Prevalence, management and outcome of traumatic diaphragm injuries managed by the Pietermaritzburg Metropolitan Trauma Service

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ABSTRACT

INTRODUCTION This audit of traumatic diaphragm injury (TDI) from a busy South African trauma service reviews the spectrum of disease and highlights current approaches to these injuries.

METHODOLOGY The Pietermaritzburg Metropolitan Trauma Service (PMTS) has maintained an Electronic Surgical Registry (ESR) and a Hybrid Electronic Medical Record (HEMR) system since January 1st 2012.

RESULTS A total of 105 TDIs were identified and repaired during the study period. The mean patient age was 30 years (range 15–68 years - SD 9.7). The majority (92.4%) of patients were male (97/105). Penetrating trauma was the leading mechanism of injury (94%). 75 patients sustained a TDI from a stab wound, and the remaining 24 injuries resulted from gunshot wounds. Multiple associated injuries and high morbidity was seen with right diaphragm injury, blunt trauma, gunshot wounds and chronic diaphragmatic hernias.

CONCLUSION TDI is a fairly uncommon injury with a local incidence of 1.6%. It presents in a spectrum from the obvious to the occult. Multiple associated injuries and high morbidity occur following blunt trauma or gunshot wounds, right diaphragm injury and chronic diaphragmatic hernias. Diagnostic laparoscopy offers a diagnostic and therapeutic tool to prevent progression of occult TDI to chronic diaphragmatic hernias.

KEYWORDS

Laparotomy – Diaphragm/injuries – Diaphragm/surgery

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The diaphragm can be injured by penetrating and blunt mechanisms. The nature and presentation of these injuries can be diverse and their management challenging. In the acute setting after penetrating trauma, these injuries may present as a simple breach of the diaphragm, which is usually diagnosed at laparotomy in conjunction with other injuries. These associated injuries result in considerable morbidity and mortality.^{1–3} An occult diaphragmatic injury may be an asymptomatic small laceration of the diaphragm in a stable patient without herniating viscera. In comparison with penetrating traumatic diaphragmatic injuries (TDIs), blunt trauma typically results in larger diaphragmatic disruptions with a higher incidence of associated anatomical injuries. If viscera herniate through the acute breach then the patient may present as an acute diaphragmatic hernia. Missed injuries in patients may present as chronic diaphragmatic herniae, with obstruction or strangulation of intra-abdominal organs.^{4,5} This study aims to review the incidence, spectrum, management and outcomes of all TDIs within the Pietermaritzburg Metropolitan Trauma Service (PMTS).

Methods

The PMTS has maintained an Electronic Surgical Registry (ESR) and a Hybrid Electronic Medical Record (HEMR) system since January 1st 2012.^{1,2} Ethics approval to maintain the ESR has been obtained from the Biomedical Research Ethics Committee (BE207/09 BREC and BCA221/13 BREC) of the University of KwaZulu–Natal (UKZN) and from the Research Unit of the Department of Health (DOH), KZN, South Africa (HRKM 265/13). Data were prospectively collected and all cases of TDI managed between the 1st January 2012 and the 31st May 2014 were extracted from the registries and analysed. Complications were categorised by severity according to the Clavien–Dindo (CD) system⁽⁶⁾. The authors considered the traditional anatomical landmarks as defining the left thoraco-abdominal region: originating medially from the sternal margin, the superior border beginning at the level of the 5th intercostal space, running caudally to the costal margin (inferior boundary), and extending posteriorly to the spinal column.

Management of TDI associated with penetrating thoraco-abdominal trauma

In our institutions the indications for immediate laparotomy following penetrating trauma include peritonitis, hemodynamic instability and radiological findings such as free air with diaphragmatic herniation (see figure 1). At laparotomy the diaphragm is inspected. If an injury is identified any herniating viscera are reduced back into the abdomen and the wound in the diaphragm is enlarged to allow copious wash out of the chest. Once this has been done a tube thoracostomy is placed under direct vision and the injury in the diaphragm is closed using a continuous non absorbable suture.

Management of occult TDI associated with penetrating thoraco-abdominal trauma

Patients with left sided penetrating thoraco-abdominal trauma who are hemodynamically stable with no signs of peritoneal irritation undergo selective non-operative management (SNOM) as described in the literature.⁷⁻⁹ They are admitted for repeated serial clinical observation, reviewed on a four hourly basis and starved. If they develop signs of peritonitis or of hemodynamic instability they are considered to have failed non-operative management and are subjected to a laparotomy. If they remain stable and do not develop peritonitis they are subjected to a semi-elective diagnostic laparoscopy (DL) under general anesthetic within forty-eight hours. If a TDI is confirmed at DL, intra-corporeal laparoscopic repair is attempted. Conversion from laparoscopy to laparotomy with open diaphragm repair is selected in the event of technical difficulty, or the identification of additional injuries to intra-abdominal organs mandating open repair.

Concomitant thoracotomy and laparotomy

Acutely unstable patients with penetrating thoraco-abdominal wounds may have injuries within the thorax, abdomen or both, a situation known as “double jeopardy”.^{1,10} As these patients require immediate surgery, choosing which cavity to open and in which order is a key decision. Opening both cavities at the same operation is associated with increased morbidity and mortality and incorrect sequencing may delay management of life threatening condition such as a cardiac tamponade.

Management of retained collections

The development of Video Assisted Thoracoscopy (VATS) has allowed us to treat retained pleural collections with minimally invasive procedures.¹² Patients who have a retained collection after a diaphragm injury are treated on an individual basis.

Management of TDI associated with blunt trauma

Patients who presented with TDI following blunt abdominal trauma are resuscitated according to ATLS principles. Once the injury has been identified they are subjected to laparotomy and the diaphragm injury is dealt with in the same way as a penetrating injury.

Management of chronic diaphragmatic hernia

Laparotomy is the default approach in patients with a chronic diaphragmatic hernia. A laparotomy is performed and the herniated viscera are reduced back into the abdomen. The edges of the defect are identified and repaired primarily. In the elective repair of a chronic diaphragmatic hernia we discourage combined thoracotomy and

Table 1 Patient demographics and procedures

All patients					
No patients	105	100%			
Mean age	30	sd 9.7			
Female	8	8%			
Penetrating	99	94%	Blunt	6	6%
GSW	24	23%	MVA	4	4%
SW	75	71%	PVA	2	2%
acute injuries	73	74%	acute injuries	3	3%
chronic injuries	3	4%	chronic injuries	0	0%
semi-elective	23	23%	semi-elective	3	3%
laparoscopies	18	17%	laparoscopies	0	0%
converted laparoscopies	4	4%	converted laparoscopies	1	1%
laparotomy	67	64%	laparotomy	4	4%
laparotomy + thoracotomy	6	6%	laparotomy + thoracotomy	1	1%
VATS	3	3%			
thoracotomy	1	1%

Figure 1 Local algorithm for management of penetrating thoraco-abdominal trauma

laparotomy. However if it is difficult to reduce the hernia contents or there is significant sepsis in the thorax, which cannot be adequately cleared from below, a thoracotomy can be performed through a separate incision

Results

During the period under review 105 TDIs were identified and repaired. During this time period a total of 6604 patients were managed within the regional trauma service. This equates to an incidence of TDI of 1.6%. The mean patient age was 30 years (range 15–68 years, standard deviation 9.7 years). The majority of patients were male (92.4%).

Penetrating trauma

Penetrating trauma was the leading mechanism of injury in 99 (94%) patients with TDI. Of these 99 patients, 69 (70%) were unstable on presentation and underwent either an emergency laparotomy (63), thoracotomy (1), or a combined thoracotomy and laparotomy (5). A further 23 patients had

TDI identified at semi-elective laparoscopy (22) or during a VATS procedure. (1) Most of the injuries were left sided (78.8%). Associated intra-thoracic injuries were present in 59 of 99 patients (60%). A total of 127 intra-abdominal injuries occurred in the 99 patients who sustained penetrating trauma. ICU admission was required in 33 patients (31%).

In the penetrating trauma sub-group, 23 (23%) patients developed a CD II type morbidity which included surgical site infection, atelectasis or nosocomial pneumonia requiring antimicrobials. CD IIIa morbidity occurred in 17 (17%) patients and included retained hemothorax, recurrent pneumothorax post intercostal drain (ICD) removal, or empyema or biloma as consequence of liver injury. These were managed by ICD insertion or image-guided percutaneous drainage. Surgical intervention under general anaesthesia (CD IIIb) was required to manage complications in 15 patients (15%). These complications included pulmonary lobar collapse, bile leak, abdominal evisceration, iatrogenic injury, anastomotic leak, intra-abdominal abscess or missed injury. Two patients required renal replacement therapy (RRT) for

Table 2: Associated injuries with TDI							
Injury side		Blunt		Penetrating		Total	
all sides		6	100%	99	100%	105	100%
left		4	67%	76	77%	80	76%
right		2	33%	19	19%	21	20%
bilateral		0	0%	2	2%	2	2%
Not recorded		0	0%	2	2%	2	2%
Associated injuries							
Thoracic	cardiac injury	1	17%	2	2%	3	3%
	lung injury	0	0%	1	1%	1	1%
	pneumothorax	1	17%	13	13%	14	13%
	haemothorax	0	0%	18	18%	18	17%
	haemopneumothorax	2	33%	23	23%	25	24%
	empyema	0	0%	2	2%	2	2%
Abdominal	vascular injury	0	0%	5	5%	5	5%
	oesophagus	0	0%	1	1%	1	1%
	stomach	0	0%	27	27%	27	26%
	duodenum	0	0%	1	1%	1	1%
	small bowel	0	0%	9	9%	9	9%
	large bowel	0	0%	19	19%	19	18%
	spleen	1	17%	20	20%	21	20%
	liver	2	33%	29	29%	31	30%
	kidney	0	0%	5	5%	5	5%
	GB/bile duct	0	0%	3	3%	3	3%
	pancreas	0	0%	6	6%	6	6%
	urogenital	0	0%	2	2%	2	2%
Other injuries	skull vault	0	0%	2	2%	2	2%
	eye	0	0%	1	1%	1	1%
	stab neck	0	0%	2	2%	2	2%
	pelvis	2	33%	1	1%	3	3%
	spinal column	0	0%	2	2%	2	2%
	spinal cord	0	0%	2	2%	2	2%
	other orthopaedic injury	2	33%	2	2%	4	4%
	isolated diaphragm injury only	1	17%	16	16%	17	16%
	isolated inc lung injury	2	33%	37	37%	39	37%
ICU admission		3	50%	30	30%	33	31%

acute kidney injury (CD IVa). Four patients developed multiple organ failure (CD IVb), and were amongst the 7 fatalities (7%) (CD V).

Blunt Trauma

Blunt trauma resulted in six TDIs. The mechanism included four motor vehicle accidents (MVAs) and two pedestrian

vehicle accidents (PVAs). Blunt trauma resulted in associated intra-thoracic, intra-abdominal, and pelvic or orthopaedic injuries. Only one patient (17%) had no associated anatomical injuries. All three patients undergoing emergency operative intervention had injuries of sufficient severity to warrant ICU admission. All six patients suffered complications. These included surgical site infection (SSI)

Table 3 CD complications

Clavien Dindo grade	Complications	Blunt		Penetrating		Total	
CD II	wound site sepsis	1	17%	13	9%	14	10%
	atelectasis	0	0%	3	3%	3	3%
	pneumonia	1	17%	7	7%	8	8%
CD IIIa	residual haemothorax	1	17%	7	7%	8	8%
	recurrent pneumothorax	0	0%	1	1%	1	1%
	empyema	0	0%	5	5%	5	5%
	biloma	0	0%	4	4%	4	4%
CD IIIb	lung collapse	2	33%	0	0%	2	2%
	bile leak	0	0%	4	4%	4	4%
	burst abdo	0	0%	1	1%	1	1%
	iatrogenic injuries	0	0%	3	3%	3	3%
	anastomotic leak	0	0%	1	1%	1	1%
	Intra-abdominal abscess	0	0%	2	1%	2	2%
	missed injury	1	17%	4	4%	6	6%
CD IVa	respiratory failure	1	17%	0	0%	1	1%
	acute kidney injury	0	0%	2	2%	2	2%
CD IVb	multi organ failure	0	0%	4	4%	4	4%
CD V	death	0	0%	7	7%	7	7%
	no complications	0	0%	46	46%	46	44%

and nosocomial pneumonia (CD II), respiratory compromise requiring bronchoscopy (CD IIIa), re-laparotomy (CD IIIb), and ventilation for respiratory failure (CD IV).

Stab Wounds vs Gunshot Wounds

Penetrating trauma was due to GSWs in 24 patients, and SWs in 75 patients. Other associated injuries, ICU admission and mortality were all more frequent in patients with GSWs than SWs.

Right-sided versus left-sided diaphragmatic injuries

Eighty-two patients sustained left-sided TDI compared to 21 patients who sustained a right-sided TDI. Two patients sustained bilateral diaphragmatic injuries. All patients with right-sided TDIs had at least one associated organ injury, and had a higher rate of abdominal and thoracic injuries and more ICU admissions compared to patients with left sided TDI's.

Chronic diaphragmatic injury

We identified three patients presenting with established chronic diaphragmatic hernia. The first patient sustained a left-sided thoracic SW, which had been sutured at a peripheral hospital. He subsequently presented to our institution one month later complaining of left sided chest pain and dyspnoea. A chest radiograph demonstrated intra-thoracic gastric herniation. The patient underwent laparotomy,

reduction of herniated contents and primary repair of the TDI. The second patient presented with epigastric pain three months following a left-sided thoracic SW. A chest radiograph demonstrated intra-thoracic gastric and colonic herniation. The patient proceeded to laparotomy, where the stomach, splenic flexure of colon and spleen had herniated into the thoracic cavity through a 10cm diaphragmatic defect. The herniated viscera were reduced and diaphragm defect was primarily repaired. A minor iatrogenic splenic injury occurred during the procedure – the injury was repaired and the patient's recovery was uneventful. The third patient presented with signs and symptoms of bowel obstruction 12 months following a left-sided thoraco-abdominal SW. Radiography demonstrated intra-thoracic colon herniation, and features of bowel obstruction. At laparotomy viable transverse colon had herniated into the thoracic cavity through a left sided TDI. The patient suffered sudden death at 72 hours post-operation, following an uneventful initial post-operative course. Post mortem revealed a pulmonary embolus (PE).

Discussion

Blunt trauma was formerly described as the predominant mechanism of injury (MOI) resulting in TDI in the developed world.^{13–17} More recently three large series from the US and Canada have described penetrating injury resulting

Table 4: GSW vs SW					
Injury side		GSW		SW	
all sides		24	100%	75	100%
left		18	75%	58	77%
right		5	21%	14	19%
bilateral		1	4%	1	1%
unknown		0	0%	2	3%
Thoracic	cardiac injury	0	0%	2	3%
	lung injury	0	0%	1	1%
	pneumothorax	0	0%	13	17%
	haemothorax	6	25%	12	16%
	haemopneumothorax	9	38%	14	19%
	empyema	0	0%	2	3%
Abdominal	vascular injury	2	8%	3	4%
	oesophagus	1	4%	0	0%
	stomach	13	54%	15	20%
	duodenum	1	4%	0	0%
	small bowel	6	25%	3	4%
	large bowel	8	33%	11	15%
	spleen	7	29%	13	17%
	liver	14	58%	16	21%
	kidney	2	8%	3	4%
	GB/bile duct	2	8%	1	1%
	pancreas	2	8%	4	5%
	urogenital	2	8%	0	0%
Other injuries	skull vault	0	0%	2	3%
	eye	0	0%	1	1%
	stab neck	0	0%	2	3%
	pelvis	1	4%	0	0%
	spinal column	2	8%	0	0%
	spinal cord	2	8%	0	0%
	other orthopaedic injury	2	8%	0	0%
	isolated diaphragm injury only	1	4%	15	20%
	isolated inc lung injury	1	4%	36	48%
ICU admission		14	58%	16	21%
Death		4	17%	3	4%

in TDI in 61%–73% of cases.^{1–3} This may reflect a higher incidence of interpersonal violence (SWs and GSWs) in the study populations, but may also be due to an increasing clinical awareness of the association of left thoraco-abdominal trauma with TDI. In our setting, penetrating trauma is the most common MOI resulting in TDI (99/105, 94%).

In our series 84% of patients sustained multiple injuries in association with a TDI. Intra-abdominal injuries occurred

in 30% of cases of penetrating injury, and in up to 45% of cases of blunt trauma.^{1–3} Single or multiple tracts from penetrating trauma can result in injury complexes involving the thorax, diaphragm and multiple intra-abdominal organs. In this series, 55% of patients (58/105) had at least 2 intra-abdominal organ injuries associated with TDI, ICU care was required in 31% of patients (33/105) patients and the mortality was 7% (7/105). In common with the results of other

Table 5: Right vs left sided injuries

Associated Injuries		R		L	
Thoracic	cardiac injury	1	5%	2	3%
	lung injury	1	5%	0	0%
pneumothorax		2	10%	12	15%
	haemothorax	4	19%	14	18%
	haemopneumothorax	6	29%	17	21%
	empyema	1	5%	1	1%
Abdominal	vascular injury	0	0%	4	5%
	oesophagus	0	0%	1	1%
	stomach	3	14%	21	26%
	duodenum	0	0%	1	1%
	small bowel	1	5%	8	10%
	large bowel	5	24%	14	18%
	spleen	1	5%	19	24%
	liver	15	71%	15	19%
	kidney	0	0%	5	6%
	GB/bile duct	2	10%	1	1%
	pancreas	0	0%	5	6%
	urogenital	1	5%	1	1%
Other injuries	skull vault	2	10%	0	0%
	eye	0	0%	1	1%
	stab neck	1	5%	1	1%
	pelvis	1	5%	2	3%
	spinal column	0	0%	2	3%
	spinal cord	1	5%	1	1%
	other orthopaedic injury	2	10%	2	3%
	isolated diaphragm injury only	0	0%	17	21%
	isolated inc lung injury	0	0%	38	48%
ICU admission		8	38%	23	29%
Death		0	0%	5	6%

reported large series; a right-sided TDI is a risk factor for morbidity and mortality.⁵ Blunt mechanisms, GSWs and right-sided TDI are associated with a bigger magnitude of injury, increased associated injuries and higher mortality rates than left sided injuries.

Complications following surgical repair of chronic diaphragmatic herniation are mostly limited to small series of less than ten cases.^{4,5} Two of the larger series of 10 to 25 patients reported a morbidity rate of 30% and a mortality rate of 10–20%, which rose to 85% when strangulation of visceral contents was present.^{18,19} Our series included three patients with chronic diaphragmatic hernias, one of whom did not survive to discharge. We employ laparotomy as the initial surgical approach as these patients usually have

extensive adhesions and may require a bowel resection, which is easier to perform via laparotomy. Enterotomy inside the thoracic cavity should be avoided if at all possible.

Stable, asymptomatic patients with a left-sided thoraco-abdominal SW who complete a trial of SNOM undergo DL prior to discharge to exclude an occult TDI. Radiological investigations can miss these injuries. The sensitivity of CT varies from 36% to 82.7%.^{20,21} and plain x rays are frequently normal.²² The natural history of these anatomical defects is unknown, but the majority of patients are initially asymptomatic. However an occult TDI may progressively enlarge with time due to the radial forces exerted on the diaphragm during ventilation. Chronic diaphragmatic herniation is associated with a high morbidity and mortality

especially during emergency presentation, whereas patients undergoing laparoscopic repair of a TDI are usually discharged the following day. This makes a compelling argument for an expansive use of DL to detect and repair these occult injuries in the appropriate patients.

Conclusion

TDI is a fairly uncommon injury with a local incidence of 1.59%. It presents in a spectrum from the obvious to the occult. The injuries associated with TDI incur a high morbidity and mortality, particularly right-sided injuries, injuries from blunt trauma or GSWs, and chronic diaphragmatic hernias. Diagnostic laparoscopy offers a diagnostic and therapeutic tool to prevent progression of occult TDI to chronic diaphragmatic hernias.

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