Update on managing diaphragmatic rupture in blunt trauma: a review of 208 consecutive cases

Talat Chughtai, MD, MSc
Syed Ali, MBBS
Phillip Sharkey, MHK
Marcelo Lins, MD
Sandro Rizoli, MD, PhD

From the University of Toronto and the John and Liz Tory Regional Trauma Centre at the Sunnybrook Health Sciences Centre, Toronto, Ont.

Presented at the Canadian Surgery Forum, Sep. 9–12, 2004, in Ottawa, Ont.

Accepted for publication
Nov. 29, 2007

Correspondence to:
Dr. S. Rizoli
Sunnybrook Tory Regional Trauma Centre
2075 Bayview Ave., Rm. H-171
Toronto ON M4N 3M5
fax 416 480-4599
sandro.rizoli@sunnybrook.ca

Background: Blunt diaphragmatic rupture (BDR) is a rare event and represents a diagnostic challenge. The purpose of our study was to review our experience with BDR at the Sunnybrook Health Sciences Centre (Sunnybrook), the largest trauma centre in Canada, and to highlight recent changes in the diagnosis and management of the condition.

Methods: We retrospectively reviewed the cases of patients with BDR who were admitted to Sunnybrook between January 1986 and December 2003 using our trauma registry. We performed Student *t* and Fisher exact tests to compare our findings on patients with BDR with those on the entire cohort of blunt trauma patients admitted to our centre.

Results: Most patients with BDR were men (64.4%) with a mean age of 42 years. Left-sided tears were most common (65.0%). Patients with BDR had a very high Injury Severity Score (38) and very high mortality (28.8%). Of those who were injured as a result of motor vehicle collisions (MVCs), a significantly greater percentage of patients in the BDR group than in the entire cohort of blunt trauma patients were drivers or front-seat passengers. Patients with BDR were also significantly less likely to be pedestrians, to have experienced a fall or to be involved in a motorcycle collision. Patients with BDR had a higher chest, abdomen, pelvis and extremity Abbreviated Injury Scale score than all blunt trauma patients in general. Most of our patients underwent laparotomy (93.3%). The most common causes of death among patients with BDR were head injury (25.0%), intra-abdominal bleeding (23.3%) and pelvic hemorrhage (18.3%).

Conclusion: Blunt diaphragmatic rupture is rare and difficult to diagnose; however, certain MVC characteristics along with severe associated injuries should raise the index of suspicion. These associated injuries include injuries to the head, chest (including the aorta), abdomen and pelvis. Computed tomographic angiography is essential to rule out associated aortic injury and to increase the diagnostic accuracy of BDR.

Contexte : La rupture diaphragmatique après un traumatisme fermé est un phénomène rare et elle pose un défi sur le plan diagnostique. Notre étude avait pour but de faire le point sur l'expérience que nous avons acquise dans ce domaine au Sunnybrook Health Sciences Centre, le plus grand centre de traumatologie au Canada, et de faire ressortir les récents changements qui ont influé sur le diagnostic et la prise en charge de ce problème.

Méthodes : Nous avons analysé rétrospectivement les cas de rupture diaphragmatique après un traumatisme fermé qui ont été admis au Sunnybrook entre janvier 1986 et décembre 2003, à partir de notre registre des traumatismes. Nous avons appliqué les tests *t* de Student et exact de Fisher afin de comparer nos résultats relativement aux patients victimes d'une rupture diaphragmatique après un traumatisme fermé à ceux de la cohorte entière de patients admis dans notre centre pour un traumatisme fermé.

Résultats : La majorité des patients victimes d'une rupture diaphragmatique étaient des hommes (64,4 %) âgés en moyenne de 42 ans. Les déchirures affectaient plus souvent le côté gauche (65,0 %). Les patients présentaient un indice de gravité du traumatisme (38) et un taux de mortalité (28,8 %) très élevés. Parmi les traumatisés victimes d'un accident de la route, un pourcentage significativement plus élevé de patients du groupe atteint d'une rupture diaphragmatique que de la cohorte entière de patients victimes d'un traumatisme fermé étaient au volant ou prenaient place sur le siège avant du côté du passager. Les patients atteints d'une rupture diaphragmatique étaient également beaucoup moins susceptibles d'être des piétons, d'avoir fait une chute ou d'avoir été victimes d'un accident impliquant une motocyclette. Les patients atteints d'une rupture diaphragmatique affichaient un score plus élevé sur l'échelle abrégée des traumatismes pour les blessures à la poitrine, à l'abdomen, au bassin et

aux extrémités, comparativement à l'ensemble des patients victimes d'un traumatisme fermé. La plupart de nos patients ont subi une laparotomie (93,3 %). Les causes de mortalité les plus fréquentes chez les patients atteints de rupture diaphragmatique après un traumatisme fermé étaient le traumatisme crânien (25,0 %), l'hémorragie intra-abdominale (23,3 %) et l'hémorragie pelvienne (18,3 %).

Conclusion : La rupture diaphragmatique après un traumatisme fermé est rare et difficile à diagnostiquer; il faut toutefois la soupçonner en présence d'un patient qui a été victime d'un accident de la route et qui présente d'autres blessures graves. Ces blessures connexes comprennent les traumatismes à la tête, à la poitrine (y compris à l'aorte), à l'abdomen et au bassin. L'angiographie par tomographie assistée par ordinateur est essentielle pour écarter une lésion aortique connexe et pour augmenter le degré de précision du diagnostic de rupture diaphragmatique après un traumatisme fermé.

Blunt diaphragmatic rupture (BDR) occurs in up to 5% of trauma patients admitted to hospital.[1] The condition is rare and represents a challenge to diagnosis and management, particularly for the general surgeon who does not see this injury routinely and who may not be comfortable managing the associated severe injuries. To avoid missing a BDR, one must maintain a high index of suspicion based on the mechanism of injury. Recent advances in imaging technology must be incorporated into the diagnostic armamentarium and into decision-making. Once diagnosed, management of BDR focuses on ventilatory support, treatment of associated injuries and surgical repair of the diaphragmatic tear. Very few large-volume studies on BDR have been conducted.[1,2] The purpose of our study was to review the extensive experience with BDR at our hospital and highlight the recent changes in the diagnosis and management of the condition to update general surgeons who may have to treat patients with BDR.

Methods

The Sunnybrook Health Sciences Centre (Sunnybrook) is an urban tertiary level-1 trauma centre in Toronto, Ont. It is the oldest and largest trauma centre in the country, and it serves the greater Toronto (population of about 4 million people) and surrounding areas. All trauma patients are managed by a multidisciplinary trauma team. All patients undergo ultrasonography (the Focused Assessment with Sonography for Trauma; FAST) in the trauma room. Stable patients with potential head and abdominal injuries now routinely receive a computed tomographic (CT) angiography scan of the chest at the time of head and abdominal CT (done with intravenous contrast; no routine use of oral contrast), even when chest radiographs appear normal.

We retrospectively reviewed the cases of all blunt trauma patients with diaphragmatic rupture admitted to Sunnybrook between January 1986 and December 2003. We identified patients using our trauma registry, and we reviewed their medical charts for demographic data, mechanisms of injury, associated injuries, management and outcomes.

Statistical analysis

We expressed data in terms of numbers, means and percentages. We compared these values using standard statistical methods. We performed Student *t* and Fisher exact tests to compare our findings on patients with BDR with those on the entire cohort of blunt trauma patients admitted to our centre.

Results

A total of 10 779 patients with blunt trauma were admitted to Sunnybrook during the 18-year study period; of these, we identified 208 patients (1.9%) with BDR. To our knowledge, our study represents the largest single-institution experience with BDR reported in the literature.

Baseline characteristics and mortality of the BDR group and of all blunt trauma patients are presented in Table 1. Most patients were men (64.4%), and the mean age of patients was similar in both groups. Among those with BDR, 65.0% had a tear on the left side of the diagphragm, 22.5% had a tear on the right side and 2.0% had a tear on both sides. The Injury Severity Score (ISS) was significantly greater in the BDR group than among all blunt trauma

Table 1. Characteristics and mortality of trauma patients admitted to the Sunnybrook Health Sciences Centre between January 1986 and December 2003

Characteristic	Group: BDR *n* = 208	Group: All patients *n* = 10 779	*p* value
Male sex, %	64.4	72.2	—
Mean age, yr	42	39	—
Mean ISS	38.0	24.9	< 0.001
28-d mortality, %	28.8	13.4	< 0.001
Location of the diaphragmatic tear, no. (%)			
Left	135 (65.0)	—	—
Right	47 (22.5)	—	—
Bilateral	4 (2.0)	—	—

BDR = blunt diaphragmatic rupture; ISS = Injury Severity Score.

patients (38.0 v. 24.9; $p < 0.001$). The 28-day mortality was also significantly greater in the BDR group than among all blunt trauma patients (28.8% v. 13.4%; $p < 0.001$).

Table 2 describes the mechanisms of injury in the 208 patients with BDR compared with those in all blunt trauma patients. Of those injured in motor vehicle collisions (MVCs), a significantly greater percentage of patients in the BDR group than in the entire cohort of blunt trauma patients were drivers or front-seat passengers. Patients in the BDR group were less likely than those in the entire cohort to be pedestrians, to have experienced a fall or to be involved in a motorcycle collision.

We assessed seatbelt use and airbag protection among patients with BDR who were involved in an MVC. These results are summarized in Table 3. Most patients were either wearing both shoulder and lap belts or no belt at all. Those wearing both belts at the time of collision and whose airbags deployed represented a small percentage of patients with BDR.

Table 4 lists the points of impact for patients with BDR who were involved in an MVC. Most drivers were hit head-on or on the driver side, whereas front-seat passengers were more likely to have experienced frontal or passenger-side impact. There was no predominant point of impact among rear-seat passengers.

Table 5 lists the Abbreviated Injury Score (AIS; low = 1, severe = 6) for associated injuries in each anatomic area among patients with BDR compared with all blunt trauma patients. Patients in the BDR group had higher chest, abdomen, pelvis and extremity AIS scores than all blunt trauma patients as a whole. Table 6 describes the specific associated abdominal and chest injuries. The liver, spleen and small bowel/mesentery were often injured in patients with BDR. Most patients with BDR had rib fractures and pulmonary contusions. Of note, the thoracic aorta was injured

Table 2. Mechanism of injury among trauma patients admitted to the Sunnybrook Health Sciences Centre between January 1986 and December 2003

	Group; %		
Mechanism of injury	BDR $n = 208$	All patients $n = 10\,779$	p value
MVC, patient location			
Driver	53.4	35.3	< 0.001
Front-seat passenger	21.6	11.6	< 0.001
Rear-seat passenger	8.2	5.5	0.57
Pedestrian	3.8	13.2	< 0.001
Fall	2.0	9.4	< 0.001
Motorcycle	2.4	6.0	0.176

BDR = blunt diaphragmatic rupture; MVC = motor vehicle collision.

Table 3. Seatbelt protection among 208 patients with blunt diaphragmatic ruptures admitted to the Sunnybrook Health Sciences Centre between January 1986 and December 2003 who were injured as a result of a motor vehicle collision

Protection	% of patients
Shoulder and lap seatbelt	44.2
None	16.8
Seatbelt and airbag	3.8
Lap seatbelt only	1.4
Unknown	16.8

Table 4. Point of impact among 208 patients with blunt diaphragmatic ruptures admitted to the Sunnybrook Health Sciences Centre between January 1986 and December 2003 who were injured as a result of a motor vehicle collision

	Group; %		
Point of impact	Driver	Front-seat passenger	Rear-seat passenger
Frontal	16.2	19.9	5.9
Driver side	27.9	8.9	11.8
Passenger side	4.5	15.5	11.8
Angled	2.7	4.4	0
Single vehicle	10.8	4.4	5.9
Rear	0	2.2	5.9
Unknown	37.9	44.7	58.7

Table 5. Mean Abbreviated Injury Scale score among trauma patients admitted to the Sunnybrook Health Sciences Centre between January 1986 and December 2003, by site of injury

	Group; mean AIS score	
Site of injury	BDR	All patients
Chest	3.7	1.6
Abdomen	2.9	1.0
Pelvis	1.5	0.7
Head	2.6	2.5
Limb	2.2	1.7

AIS = Abbreviated Injury Scale; BDR = blunt diaphragmatic rupture.

Table 6. Associated injuries among patients with blunt diaphragmatic ruptures admitted to the Sunnybrook Health Sciences Centre between January 1986 and December 2003

Site of injury	% of patients
Abdomen	
Liver	63.5
Spleen	52.9
Small bowel / mesentery	46.2
Colon / rectum	30.3
Kidney	25.0
Bladder	15.4
Vascular	10.1
Stomach	5.3
Chest	
Rib fracture	75.5
Pulmonary contusion	63.0
Hemothorax	40.4
Hemopneumothorax	22.1
Flail chest	20.7
Pneumothorax	19.7
Cardiac contusion / laceration	18.8
Lung laceration	8.7
Thoracic aorta	7.7

in 7.7% of patients with BDR compared with 1.2% of all blunt trauma patients, representing a 6-fold increased risk.

With respect to management of BDR, 93.3% of patients received laparotomy and 1.4% received thoracotomy; the BDR was diagnosed at autopsy in 5.3%.

Table 7 lists the causes of death in the 60 patients with BDR who died within 28 days of injury. Head injury and intra-abdominal bleeding were the leading causes of death. Of note, pelvic fracture–related retroperitoneal bleeding was the cause of death in 18.3% of patients.

Discussion

During embryological development, the diaphragm develops such that its posterolateral portion is its weakest point, and it is this part that is injured most commonly. Usually, after a high-impact MVC or fall, a pressure gradient is created, resulting in a rupture at this weak point of the diaphragm.[3,4]

We performed a thorough search of the literature on BDR published from 1960 to 2006. Characteristics of some of the few studies previously published are summarized and compared with our study in Table 8.[5–7] About 88% of blunt diaphragmatic injuries reported in the literature were the result of MVCs with an overall reported incidence of BDR of up to 5%,[2,8,9] which is similar to our findings. The left side of the diaphragm was injured in most patients, possibly owing to the protective effect of the liver on the right side; we similarly observed a higher incidence of injuries to the left side of the diaphragm (65%). However, injuries to the right side are likely underreported because of the associated diagnostic difficulties.[10,11] In addition, the incidence of injuries to the right side of the diaphragm may be higher in countries where vehicles are driven on the right side of the road.[12]

Table 7. Cause of death among 60 patients with blunt diaphragmatic ruptures admitted to the Sunnybrook Health Sciences Centre between January 1986 and December 2003 who died within 28 days of injury

Cause of death	% of patients
Head injury	25.0
Intra-abdominal bleeding	23.3
Pelvic bleeding	18.3
Sepsis / multiple organ failure	6.7
Intrathoracic bleeding	5.0

Patients with BDR are often severely injured and have important associated injuries; chest and abdominal injuries are the most common, followed by pelvic and head injuries.[12,13] The spleen is more commonly injured among patients with diaphragmatic tears on the left side,[2] and the liver is more commonly injured among patients with tears on the right side.[2] The mean age of patients with BDR in the literature ranges from 32 to 65 years. The mean age in our study was 42 years. Injury Severity Scores range from 26.9 to 36.0 in the literature. In our study, the ISS was particularly high at 38.0, signifying the severity of the associated injuries.

Many patients require mechanical ventilation; however, paradoxically, once mechanical ventilation is started, detecting a diaphragmatic injury on radiographs may become more difficult because the positive pressure ventilation may push herniated contents down.[14]

The diagnostic tools used to detect BDR are the subject of controversy.[15] Radiography is a useful initial approach, but it was only able to confirm BDR preoperatively in 39% of patients in our study. Once mechanical ventilation is started,[14] serial radiographs and a Valsalva manoeuvre increase the efficacy of radiography.[16] In our study, CT scans were able to confirm BDR in only 6% of patients, but this method can be used as a useful adjunct. Intraoperative diagnosis was made in 45% of patients, and at least 38 cases of BDR were diagnosed after 48 hours either during second-look surgery, on chest radiographs, CT scans, radionuclide scans or magnetic resonance images. Computed tomography scans, ultrasounds, upper gastrointestinal studies, diagnostic peritoneal dialysis and radionuclide scans all have a low sensitivity to detect BDR.[6,7,12,17]

The biggest change in recent years in managing BDR has been the use of high-resolution, multislice CT angiography of the chest. This is now a routine test performed in most blunt trauma patients in level-1 trauma centres. Its impact has been seen in 2 areas. Increasingly, diaphragmatic tears are found on CT scans that otherwise would not have been picked up on chest radiographs; some of these have led to surgical repair. In addition, the now well established high degree of association with blunt aortic injury is being ruled in or out with a high degree of accuracy

Table 8. Comparison of characteristics of the present study with those of previously published studies involving patients with blunt diaphragmatic ruptures

Study	No. of patients	Location of rupture; no. of patients			Mean age, yr	No. of male patients	Mortality, %	Mean ISS
		Left	Right	Bilateral				
Present study	208	135	47	4	42	134	28.8	38.0
Bergeron et al.[7]	160	126	31	3	40	91	14.4	26.9
Brasel et al.[5]	32	25	7	0	41	18	22.0	32.0
Shapiro et al.[6]	21	14	7	0	34	17	25.0	36.0

ISS = Injury Severity Score.

early on in the work-up of blunt trauma patients, without the need for formal angiography.[18,19]

Reiff and colleagues[20] found that a combined frontal or near-side lateral occupant compartment intrusion greater than 30 cm, or a delta-velocity (the instantaneous velocity of the vehicle at the time of impact) substantially greater than 40 km/h with specific organ injuries (e.g., thoracic aortic tears, splenic injury, pelvic fractures and hepatic injuries) generated a sensitivity of 68%–89% for indicating the likelihood of diaphragm injury; we found a sensitivity of 91% for detecting BDR in patients with any of these characteristics. We also found a significant association between BDR and thoracic aortic rupture, pelvic and head injuries among patients who were injured as a result of an MVC in which they were drivers or front-seat passengers of the vehicle. Thus such injuries should raise the index of suspicion for a BDR. A useful clinical approach to BDR has been proposed by Guth and colleagues.[9]

Once diagnosed, treatment of the diaphragmatic tear is straightforward; primary repair of the defect is performed. In our view, laparotomy remains the gold standard, but there have been some case reports with successful laparoscopic repair. Thoracoscopic approach has also been used successfully[7,13] not only for repair, but also for diagnosis. Only 3 patients with BDR in our study underwent thoracoscopy and 197 underwent laparotomy. Because of the serious associated injuries, most commonly head, pelvis, abdomen and chest injuries, the mortality reported in the literature is high (10%–35%) Mortality in our study (28.8%) was on the higher end reported in the literature owing to the higher ISS in our patients. The most common causes of death reported in the literature are shock, multiple organ failure and head injuries.[7,13,21] In our study, we found head injuries to be the most common cause of death; however, if we had combined the number of deaths due to shock resulting from intra-abdominal, intrathoracic or pelvic bleeding, shock would have been the most common cause of death. We also observed that seatbelt use among our patients did not confer any protection against BDR, but this finding was not statistically significant.

Conclusion

Blunt diaphragmatic rupture is uncommon in trauma. We have, however, accumulated extensive experience with this condition over the past 2 decades. Early diagnosis and repair help avoid the late complications due to herniation of intra-abdominal contents into the chest.[22] Computed tomographic angiography is now essential to rule out associated aortic injury and for increased accuracy in the diagnosis of BDR. Patients with BDR often have severe associated injuries including the head, chest (including aorta), abdomen and pelvis that need to be diagnosed and managed expeditiously, as their severity and successful timely treatment will ultimately determine the patients' outcomes.

Competing interests: None declared.

Contributors: Drs. Chughtai, Ali and Rizoli designed the study. Drs. Sharkey and Lins acquired the data, which Drs. Chughtai and Rizoli analyzed. Drs. Chughtai, Ali, Lins and Rizoli wrote the article. Drs. Chughtai, Ali, Sharkey and Rizoli reviewed the article, which all authors approved for publication.

References

1. Shah R, Sabanathan S, Mearns AJ, et al. Traumatic rupture of diaphragm. *Ann Thorac Surg* 1995;60:1444-9.
2. Boulanger BR, Milzman DP, Rosati C, et al. A comparison of right and left blunt traumatic diaphragmatic rupture. *J Trauma* 1993;35: 255-60.
3. Haciibrahimoglu G, Solak O, Olcmen A, et al. Management of traumatic diaphragmatic rupture. *Surg Today* 2004;34:111-4.
4. Mihos P, Potaris K, Gakidis J, et al. Traumatic rupture of the diaphragm: experience with 65 patients. *Injury* 2003;34:169-72.
5. Brasel K J, Borgstrom, DC, Meyer P, et al. Predictors of outcome in blunt diaphragm rupture. *J Trauma* 1996;41:484-7.
6. Shapiro MJ, Heiberg E, Durham RM, et al. The unreliability of CT scans and initial chest radiographs in evaluating blunt trauma induced diaphragmatic rupture. *Clin Radiol* 1996;51:27-30.
7. Bergeron E, Clas D, Ratte S, et al. Impact of deferred treatment of blunt diaphragmatic rupture: a 15-year experience in six trauma centers in Quebec. *J Trauma* 2002;52:633-40.
8. Vermillion JM, Wilson EB, Smith RW. Traumatic diaphragmatic hernia presenting as a tension fecopneumothorax. *Hernia* 2001;5:158-60.
9. Guth AA, Pachter HL, Kim U. Pitfalls in the diagnosis of blunt diaphragmatic injury. *Am J Surg* 1995;170:5-9.
10. Gelman R, Mirvis SE, Gens D. Diaphragmatic rupture due to blunt trauma: sensitivity of plain chest radiographs. *AJR Am J Roentgenol* 1991;156:51-7.
11. Sharma OP. Traumatic diaphragmatic rupture: not an uncommon entity—personal experience with collective review of the 1980's. *J Trauma* 1989;29:678-82.
12. Thakore S, Henry J, Todd AW. Diaphragmatic rupture and the association with occupant position in right-hand drive vehicles. *Injury* 2001;32:441-4.
13. Williams M, Carlin AM, Tyburski JG, et al. Predictors of mortality in patients with traumatic diaphragmatic rupture and associated thoracic and/or abdominal injuries. *Am Surg* 2004;70:157-63.
14. Karmy-Jones R, Carter Y, Stern E. The impact of positive pressure ventilation on the diagnosis of traumatic diaphragmatic injury. *Am Surg* 2002;68:167-72.
15. Nau T, Seitz H, Mousavi M, et al. The diagnostic dilemma of traumatic rupture of the diaphragm. *Surg Endosc* 2001;15:992-6.
16. Eren S, Kantarci M, Okur A. Imaging of diaphragmatic rupture after trauma. *Clin Radiol* 2006;61:467-77.
17. Koplewitz BZ, Ramos C, Manson DE, et al. Traumatic diaphragmatic injuries in infants and children: imaging findings. *Pediatr Radiol* 2000;30:471-9.
18. Bergin D, Ennis R, Keogh C, et al. The 'dependent viscera' sign in CT diagnosis of blunt traumatic diaphragmatic rupture. *AJR Am J Roentgenol* 2001;177:1137-40.
19. Chughtai TS, Sharkey P, Brenneman F, et al. Blunt diaphragm rupture mandates a search for blunt aortic injury: an update. *Ann Thorac Surg* 2007;83:1234-5.
20. Reiff DA, McGwin G Jr, Metzger J, et al. Identifying injuries and motor vehicle collision characteristics that together are suggestive of diaphragmatic rupture. *J Trauma* 2002;53:1139-45.
21. Broos PL, Rommens PM, Carlier H, et al. Traumatic rupture of the diaphragm. Review of 62 successive cases. *Int Surg* 1989;74:88-92.
22. Reber PU, Schmied B, Seiler CA, et al. Missed diaphragmatic injuries and their long-term sequelae. *J Trauma* 1998;44:183-8.