

Traumatic Lesions of the Diaphragm Our Experience in 33 Cases and Review of the Literature

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Abstract. We reviewed 33 consecutive patients with diaphragmatic injuries. Twenty-nine were admitted in emergency conditions after blunt (22 patients) or penetrating injury, presenting shock, dyspnoea, coma or acute abdomen in 21 cases ; major associated lesions were found in 23 patients. Four patients presented acute complications of visceral herniation 2, 4, 84 and 216 months after the trauma. The diagnosis was preoperative in 23 cases, intraoperative in 9 ; in one case it was missed at laparotomy, becoming evident the day after. The sensibility of preoperative chest x-ray and CT was 86% and 100% in presence of visceral herniation, 14% and 0% in absence of visceral hernia.

The diaphragmatic repair was always obtained by direct suture, following 20 haemostatic procedures (liver, spleen, mesenterium) and two bowel resections. The mortality rate was 24.4% ; the morbidity rate was 48%.

Traumatic lesions of the diaphragm are generally expression of particularly severe trauma whose outcome is mainly influenced by the associated lesions. They are also correlated to specific morbidity and mortality, so the surgical exploration is mandatory whenever this injury is suspected, considering that the preoperative diagnosis relies on visceral dislocation. Associated lesions influence the surgical strategy but a direct suture is usually effective in preventing specific complications.

Introduction

In western countries, the traumatic rupture of the diaphragm is a rare observation generally consequent to severe traffic or working accidents.

When dealing with patients with severe thoracic and/or abdominal trauma, special attention should be given to the possibility of diaphragmatic rupture, owing to the important sequels of a missed diagnosis. The recognition of these lesions may present some difficulties and it needs a specific attention both during the clinical and instrumental work-up : SHAH *et al* (1), in a multicentric review including 980 patients, showed that a preoperative diagnosis was made only in 44% of cases, while 14.6% of the ruptured diaphragms were missed at first.

Furthermore, when treating a diaphragmatic injury, several technical options should be considered, concerning both the surgical approach and the reparation technique itself.

The aim of this retrospective work is to contribute in focusing the critical diagnostic and therapeutic points of diaphragmatic rupture through the analysis of our experience and a wide review of the literature.

Material and methods

Patients

This is a retrospective chart review of 33 patients affected by diaphragmatic injuries and operated on in the period 1988-2003. Thirty were males and 3 females ; the mean age was 41 years (range 18-72). Twenty-six patients had a blunt trauma due to motor vehicle (22 cases) or working (4 cases) accidents ; 7 patients sustained penetrating injuries (3 stab wounds, 2 gunshot wounds and 2 vehicle accidents). Twenty-nine patients were admitted immediately after the traumatic event ; 4 had a late presentation of a traumatic diaphragm laceration 2 and 4 months, 7 and 18 years after a blunt abdominal trauma : these patients had been initially observed in other institutions and discharged without any clinical and radiological suspicion of diaphragmatic injury.

Clinical presentation and diagnosis

Shock, respiratory failure, coma and acute abdomen were the most common clinical features in acute post-traumatic patients (Table I) ; among these only 8 patients

Table I
Clinical presentation

Early presentation	Blunt (22 patients)	Penetrating (7 patients)
Shock	8	4
Respiratory failure	8	2
Coma	3	1
Acute abdomen	0	3
Late presentation (4 patients)		
Bowel occlusion	3	
Septic shock and respiratory failure	2	
Mild dysphagia	1	

(27.5%) presented fairly good clinical conditions at admission. The clinical presentation of patients affected by penetrating trauma was particularly severe: cardiovascular instability was observed in 4/7 (57%) and in 8/22 (36.4%) patients after open and blunt trauma, respectively, while peritonitis was never observed after blunt trauma.

The patients with late presentation of diaphragmatic rupture were admitted for acute occlusion of herniated viscera; in 2 cases with bowel necrosis, the clinical picture was dominated by septic shock and acute respiratory distress.

In 1 case the diaphragmatic injury was immediately evident as omentum, ileum and stomach extruded through an open chest wound. The presence of bowel bruits inside the thorax associated to the reduction of respiratory bruits at the physical examination oriented the diagnosis in 8 more cases. In 10 patients (including the 4 patients with late presentation of diaphragmatic rupture) the physical examination was pathological but non-specific as pneumothorax, pleural collection or fixity of the diaphragm were detected. Thirteen patients (39.3%) had a negative clinical examen.

Twenty-nine patients were studied with chest x-ray which was diagnostic in 14 cases (48.2%) as visceral dislocation (12 patients) or interruption of the diaphragmatic profile in absence of visceral herniation (2 patients) was detected; in 13 cases (44.8%) the chest x-ray showed non-specific signs such as elevated hemidiaphragm, rib fractures, pneumothorax, haemothorax, pulmonary contusion or infiltrate. Fifteen patients had a thoracoabdominal CT scan which was diagnostic in 11 cases with visceral hernia, including 5 patients with non diagnostic chest x-ray. The preoperative diagnostic approach included diagnostic peritoneal lavage in 8 cases, thoracentesis in 3 and abdomen ultrasound scanning in 3 patients.

The diaphragmatic injury was recognised before surgery in 19/29 (65.5%) acute patients and in all the patients with late presentation. In 9 patients observed in

Table IIa

Associated abdominal injuries in 29 patients admitted immediately after the traumatic event

Injury	Blunt (16/22 patients)	Penetrating (7/7 patients)
Spleen	13	3
Liver	8	3
Digestive tube	1	3
Retroperitoneum	4	0
Kidney	0	1
Pancreas	0	1
Mesenterium	2	1

Table IIb

Associated extra-abdominal injuries in 29 patients admitted immediately after the traumatic event

Injury	Blunt (20/22 patients)	Penetrating (6/7 patients)
Haemothorax	7	2
Pneumothorax	2	2
Lung laceration	2	0
Heart injury	0	1
Bone fractures	15	3
Cage fractures	15	2
Pelvic fractures	1	1
Limb fractures	7	
Spine fractures	4	
Head trauma	9	0
Lower limb ischaemia	0	1
Minor superficial wounds	7	1

the acute phase, including 6/7 patients (85.7%) with penetrating trauma, it was recognised at laparotomic inspection. In 1 case the diaphragmatic tear, initially unrecognized both preoperatively and at laparotomy, was recognized by control chest x-ray during postoperative day 1 and the patient was re-operated on. All the patients with intraoperative diagnosis of diaphragmatic injury had a preoperative chest x-ray, 2 had also been studied by CT; in these cases the radiological work-up did not show the diaphragm injury.

Associated injuries

Associated abdominal injuries were present in 23/29 patients (79%) observed in the acute posttraumatic phase (Table IIa). Haemoperitoneum was present in 21 patients and was always related to splenic or hepatic trauma; in 9 cases the amount of peritoneal blood exceeded 500 cc.

Associated thoracic lesions were observed in 10/29 patients (34.5%) while in 26/29 cases (89.6%) were observed other concomitant lesions, bone fractures being the most common (Table IIb).

Table III
Viscera herniation

Visceral herniation	2/7 pts with open trauma	22/26 pts with blunt trauma
Left diaphragmatic injury		
Stomach	2	15
Small bowel	1	1
Colon	1	4
Spleen	1	5
Right diaphragmatic injury		
Liver	0	2
Small bowel	0	1

Surgical treatment

The operative approach was made through a laparotomy in 29 patients (median in 15 cases, subcostal in 14), 2 patients were approached by thoracotomy, dictated by massive haemothorax, in one case a laparotomy was extended to the thorax while 1 patient received both a thoracotomy and a laparotomy.

After achievement of the haemostasis by means of 12 splenectomies, one splenorrhaphy, 7 haemostatic sutures of hepatic, mesenteric and lung ruptures and repair of bowel disruption by intestinal resection and anastomosis, the subsequent exploration allowed the detection of 23 left sided and 8 right sided diaphragmatic ruptures; in one case the centrum tendineum and in 1 the posterior aspect of the oesophageal hiatus were lacerated. In 24 cases the herniation of abdominal viscera through the diaphragmatic defect into the chest (Table III) was observed; in 9 cases the diaphragm injury was not associated to visceral herniation. A visceral herniation was intraoperatively detected in 3/10 patients whose diaphragmatic lesion had been preoperatively undiagnosed.

After repositioning of the herniated organs, diaphragm defects were directly closed, most commonly with a single row of separated stitches; long lasting resorbable and non resorbable sutures were indifferently adopted. We never observed lesions requiring a prosthetic mesh repair but in 11/33 patients (33%) prosthetic pledgets were placed in order to avoid tissue lacerations. Abdominal drains were always placed while a chest tube was positioned in 17 cases.

Correction of associated lesions also included a prosthetic reconstruction of the thoracic wall and a radial artery repair.

Results

The overall mortality rate was 24.2% (8/33 patients). Deaths occurred more often in the group of patients

observed immediately after the traumatic event (7 patients, Table IV); among these patients its rate was 24%, growing to 58.3% considering the subgroup of patients presenting shock in the preoperative phase. Four patients died intraoperatively due to haemorrhagic shock, 1 in the first postoperative period due to intravascular disseminated coagulation. Two more patients developed progressive multi-organ failure and sepsis and expired later during their hospital course (1 and 2 months after surgery). One patient in the late presentation group died 35 days after the surgical intervention, owing to progressive respiratory insufficiency. No deaths were directly related to the diaphragmatic injuries.

Morbidity rate was 48% (12/25 patients) and severe lung complications were the most frequent, occurring in 8 patients. Two patients required a second surgical procedure: in one case a gastric resection for bleeding ulcer and in the second a bowel resection for enterocutaneous fistula.

The hospital stay of the 25 discharged patients ranged from 7 to 120 days (mean 27.8).

A clinical and radiological (chest x-ray) follow-up was possible in 16 cases; at a mean follow-up of 6.5 years (range 1-14), we have observed 1 recurrence (6.2%) of diaphragmatic hernia, associated to gastric herniation through a posterohiatal diaphragmatic defect, 15 months after the primary surgical repair. This patient was successfully re-operated on and the diaphragmatic defect corrected by direct suture.

Discussion

The rupture of the diaphragm is observed in a subgroup of trauma patients sustaining particularly severe injuries. The vast majority of these patients is hospitalized in the acute phase, when the clinical picture is dominated by major visceral lesions often demanding immediate surgical procedures, so that the diaphragmatic rupture itself is considered by some authors (2) an associated lesion. In those rare cases without concomitant visceral lesions, the diaphragmatic injury may easily remain unrecognized. In these patients, as reported by GRIMES (3), after a latent phase sustained by an asymptomatic and progressive visceral herniation, patients generally present an occlusive complication requiring surgical correction, often correlated to significant morbidity and long hospital stay, observed also in our cases. The incidence of delayed detection of diaphragmatic lacerations is higher after penetrating than blunt trauma (8-36% versus 3-14.6%) (4-7) and the literature is unanimous in considering these late presentations as expression of the evolution of small, initially unrecognized lacerations. In a series of 45 cases of diaphragmatic injury sustained by penetrating trauma, DEGIANNIS *et al.* (5) report that diag-

Table IV
The 8 patients who have died

Age (sex)	Mechanism of trauma	Clinical presentation	Diagnostic work-up	Interval trauma surgery	Findings at operation	Operation procedures	Cause of death time
48 (M)	penetrating (vehicle accident)	Shock	None	3 h	Haemothorax. Stomach and spleen herniated through a left diaphragmatic rupture	Laparotomy. Reduction of viscera and diaphragmatic suture	DIC (post op. hour 10)
63 (M)	penetrating (gunshot wound)	Shock, coma	None	1 h	Haemoperitoneum. Spleen rupture. Lesions of left hepatic lobe, transverse colon, pancreatic body, stomach wall. Linear tear of left diaphragm and pericardium without visceral herniation	Laparotomy Splenoectomy. Left hepatectomy	Intraoperative cardio-respiratory failure for haemorrhagic shock
72 (F)	blunt (vehicle accident)	Shock, coma, dyspnoea	None	13 h	Haemothorax. Haemoperitoneum. Right diaphragmatic defect with total liver herniation.	Right thoracotomy, subcostal laparotomy. Reduction of liver and diaphragmatic suture	Sepsis and MOF (post op. day 60)
61 (M)	blunt (vehicle accident)	Shock, dyspnoea	Chest radiograph	1 h	Haemoperitoneum. Rupture of the spleen, herniated into the chest through a left diaphragmatic defect	Laparotomy. Splenoectomy	Intraoperative cardio-respiratory failure for hemorrhagic shock
29 (M)	blunt (vehicle accident)	shock, coma, dyspnoea	Chest radiograph	1 h	Haemoperitoneum. Lesions of the liver, mesocolon and mesentery. Post op. day 1 : Left diaphragmatic defect with gastric herniation	Laparotomy. Hepatic conservative haemostasis. Reduction of viscera and diaphragmatic suture	Sepsis and MOF (post op. day 32)
29 (M)	blunt (vehicle accident)	shock, coma	None	1 h	Haemoperitoneum. Lesions of the liver. Right diaphragmatic defect without visceral herniation	Laparotomy. Hepatic conservative haemostasis	Intraoperative cardio-respiratory failure for hemorrhagic shock
26 (F)	blunt (vehicle accident)	shock, coma	None	1 h	Haemothorax. Haemoperitoneum. Lesions of the spleen, liver, right kidney. Rupture of the right diaphragm without herniation	Laparotomy. Splenoectomy. Hepatic packing	Intraoperative cardio-respiratory failure for hemorrhagic shock
73 (M)	blunt	shock, dyspnoea	Chest radiograph, CT scan	60 days	Small bowel herniated through a right diaphragmatic rupture Small bowel necrosis	Laparotomy: Small bowel resection	Respiratory insufficiency (post operative day 35)

nosis was missed in 16 cases (36%), readmitted some months or years later, with a significant rise of morbidity and mortality following surgical correction when compared to patients diagnosed during the first admission (respectively 50% versus 37% and 25% versus 3%). Consequently the hypothesis of a diaphragm laceration should be always considered when evaluating a patient with a history of trauma presenting occlusive symptoms. In order to minimize the risk of unrecognized thoracic or abdominal lesions, our policy is to surgically explore every penetrating injury; it is worth of note that in 6/7 patients with penetrating trauma the diagnosis was intraoperative. Independently from the type of trauma sustained, we stress the importance of a careful visual and manual evaluation of both the hemi-diaphragms

along their entire surface, from the rib and vertebral insertion to the dome, during the surgical exploration. In fact in emergency conditions the surgeon may be tempted to quickly conclude the surgical procedure once treated the most threatening lesions (8). In our experience this happened in one case: a diaphragmatic tear was recognized by chest film in the first postoperative day, after a complex haemostatic procedure on the liver, and the patient was re-operated on.

The diagnostic challenge is obviously more evident in case of blunt thoracoabdominal trauma. The recent progress toward a conservative management of hepatic, lienal and kidney injuries emphasizes the importance of the available clinical and instrumental tools to exclude the presence of a diaphragmatic tear in those patients

Table V
Diagnostic sensitivity of first-line diagnostic tools :
relationship with visceral herniation

Sensitivity	Overall	In presence of visceral herniation	In absence of visceral herniation
Chest X-ray			
VAN VUGT '89 (25)	14/28 (50%)	11/14 (79%)	3/14 (21%)
SHARMA '89 (22)	11/28 (41%)	11/11 (100%)	0/11 (0%)
KAUSELAR '91 (16)	20/56 (36%)	12/20 (60%)	8/20 (40%)
GELMAN '91 (15)	21/50 (42%)	19/21 (90%)	2/21 (10%)
DEGIANNIS '96 (5)	16/36 (44%)	9/16 (56%)	7/16 (44%)
This paper	15/29 (51%)	13/15 (86%)	2/15 (14%)
CT scan			
GELMAN '91 (15)	2/7 (29%)	2/2 (100%)	0/2 (0%)
KILLEEN '99 (27)	26/41 (63%)	15/26 (58%)	11/26 (42%)
SCAGLIONE '00 (28)	26/35 (74%)	26/26 (100%)	0/26 (0%)
BERGIN '01 (26)	9/10 (90%)	6/9 (66%)	3/9 (33%)
This paper	11/15 (73%)	11/11 (100%)	0/11 (0%)

that do not present haemodynamic instability or other immediate indications to surgery. In our as in other experiences, the clinical evaluation showed a limited diagnostic value, even when indirect parameters such as the increase of central venous pressure or the need of positive pressure ventilation are considered. Ultrasound investigation has been proposed as diagnostic method (9), but in another experience in no case was it reliable (10). The diagnostic sensitivity of chest x-ray and CT scan ranges respectively from 19 to 95% (2, 5, 7, 10-25) and from 14 to 90% (10, 15, 17, 21, 26-28). The recent literature and our experience show that the diagnostic sensitivity of the routine radiological work-up of trauma patients in the detection of diaphragmatic lesions is strictly related to direct or indirect signs of visceral dislocation (Table V) and that the diagnostic value of CT scan is particularly disappointing when faced to small diaphragmatic lesions not associated to visceral herniation (28). Interestingly, our data and the recent literature only confirm what was already known 20 years ago, showing that the diagnostic gain achievable by multiplanar reconstructions with the use of the multislices-CT (multidetector) is, at matter of facts, vanished in emergency conditions, due to lack of time, fully competent personnel or, more appropriately, to the fact that in these situations attention is primarily drawn to the most important and life-conditioning injuries. This is not the case of the late, elective diagnosis, in which a good visualization of diaphragmatic abnormalities is also obtained by MR imaging (29-31).

The diagnostic value of thoracoscopy and laparoscopy in trauma patients has recently been signalled. Although limited to the exploration of a hemidiaphragm, thoracoscopy has been proposed as the most effective method for the initial diagnostic evaluation and

surgical management of stable patients with penetrating thoracic trauma (32-33); its indication being already validated for the treatment of clotted haemothorax or posttraumatic empyema, traumatic chylothorax and traumatic pneumothorax. We do not practice diagnostic laparoscopy in patients considered for non-operative management of injured abdominal viscera, due to its invasiveness, to the limitations imposed by haemoperitoneum and, as far as diaphragmatic injuries are concerned, to the wide unexplorable surfaces and the adjunctive risks imposed by their exposure; considering the severe associated lesions observed in all patients affected by penetrating injuries, in no case did the surgeon consider the laparoscopic approach in our experience.

A wide consensus exists concerning the indication to surgery whenever a diaphragmatic injury is recognised or suspected. When the patient is observed in the acute phase, the dominating and life-threatening lesion, if present, dictates the surgical approach. As far as the diaphragmatic injury is concerned, we prefer the laparotomic approach, which permits an easier reduction of herniated viscera (8). Thoracotomy allows for an easier exposure of the right hemi-diaphragm, and permits a more accurate detachment of herniated viscera from thoracic structures in chronic hernias, so that it is by some authors preferred in the treatment of such cases (30-31).

Both laparotomy and thoracotomy can be extended respectively to the chest and to the abdomen, or associated to the reciprocal approach, in order to permit a better control in difficult situations. In our experience a left thoracic extension of a laparotomy was dictated in 1 case by an insufficient control of a diffuse pleural bleeding; furthermore in 1 of our cases of late presentation of diaphragmatic tear, approached by thoracotomy,

Table VI
Reported morbidity and mortality

Author (ref.)	Cases	Morbidity	Mortality
MORGAN '86 (2)	44	n.a.	20.4%
R. MORALES '86 (7)	60	65%	26.7%
SHARMA '89 (22)	28	46%	7%
VAN VUGT '89 (25)	28	n.a.	28.6%
ARENAS-MARQUEZ '91 (11)	20	50%	10%
SMITHERS '91 (24)	85	n.a.	19%
KAUSELAR SUKUL '91 (16)	63	68%	19%
MEYERS '93 (36)	68	n.a.	7.4%
STEINMAN '93 (40)	35	40%	22.8%
LEE '94 (19)	50	40%	6%
LETOQUART '95 (34)	28	60.7%	3.6%
SHAH * '95 (1)	980	n.a.	17%
RUF '96 (37)	99	13%	19.2%
STEINAU '97 (38)	17	n.a.	11.7%
ATHANASSIADI '99 (4)	41	n.a.	16.6%
SIMPSON '00 (23)	16	44%	12.5%
BERGERON '02 (39)	160	n.a.	14.4%
KUCUK '02 (18)	48	8.3%	10.4%
This paper	33	48%	24.2%

n.a. : not available.

* Collective retrospective multi-centric review.

the required bowel resection was performed through an associated abdominal approach.

From the technical point of view, different kinds of reparation have been described. Detached stitches in single or double layer, using re-absorbable or non absorbable materials, with or without interposition of prosthetic pledgets in order to achieve an homogeneous tension of the suture and to avoid tissue lacerations, have all been reported, as in our patients, and all seem to achieve good results, whence recurrence has very rarely, to our knowledge, been described (16, 34). We never used prosthetic meshes which are generally reserved to selected cases with huge tissue loss. The employment of these devices is most often described in case of laparoscopic or thoracoscopic repair, generally reserved to patients with chronic hernias, in order to simplify the laparoscopic suture (31).

The operative mortality and morbidity rates, respectively 24.2% and 48% in our series, reflect the severity of the trauma and the magnitude of associated lesions ; this same data would be considered evaluating the high splenectomy rate in the present series : in fact, when in presence of multiple and life-threatening lesions, we generally do not consider the conservative approach of the lineal parenchyma.

Interestingly, when considering acute patients, the results of recent series (Table VI) are not dramatically improved when compared to those reported in the seventies and eighties, in spite of the development of a dedicated medical culture. Presumably, when the diaphragm rupture is principally sustained by blunt working or traf-

fic trauma, as it is commonly observed in no war conditions, this may be explained by a substantial difference in patients observed in the past and at present : the latter reach the emergency department even if more severely injured due to the substantial evolution of life support protocols for critical patients and transport capabilities while in the past this was not the case.

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