoring (p=0.661 for all) than RTDI patients. Surgical repair was performed for 85% LTDI vs. 73% RTDI (p=0.342). Recurrent DIs was reported only in LTDI (5.1% vs. 0.0%; p=0.911). Twelve patients died (9 LTDI and 3 RTDI), of them 5 had associated head injury.
Conclusion: This single-institution study confirms that LTDI are more commonly diagnosed than RTDI. Exploratory laparotomy is the most frequent procedure considered for the management of diaphragmatic injuries in the emergency settings. To improve outcomes in patients presenting with TDI, large prospective multicenter studies are needed to standardize the TDI management protocols including the diagnostic workup, timing of surgical intervention, and the most appropriate approach of treatment.

Keywords: Diaphragmatic; Injury; Rupture; Herniation; Blunt trauma; Penetrating injury.

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Introduction

Traumatic diaphragmatic injury (TDI) is an infrequent but important thoracoabdominal injury that is potentially life-threatening condition. The proportion of blunt to penetrating trauma differs based on the regional characteristics and sociodemographic factors [1-3]. Penetrating injuries (10-15%) are more common cause of TDI than blunt trauma (1-7%) [1-3]. Motor vehicle crash (MVC) is the most frequent blunt injury mechanism involved in ~ 90% of the cases [4]. The possible cause of TDI in such cases may be lateral impacts which shear the stretched diaphragm as well as the frontal impacts and crushing which increase the intra-abdominal pressure resulted in avulsion and extensive rupture [5]. Penetrating injuries such as gunshot or stab wounds resulted in direct diaphragmatic rupture with small holes (<1 cm), which are often missed or difficult to diagnose [6]. Notably, bilateral diaphragmatic tear and extension into the central tendon are rare and are often identified in patient with severe thoracoabdominal injuries [7].

Anatomically, most ruptures occur postero-laterally which is the weakest point of the diaphragm whereas; the peripheral detachment is the least frequent type [6]. The appropriate diagnosis of TDI depends on a high index of suspicion, careful physical examination and looking for TDI during explorative surgery for other injuries. Clinically, there are no specific signs or symptoms enough to diagnose TDI and the routine imaging which depends on associated organ herniation plays a limited role due to lower sensitivity and specificity [6]. Therefore, the initial radiological assessment might overlook TDI, and there may be a missed diagnosis, which leads to increased morbidity and mortality [8]. The recent adoption of non-operative management approach for blunt abdominal trauma also attributed to the increased underlying missed TDI injuries ranging from12%-66% [5]. This wide variation could be explained in part by the widespread adoption of non-operative management strategy in hemodynamically stable patients. These missed injuries may present later with severe complications of diaphragmatic herniation such as strangulation of visceral organs and pressure compression-like symptoms [1]. TDIs are usually associated with other injuries, and can be left-sided (LTDI), right-sided (RTDI), or bilateral. Based on clinical observations, injuries to the left hemi-diaphragm are more frequent than the RTDI but there is equal consideration of TDI on either side as suggested by autopsy findings [3]. The predominance of LTDI could be attributed to congenital weakness and the shielding effect of the liver to the right hemi diaphragm which could possible results in different clinical presentation and outcome [1]. The aim of this study is to analyze the frequency, presentation, management and outcomes of left and right-sided TDI in a single level I trauma center.

Materials and Methods

Study Population

A descriptive observational cases series was conducted based on the prospectively maintained databases of trauma patients at a single level I Hamad trauma center, in Qatar. The study was registered at http://www.researchregistry.com (researchregistry2434). We retrospectively reviewed all thoracoabdominal trauma patients sustaining TDI who were admitted during the period from January 2008 to June 2015. The trauma registry database was queried to retrieve information for the demographic characteristics (age and gender), type of injury, mechanism of injury (MOI), associated injuries, emergency department (ED) initial vitals (systolic blood pressure and diastolic blood pressure), Glasgow Coma Score,

Abbreviated Injury Score for head, chest and abdomen, Injury Severity Score (ISS), rib fracture, pneumothorax, hemothorax, lung contusion, length of ICU stay, ventilator days, and outcomes which were primarily analyzed for patients grouped according to LTDI and RTDI. ED records and operative notes were reviewed to obtain data on TDI characteristics, presentation (acute or delayed), organ injury score based on the American Association of Surgery of trauma (AAST) Organ Injury Scale (OIS) criteria, (classification of traumatic herniation), specific methods and approach to repair, need for damage control surgery, post-operative complications, mortality and recurrence on follow-up.

Definitions [9-13]

Acute TDI is diagnosed when the diaphragmatic injury made on the immediate post traumatic period with aid of clinical assessment, imaging studies (including chest radiographs and Computed Tomographic scan findings) and intra-operative findings on initial presentation.

Delayed TDI refers to the injury of diaphragm that is not recognized during the immediate post-traumatic period, the patient may remain asymptomatic or present with symptoms after discharge due to complications from herniation of abdominal content.

Recurrent traumatic diaphragmatic herniation: It usually recurred after surgical repair and is diagnosed by imaging either due to development of symptomatic or for asymptomatic patients that needs imaging, gastroscopy or surgery for other reasons.

Missed traumatic diaphragmatic herniation: injury is not recognized during the immediate posttraumatic period, despite the CT imaging and found later during exploratory laparotomy or thoracotomy for other indications in the same admission for the index trauma [10].

All patients with TDI were graded according to the American Association of Surgery of trauma (AAST) Organ Injury Scale (OIS) criteria into 5 different grades [11]. This study was reviewed and approved

with waiver of informed consent by the institutional IRB at the Medical Research Center, Hamad Medical Corporation (IRB# 15423/15), Qatar.

Statistical Analysis

Data were presented as proportions, medians (range), or mean (±standard deviation; SD), as appropriate. Baseline demographic characteristics, presentation, management, and outcomes were compared between patients with LDI and RDI using the Student's t test for continuous variables and Pearson χ^2 test for categorical variables. Furthermore, clinical findings, management, and outcomes of patients with TDI were also analyzed according to the outcome (survivors vs. non-survivors). The Yates corrected chi square test was used, if the expected cell frequencies were below 5. Data were analyzed using the Statistical Package for the Social Sciences version 18 (SPSS Inc., Chicago, IL, USA).

Results

During the study period, a total of 8000 trauma patients were admitted (blunt injury: 7600 & penetrating injury: 400); of which 52 (0.7%) were identified to have TDI. The mean age of patients was 30.7±11 years and the majority (92.3%) was males. The TDI was left-sided in 41 (79%), and right-sided in 11 (21%) cases (4:1 ratio). Patients with LTDI were 5 years older than those with RTDI. The type of injury was blunt in 36 (69%) whereas, 16 (31%) cases sustained penetrating injuries. The leading cause of injury was motor vehicle crashes (56%), followed by stabbing (23.1%) and fall from height (9.6%). Thirty-seven patients (72.5%) were directly taken for emergency surgery, and seven (13.7%) were shifted to trauma intensive care unit (ICU). Patients with RDI were more likely to be hypotensive and had low mean GCS at ED (Table 1). Figure 1 shows the distribution of coexisting injuries in patients with TDI. Chest (100%), abdomen (77%), head (23%), and pelvis (19%) were the frequently associated injuries. Fifty (96%) patients were diagnosed with acute presentation (Figure 2A).

The organ injury scaling grade 3 (63.3%) was the most common followed by grade 4 (14.3%) and grade 1 (12.2%). Patients with LTDI were more likely to have high organ injury score (grade-4 and 5), whereas low injury scores (grade-1 and 2) were more evident in RTDI. The mean injury severity score (ISS) was higher in LTDI (24±14 vs. 21±9; p=0.50).

The most common organ to herniate was the

Table 1. Demographics, clinical presentation and severity of injury in patients with traumatic diaphragmatic injury (TDI).

Variable	All TDI n=52	RDI [a] n=11 (21%)	LDI [b] n=41 (79%)	*p* value
Age (mean±SD)	31±11	27±4	32±12	0.04
Males	48 (92.3%)	11 (100.0%)	37 (90.2%)	0.28
Blunt injury	36 (69.2%)	7 (63.6%)	29 (70.7%)	0.65
Mechanism of injury				
Motor Vehicle Crash	29 (55.8%)	6 (54.5%)	23 (56.1%)	0.95
Stab	12 (23.1%)	3 (27.3%)	9 (22.0%)	
Fall from height	5 (9.6%)	1 (9.1%)	4 (9.8%)	
Fall of heavy object	2 (3.8%)	0 (0.0%)	2 (4.9%)	
Gunshot wound	4 (7.7%)	1 (9.1%)	3 (7.3%)	
Systolic blood pressure ED	115±33	99±29	120±33	0.06
Diastolic blood pressure ED	71±24	59±17	74±24	0.07
Glasgow Coma Score ED	11±5	9±6	12±5	0.18
Head AIS	3.4±1.1	4±1	3.4±1.1	0.47
Chest AIS	3.2±0.8	3±0.8	3.3± 0.7	0.29
Abdomen AIS	2.8±0.9	2.5± 0.7	3.9± 1.0	0.22
Injury severity score	24±12	21±9	24±13	0.50
Organ injury score (AAST) (n=49)				0.66
Grade 1: Contusion	6 (12.2%)	2 (18.2%)	4 (10.5%)	
Grade II: Laceration <2cm	2 (4.1%)	1 (9.1%)	1 (2.6%)	
Grade III: Laceration 2-10cm	31 (63.3%)	7 (63.6%)	24 (63.2%)	
Grade IV: Laceration >10 cm with tissue loss < 25 cm	7 (14.3%)	1 (9.1%)	6 (15.8%)	
Grade V: laceration with tissue loss >25cm	3 (6.1%)	0 (0.05)	3 (7.9%)	
Acute presentation (%)	50 (96.2%)	11 (100%)	39 (95.1%)	0.45
Delayed presentation (%)	2 (3.8%)	0 (0.0%)	2 (4.9%)	
Herniation				
Stomach	13 (26.0%)	0 (0.0%)	13 (33.3%)	0.08
Omentum	1 (2.0%)	0 (0.0%)	1 (2.6%)	
Multiple visceral organs	6 (12.0%)	0 (0.0%)	6 (15.4%)	

[a]RDI: right-sided diaphragmatic injury; [b]LDI: left-sided diaphragmatic injury

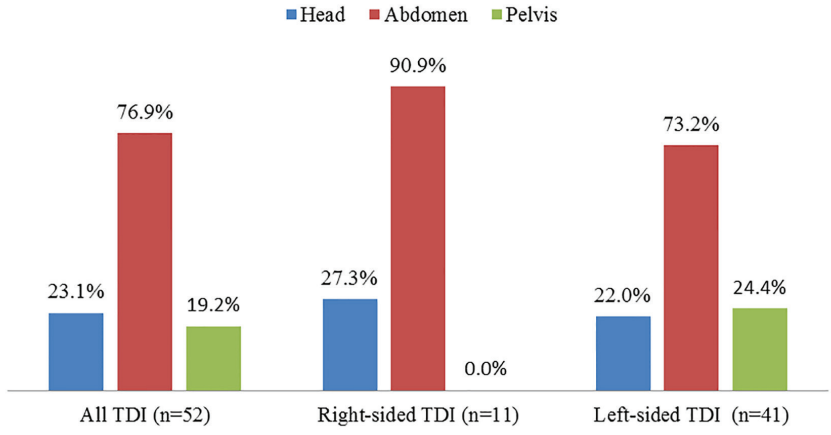

Fig. 1. Distribution of concomitant injuries in patients with traumatic diaphragmatic injury (TDI).

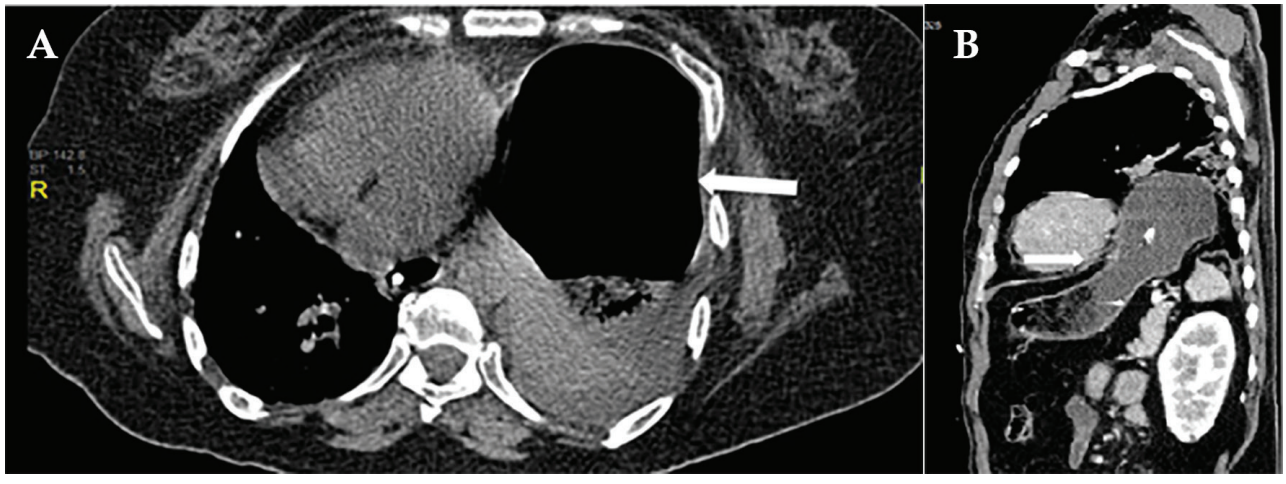

Fig. 2. An example of the delayed presentation: axial chest CT scan showing stomach herniated into the left chest with distention and total collapse of the left lung. The mediastinum displaced to the right and failure of the nasogastric tube to pass into the stomach (white arrow showing the distended stomach) (A); An example of an acute injury: A sagittal CT scan of the left chest showing a tear in the left dome of the diaphragm and a defect of 3.5×7.5 cm with herniated gastric lumen (white arrow) (B).

stomach (26%) followed by involvement of multiple visceral organs (12%). Left-sided herniation was observed in 34 cases; whereas right-sided hernia was identified in nine cases.

Table 2 shows types of associated chest injuries, management, complications and outcomes of patients with TDI. Seventeen patients sustained rib fractures of which more patients with unilateral rib fractures had RTDI, whereas, patients with LTDI were more likely to have bilateral rib fractures. The frequency of hemothorax, lung contusion, and pneumothorax were 80%, 65% and 50%, respectively. Most of TDI cases were primarily managed by surgical approach (82.4%) including exploratory laparotomy (78.6%), laparoscopy (9.5%), whereas 12% required an extended thoraco-abdominal approach often for associated multiple injuries.

The rate of exploratory laparotomy was more in LTDIs (85.3% vs 50.0%; p=0.14) than RTDIs. In comparison with patients who underwent emergency surgery, 10 patients were not operated (hemodynamically stable initially). The frequency of surgical repair was comparable for the LTDIs (85%) vs. RTDIs (73%) cases.

Twenty-five percent of the cases were managed as part of damage control surgery; which reflects the severity of the associated injuries and hemodynamic instability. The two groups were comparable for the surgical approach of diaphragmatic repair and need for damage control surgery. Recurrent diaphragmatic defect was reported only in 2 cases (5.1%) with LTDIs. There was no reported abdominal herniation at the right side, whereas less than half of the LTDI had abdominal herniation. Patients with RTDI required more mechanical ventilation than LTDI. The mean ISS was higher in LTDI (24±14 vs 21±9; p=0.50). There were 12 deaths (9 LTDIs and 3 RTDIs), of them 5 had associated head injury (2 in RTDIs and 3 in LTDIs) and those who died had significantly higher mean ISS (Table 3). In comparison to those who survived, advanced age, blunt trauma, high organ injury scores (IV & V), site of diaphragm, presence of associated injuries and need for damage control surgery showed a higher trend of mortality, but it did not reach statistical significance.

Delayed, Recurrent and Missed Diagnosis

Two patients showed the criteria of delayed TDI,

Table 2. Types of chest injuries, management, complications and outcomes of traumatic diaphragmatic injury (TDI).

	All TDI n=52	RDI[a] n=11 (21%)	LDI[b] n=41 (79%)	*p* value
Rib fracture	17 (32.7%)	6 (54.5%)	11 (26.8%)	0.08
Right	4 (23.5%)	3 (50.0%)	1 (9.1%)	0.16
Left	9 (52.9%)	2 (33.3%)	7 (63.6%)	
Bilateral	4 (23.5%)	1 (16.7%)	3 (27.3%)	
Pneumothorax	25 (50.0%)	6 (54.5%)	19 (48.7%)	0.73
Hemothorax	40 (80.0%)	8 (72.7%)	32 (82.1%)	0.49
Lung contusion	33 (64.7%)	7 (63.6%)	26 (65.0%)	0.93
Diaphragmatic repair	42 (82.4%)	8 (72.7%)	34 (85.0%)	0.34
Type of repair				0.14
Laparotomy	33 (78.6%)	4 (50.0%)	29 (85.3%)	
Laparoscopy	4 (9.5%)	1 (12.5%)	3 (8.8%)	
Thoraco-abdominal	5 (11.9%)	3 (37.5%)	2 (5.9%)	
Damage control surgery	12 (25.5%)	1 (10.0%)	11 (29.7%)	0.39
Post-operative Complications	23 (47.9%)	4 (40.0%)	19 (50.0%)	0.83
Recurrence on follow-up	2 (4.0%)	0 (0.0%)	2 (5.1%)	0.91
Intensive care unit stay(days)	7.5 (2-161)	21 (2-161)	5 (2-46)	0.22
Ventilatory days	4 (1-25)	10 (1-23)	3 (1-25)	0.15
Mortality	12 (23.1%)	3 (27.3%)	9 (22.0%)	0.97

[a]RDI: right-sided diaphragmatic injury; [b]LDI: left-sided diaphragmatic injury

Table 3. Characteristics of patients with traumatic diaphragmatic injury (TDI) based on outcome.

	Survivors (n = 40)	Non-survivors (n=12)	*p* value
Age (mean±SD)	30±11	33±12	0.52
Males	37 (92.5%)	11 (91.7%)	0.92
Diaphragmatic injury			0.97
Left	32 (80.0%)	9 (75.0%)	
Right	8 (20.0%)	3 (25.0%)	
Type of injury			0.11
Blunt	25 (62.5%)	11 (91.7%)	
Penetrating	15 (37.5%)	1 (8.3%)	
Associated injury			
Head	7 (17.5%)	5 (41.7%)	0.08
Abdomen	29 (72.5%)	11 (91.7%)	0.16
Pelvis	7 (17.5%)	3 (25.0%)	0.56
Lung contusion	24 (61.5%)	9 (75.0%)	0.39
Pneumothorax	21 (55.3%)	4 (33.3%)	0.32
Hemothorax	30 (78.9%)	10 (83.3%)	0.74
Rib fracture	12 (30.0%)	5 (41.7%)	0.45
Injury severity score	20±11	36±10	0.001
Organ injury score (AAST) (n=49)			0.85
Grade 1: Contusion	4 (10.8%)	2 (16.7%)	
Grade II: Laceration <2cm	1 (2.7%)	1 (8.3%)	
Grade III: Laceration 2-10cm	26 (70.3%)	5 (41.7%)	
Grade IV: Laceration >10 cm with tissue loss < 25 cm	4 (10.8%)	3 (25.0%)	
Grade V: laceration with tissue loss >25cm	2 (5.4%)	1 (8.3%)	
Acute presentation	38 (95.0%)	12 (100%)	0.94
Delayed presentation	2 (5.0%)	0 (0.0%)	
Diaphragmatic repair	34 (87.2%)	8 (66.7%)	0.10
Type of repair			0.59
Laparotomy	26 (76.5%)	7 (87.5%)	
Laparoscopy	4 (11.8%)	0 (0.0%)	
Thoraco-abdominal	4 (11.8%)	1 (12.5%)	

both occurred following blunt abdominal trauma. One patient presented with large bowel obstruction 2 years later and CT scanning confirmed the herniation of the transverse colon into the left pleural cavity through the diaphragm and underwent laparoscopic hernia repair of the left diaphragm. The second patient presented a year later with nonspecific abdominal pain and CT scan showed a small hernia measuring 2 cm with some fat inside it and he was treated conservatively.

One female patient had a history of trauma 3 years prior to the index presentation, presented with respiratory distress and severe abdominal pain. She was intubated and CT scan revealed herniation of the stomach into the left chest (Figure 2B). This patient underwent laparotomy and then converted to left thoracotomy i.e. thoracoabdominal approach because the stomach was difficult to bring down in the peritoneal cavity using laparotomy due to significant intra-thoracic adhesion and the left thoracotomy showed necrosis of the fundus of the stomach that requires resection and repair of the stomach. This patient stayed in the hospital for longer period necessitates prolonged ventilatory support, as well as jejunostomy tube for enteral feeding.

One patient had missed traumatic diaphragmatic herniation, and was investigated on the same admission post trauma with a CT scan and 2 days later he required laparotomy for peritonitis due to large bowel injury, on the same exploration he was found to have RTDI that was missed on the initial CT scan.

Non-Operative Management

Twelve patients with no surgical intervention: 6 patients had a grade 1 injury treated conservatively, 5 patients were managed as a damage control surgery although the diaphragmatic injury was recognized but these patients died from severe head injury prior to the definite surgery. The last patient was not operated because he had recurrent diaphragmatic hernia which was small asymptomatic and treated conservatively.

Discussion

This is a single-institution report to present the characteristics, injury profile, management, and outcome of TDI patients from a national representative level I trauma center over 8 years. Table 4 summarizes the most recent TDI studies from different countries [1,3,14-27]. However, we may underestimate the incidence of TDI as the majority of mild (missed) or severe (died before diagnosis) lesions can be difficult to diagnose or because of the unavailability of routine postmortem examination in the state of Qatar. In our series, around two-third of TDIs were related to blunt trauma as penetrating injuries are relatively uncommon in country due to smaller landscape with stringent legislations to resolve conflict similar to a previous study from Canada [28]. In the present study, the primary cause of blunt TDIs is high-impact MVC which corroborates with other reports [29,30].

The current literature suggests that the proportion of blunt to penetrating trauma varies according to the regional characteristics and sociodemographic factors [3,18]. Ties *et al*., [14] showed that blunt trauma accounted for only 10-30% of TDI in North America, and for 80-100% of cases in a cohort study from Western Europe. Another study demonstrated that 75% of TDI were accounted for blunt trauma [29]. In contrast, a retrospective review of 15 years data reported penetrating trauma to be the leading cause of TDI (61%) in the USA [1].

The reported incidence of TDI ranges from 0.8-7% in patients presented with blunt trauma [25] and 10-15% for penetrating injuries [19]; in our study it was 0.5% and 4%, respectively. The contemporary literature suggests that the left hemi-diaphragm is the most frequent site of diaphragmatic rupture followed by right and bilateral TDIs [1,3,21,27]. The ratio of RTDI-to-LTDI grossly varies in the literature. Most of the blunt injuries occur on the left postero-lateral aspect (68.5%-87%) of the diaphragm which is the weakest point that originates from pleuroperitoneal membrane [31]. Therefore, LTDI are more clinically apparent and symptomatic. On the other hand, the right hemi-diaphragm is protected by the buffering effect of the liver [6]. Our findings are in accordance with these reports with predominance of LTDI (79%) followed by RTDI (21%).

TDI is considered as a marker of severe trauma with high injury severity [23], which is evident from the overall mean ISS of 23 in our cohort. Furthermore, patients with LTDI had higher mean ISS than RTDI. TDI represents only 5% of all diaphragmatic hernias, and it is responsible for 90% of hernias that eventually become incarcerated, and mostly manifested within few years post injury [32]. Delayed presentation of TDI can occur years after trauma with a high rate of mortality (30-60%) [33]. In some cases, herniation of abdominal contents into the thoracic cavity might occur after trauma. For intubated patients, the positive pressure ventilation impedes organ herniation, and the diagnosis becomes evident only after extubation. As the omentum is flexible and mobile abdominal structure, it might initiate a herniation into the thorax [34]. It has been reported that the diagnosis of TDI may be missed in 30% of cases on initial CT scanning [35]. Affected patients are typically showed severe multi-organ injures that may dominate and mask the presentation of TDI.

TDI is rare to heal-up spontaneously (diaphragm does not heal as it moves all the time), and so most cases needed surgical repair [32]. Early diagnosis is crucial due to the fact that smaller lacerations are easy to be repaired. On the other hand, patients with extensive TDI may end up with more complications and associated adhesions [32]. In blunt TDI

Table 4. Review of injury characteristics and outcomes of patients with traumatic diaphragmatic injury (TDI).

References	Country of origin	Study duration (years)	Age (years)	MOI (Penetrating/ Blunt)	Site of Injury (left/ right/ bilateral)	Injury severity score	Mortality rate (%)
Zarour *et al.*, [1]	United States	14	33	773 (561/212)	441/309/23	Right:29±16 Left: 28±15	21.0
Lewis *et al.*, [3]	United States	13.5	35	254 (155/99)	129/78/9	36±22	32.0
Ties et al[14]	United States	16	Blunt: 44 Penetrating:32	454 (339/115)	Early (80/36/4) Recent (169/126/7)	Early:22 Recent:19	Blunt:15.0 Penetrating: 4.0
Thiam *et al.*, [15]	Senegal	21	33	20 (14/6)	18/2/0	-	5.0
D'Souza *et al.*, [16]	South Africa	4	29	96 (96/0)	96/0/0	-	-
Khan *et al.*, [17]	India	1	20-60	6 (1/5)	5/0/1	-	17.0
Okada *et al.*, [18]	Japan	12	52±17	28 (16/12)	23/5	Blunt:47 & penetrating: 26	28.6
Ahmed *et al.*, [19]	Iraq	3	32	67 (51/16)	32/24/11	-	7.5
Fair *et al.*, [20]	United States	1	Blunt: 44±19 Penetrating: 31±13	3873 (2543/1240)	-	Blunt: 33 & Penetrating: 24	Blunt: 19.8 Penetrating: 8.8
Gao *et al.*, [21]	China	19	32.4	256 (152/104)	158/ 94/ 4	26.9 (13-66)	Blunt: 21.2 Penetrating: 6.6
Panda *et al.*, [22]	India	4	29	23 (6/17)	15/7/1 (central dome)	-	-
Kumar *et al.*, [23]	India	5	Survivors: 27; Non-survivors: 38	75 (26/49)	46/41/12	mean ISS among dead=35.9	9.3
Radjou *et al.*, [24]	India	6	34	25 (15/10)	22/3	9	4.0
Gaine *et al.*, [25]	India	3	35	21 (4/17)	19/2	-	-
Alanezi K *et al.*, [26]	Qatar	11	43±18	59 (9/50)	43/16	39±15	7.0
Bilal *et al.*, [27]	Pakistan	4	32	50 (12/38)	46/4	-	6.0
Present study	Qatar	7.5	30.7±11	52 (16/36)	41/11	24±12	23.1

cases with severe associated injuries; the initial radiological diagnosis is difficult and some cases are detected only during intra-operative exploration or later. Therefore, careful inspection of diaphragm is necessary with thorough visual as well as manual evaluation of the surface of the diaphragm [18]. In all cases with significant blunt thoraco-abdominal trauma, thorough evaluation is required to exclude TDI, and the follow-up assessment is needed to identify the delayed onset of TDI after extubation or discharge in some cases [36]. In selected cases with high index of suspicion but inconclusive imaging studies, laparoscopic or thoracoscopic exploration may be helpful. The clinical diagnosis is usually unreliable; and currently there is no gold standard diagnostic tool, though laparoscopy is a promising diagnostic tool.

The surgical approach is often used to treat diaphragmatic repair including laparotomy, thoracotomy (or both), and laparoscopy/thoracoscopy. Ahmad Ganie *et al.*, [37] surgically treated all 21 patients who sustained TDI and considered thoracotomy to be the preferred manangement option to repair diaphragmatic herniation. The authors suggested laparotomy for patients with acute presentation and concomitent intra-abdominal injuries. The decision for surgical intervention is primarily dictated by hemodynamic stability of the patient and the severity of associated injuries as the most threatening injuries should be treated first [38].

Laparotomy is indicated in patients with associated abdominal injuries or hemodynamic instability otherwise it is considered urgent indication that can be done within the same admission once the patient condition allows. Notably, on the right side the liver can hinder repair, so an additional

thoracotomy may be helpful. In delayed and chronic cases, repair via thoracotomy was preferred in which adhesions of organs to chest structures could be more safely managed [39]. However, minimally invasive techniques are now commonly used to treat hemodynamically stable patients. So these patients can undergo diagnostic laparoscopy or video-assisted thoracoscopy and do not require an open surgery with the potential advantages of minimally invasive approach. Diagnostic laparoscopy is useful in left thoraco-abdominal penetrating trauma, as observed in 8.8% of our cases.

Thoracoscopy is a very sensitive and specific diagnostic tool; but it is useful in obvious thoracic trauma with no associated abdominal organ injury and in right-sided penetrating thoraco-abdominal injuries [40].

The anatomic location of injury, involvement of intrathoracic and abdominal organ, and the severity of injury are well correlated with the presence of associated injuries (52%-100%) in patients with TDI [30]. TDI are often occurring in a context of multiple trauma with pelvic fractures (40%–55%), splenic (60%), and renal injuries [30]. There observed a higher frequency of liver injuries, which are associated more with RTDI (93%) as compared to LTDI (24%) which logically corresponds to the anatomic location [41].

According to previous reports, thoracic injuries such as hemo-pneumothorax and multiple rib fractures (90%), pelvic fractures (40%), both hepatic and splenic injuries (25%) and blunt rupture of the thoracic aorta (5%) are associated injuries with TDI [42]. Moreover, the mechanism of trauma, injury severity, associated injuries, hemodynamic status, and time to diagnosis are the leading factors affecting outcome in patients with TDI [42]. The reported rate of postoperative complications such as pneumonia, empyema and intra-abdominal abscesses ranges from 11% to 62.9% [43]. In our study, post-operative complications were seen in 49% of cases (LTDI had a higher frequency than RTDI). Also, herniation recurrence was seen in 5.3% of the cases (all left sided).

The overall reported mortality in TDI patients ranges from 4 to 32% in various studies involving penetrating as well as blunt injuries. Al-Refaie *et al*., [43] reported mortality rate between 1% and 42%, and the primary causes of death were shock, blunt trauma, higher severity of injury, and the presence of solid organ injury. In our study, the overall mortality among TDI cases was 23%. In addition, the mortality rate was more likely to be higher in patients who had RTDI compared with LTDI. This mortality rate is in accordance with the reported literature which is attributed mainly to the severity of the associated injuries.

Limitations

There were many limitations in the present study. The retrospective nature of the study and small sample size are the major limitations. As the study is underpowered, we cannot generalize the results. Most of the differences between the study groups' variables were not statistically significant but this difference could be important from the clinical point of view. Details of delayed presentation (time to diagnosis post-injury or missed injury), post-operative complications, delayed intervention, cause of death and follow-up are not elaborated well. Moreover, the exact reasons for immediate non-operative interventions are lacking. Also, data for spine or limb injuries are not available. Furthermore, the modalities of diagnosis do not show what percentage of injuries were apparent on admission chest x-ray, CT scan, and intra-operatively. Despite these limitations, our study has clinical relevance as it reviews the management of TDI which is an important, uncommon and often difficult to diagnose injury that may result in potentially life threatening condition.

Conclusions

This single-institution study confirms that LDI are more commonly diagnosed than RTDI. Exploratory laparotomy is the most frequent procedure considered for the management of diaphragmatic injuries in the emergency settings. To improve outcomes in patients presenting with TDI, large prospective multicenter studies are needed to standardize the TDI management protocols including the diagnostic workup, timing of surgical intervention, and the most appropriate approach of treatment.

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