Traumatic Injury of the Diaphragm: Report of Seven Cases and Extensive Literature Review

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Seven proven cases of traumatic rupture of the diaphragm (TRD) following blunt trauma and an extensive 32-article review of 1345 cases of penetrating and blunt trauma are presented. The distribution of TRD was relatively consistent through the decades, with 458 cases of penetrating trauma (34%) and 887 cases of blunt trauma (66%); less than 1% of the cases were iatrogenic. There were 853 left-sided cases (67.2%), 359 right-sided cases (28.3%), and 48 bilateral and 10 central tendon cases (4.5%). In penetrating TRDs, 188 were left-sided (50%), 158 right-sided (42%), and 30 bilateral (8%). In the blunt TRDs, 606 were left-sided (73.1%), 195 right-sided (23.5%), and 18 bilateral and 10 central tendon (3.4%). Over 94% of 926 cases had another organ injured along with the diaphragm. There was an overall mortality of 21.6%; however, no fatalities were directly related to the TRD. Eighty-seven percent of TRDs were diagnosed within 24 hours, 81% within 12 hours, and 72% in less than 6 hours. The location of the laceration along the surface of the diaphragm was imperfectly described in the literature, offering no statistical information.

The role of radiographic studies [plain films, barium studies, ultrasound, nuclear medicine, computed tomography (CT), and magnetic resonance imaging (MRI)] vs. surgical outcome in making the diagnosis of TRD is examined. Emphasis was placed on analyzing TRD in blunt trauma since it poses a more challenging clinical and radiographic dilemma in making a preoperative diagnosis. Plain radiographs were suggestive in 77% and diagnostic in 50% of TRD cases, while 47% were diagnosed at surgery and 3% by other radiologic studies. Barium studies are especially useful following a misdiagnosed TRD where the patient presents with a clinical history suspicious for strangulated abdominal viscera that occurred after herniation into the thorax.

Radionuclide scanning may demonstrate liver within the thorax that herniated following a right-sided TRD. The role of CT is uncertain since we found only 32 cases (3.6%) in which CT was utilized, and only six of these (18.2%) were diagnostic for TRD. Early studies using MRI show high accuracy in diagnosing TRD; it is especially valuable in uncertain cases. At present, nasogastric tube placement and serial chest radiographs are the recommended initial management for evaluating patients with potential TRD.

Key Words

Blunt; Diaphragm; Injuries; Penetrating; Trauma

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A 1993 report (1) stated that the incidence of traumatic rupture of the diaphragm (TRD) was only 0.8% of all patients admitted to a major trauma center, but the overall incidence of TRD is more likely to be in the range of 3–8% of all patients surviving blunt trauma (2–7). TRD is recorded in 3–8% of patients undergoing emergency surgery for blunt thoracoabdominal trauma (5, 8, 9). Autopsy studies by Andrus and Morton (10) and by Pagliarello and Carter (6) suggest that 5–10% of TRDs are never diagnosed antemortem.

Most authors agree that absence of distinct and specific diagnostic signs and symptoms makes the diagnosis of TRD difficult. About 77% of blunt trauma patients with TRD will have an abnormal chest radiograph; yet findings diagnostic for TRD are present in only about half of the patients. Many ruptures are discovered at laparotomy because up to 94% of TRD patients have other major injuries to the liver, spleen, brain, pelvis, spine, and lung. These may distract attention from the TRD as life-saving efforts are performed. Because of differential pressure between the abdomen and thorax, a diaphragmatic rupture predisposes to a herniation of abdominal contents into the thorax. Small TRDs may remain undiagnosed; a few enlarge and eventually herniate, which may lead to a strangulating obstruction years after the original injury.

MECHANISMS IN TRD

Although there may be similarities between the mechanisms in blunt and penetrating traumatic rupture, clearly the penetrating agent—usually a bullet or a blade—leaves telltale surface evidence of location and sometimes also of direction. In general, the penetrating injury will cause a shorter tear (less than 2 cm for entrance wounds) than blunt trauma. Guidelines for penetrating injury that is likely to affect the diaphragm include any injury penetrating anteriorly at or below the fourth intercostal space, laterally below the sixth intercostal space, or posteriorly below the eighth intercostal space.

Blunt TRD is a considerably more complex mechanism which may never be fully understood, and the tears are larger, frequently longer than 10 cm. There are two mechanisms that are said to result in blunt rupture of the diaphragm (10–13): (a) a force applied to the abdomen transmitted to the diaphragm by the abdominal viscera, and (b) a chest wall impact from a frontal or lateral crushing injury. The first mechanism causes TRD more commonly; it results in tears that occur randomly, but usually in the dome, with extensions laterally and posteriorly (2, 3, 11, 14–17). The thoracic crush is more likely to avulse the diaphragm from its peripheral attachments; associated rib fractures may also lacerate the diaphragm peripherally. Extensions of the laceration to the aortic, caval, or esophageal openings occur infrequently; however, when the tears involve these natural openings, pericardium, or *both* hemidiaphragms, more severe trauma has occurred, and great vessel injuries as well as higher mortality are likely (2).

RESULTS

Seven sequential cases of surgically proven TRD following blunt trauma between August 1991 and March 1993 at Ohio State University Hospitals are presented in Table 1. Cases 1–5 occurred on the left (71.4%), whereas cases 6 and 7 occurred on the right (28.6%). Case 1 was left-sided with extension to the central tendon, case 3 left and posterolaterally, case 5 laterally, case 6 right-sided with extension to the hepatosplenic ligament, and case 7 posteromedially. Cases 2 and 4 were not further specified. Cases 1–6 were diagnosed within 2 hours of admission (85.7%), whereas case 7 was diagnosed 9 days after injury. Cases 1–4 had abnormal chest radiographs (57.1%); cases 1–3 were diagnosed by virtue of a nasogastric tube (42.9%), and radiographs of case 4 suggested the TRD that was confirmed at surgery. Cases 5–7 were diagnosed at surgery (42.9%); these included one left-sided and two right-sided lacerations.

CASE STUDIES

Two representative cases are presented in greater detail to highlight the salient features and radiologic challenges associated with making the diagnosis of TRD.

Case 1

A 17-year-old male motor vehicle accident victim with tachycardia, hypotension, and abdominal pain became short of breath and vomited, requiring chemical paralysis and intubation. His initial portable anteroposterior chest radiograph showed a tubular gas pattern in the left lower thorax which admitted a nasogastric tube (Fig. 1A), confirming rupture of the left hemidiaphragm. Later, his breath sounds became decreased bilaterally, especially on the right, and a repeat chest radiograph (Fig. 1B) showed a right tension pneumothorax, pneumomediastinum, and left lung atelectasis with thoracostomy tube placement.

Case 7

A 46-year-old female victim of a right broadsided motor vehicle accident presented with bilateral chest pain, tachycardia, flail chest, and dyspnea. The initial chest radiograph (Fig. 2A) showed a right-sided hemopneumothorax, right distal clavicle fracture, and bilateral rib fractures for which she received chest tubes. An

TABLE 1

Seven Ohio State University Hospital cases of TRD from motor vehicle accidents between August 1991 and March 1993

Case	*Side*	*Location*	*Time to Diagnosis*	*How Diagnosis Made*
1	Left	10-cm transverse tear in central tendinous portion	<1 hour	Admission CXR* with NGT†
2	Left	?‡	<1 hour	Admission CXR with NGT
3	Left	Lateral abdominal wall posteriorly to esophageal hiatus	<1 hour	Admission CXR with NGT
4	Left	?	<1 hour	Abnormal pre-op CXR confirmed at surgery
5	Left	8 to 10-cm tear completely dividing entire lateral diaphragm	<2 hours	Surgery
6	Right	Large tear at hepatosplenic ligament	<1 hour	Surgery
7	Right	7 × 6-cm tear posteriorly along medial aspect	9 days after accident	Surgery

* Chest radiograph
† Nasogastric tube
‡ Data not provided

Figure 1A

Figure 1B

Figure 1A. Case 1. Chest radiograph after nasogastric tube placement shows the tip of the tube within the stomach (arrow), pneumomediastinum (arrowheads), and a subpulmonic pneumothorax (open arrows). Bilateral perihilar contusions are present. **B.** After endotracheal intubation, the pneumothorax and pneumomediastinum enlarge significantly; the mediastinum is balanced in the midline between the tension pneumothorax (right) and the tension enterothorax (left).

Figure 2A

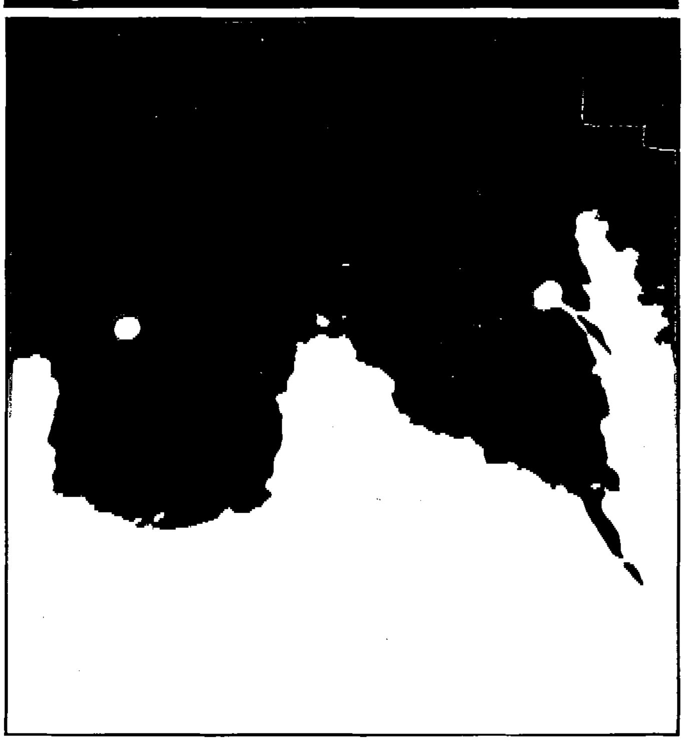

Figure 2B

Figure 2A. Case 7. Initial chest radiograph shows multiple right lateral rib fractures, indistinct right hemidiaphragm, and right pleural air and fluid. Subcutaneous emphysema extended over upper chest into neck (arrows). Diaphragm position and outline both appear normal. **B.** Day 7, neurosurgical intensive care unit radiograph shows progressive elevation and lateral doming of apparent right hemidiaphragm. Rib fractures are more obviously displaced.

abdominal CT scan confirmed the lower rib fractures, bilateral pneumothoraces (treated), multiple pelvic fractures, and a possible small liver laceration but no apparent hemoperitoneum, ascites, or TRD. A head CT showed subarachnoid and intraventricular hemorrhage. After intubation, the patient went to the neurosurgical intensive care unit for observation. For the following week, serial chest radiographs showed a persistently elevated right hemidiaphragm (Fig. 2B). Although stable during this period, the patient could not be weaned off the ventilator; on the ninth day, surgical intervention including tracheostomy, gastrostomy, and jejunostomy were performed, at which time the 7- × 6-cm tear posteriorly along the medial aspect of the right hemidiaphragm was discovered.

Case discussion

Case 1 suffered rupture of the left hemidiaphragm, lung parenchymal lacerations, and a right pneumothorax without a spine or rib fracture, typical of thoracic compliance of a younger patient (4). A branch of this stellate tear extended into the central tendon, which permitted communication of the right pneumothorax with the mediastinum and resulted in the pneumomediastinum. After endotracheal intubation, he developed the *right* tension pneumothorax from air leaking through the lacerated right lung under positive pressure ventilation. Despite his right tension pneumothorax, the mediastinum remained unshifted because of the increased volume and pressure exerted by the intrathoracic abdominal contents—the "tension enterothorax" (18). One technique for confirming a left-sided TRD is to place a nasogastric tube; the tube will usually follow the esophagus into the abdomen and the stomach into the thorax if sufficient tubing is inserted (19).

In case 7, the diagnosis was delayed for 9 days because priority consideration was being given to the patient's respiratory and neurologic status and because radiographic findings were masked by right basal atelectasis and liver plugging the laceration. The abdominal CT scan suggested only a small liver laceration and not the diagnosis of TRD. Several authors (5, 6) have commented that CT is misleading in TRD. Both the mechanism and extent of trauma together with the chest radiograph should have suggested TRD, yet the inability to see the diaphragm rupture on CT perhaps delayed further consideration. Typically, in right-sided TRD, radiographic studies are ambiguous, and the laceration usually is diagnosed incidentally at surgery (1, 20–22).

REVIEW OF ARTICLES, 1951–1993

As we reviewed the 32 articles and the results of 1345 cases of blunt and penetrating TRD already in the literature, we divided the cases into time periods based on the dates of publication of the series from recent to remote. Table 2A reviews those articles from the 1990s providing statistics for both blunt and penetrating TRD (1, 4–6, 8, 23–25). Table 2B reviews the articles published during the 1980s with statistics for blunt and penetrating TRD (2, 9, 13, 15, 16, 18, 26–33). Table 2C reviews the articles from the 1970s (3, 10, 14, 34–36). Table 2D reviews those initial articles prior to 1970 with blunt and penetrating trauma (11, 17, 21, 37). The reviewed cases date from 1926 to 1993. The perspectives of the authors have some important variations. Surgeons authored 26 of the articles (Tables 2A-D), surgeons and radiologists together authored two (17, 23), and radiologists authored four articles (8, 21, 26, 34). Older articles tend to lump blunt and penetrating TRD together because of the less apparent frequency of this entity in the past; newer articles tend to address only blunt diaphragmatic rupture and the special challenges of that diagnosis. The relative frequency of blunt vs. penetrating TRD seems more an important descriptor of the demography of the institution from which the cases arose than it is as a clinical aid or diagnostic tool. Our tabulation concludes (Table 2E) that 458 cases (34%) were penetrating, whereas 887 (66%) were due to blunt trauma, and less than 1% of TRDs were iatrogenic. Table 2E also presents the accumulated statistics by decades for sidedness: we found 853 left-sided cases (67.2%), 359 right-sided cases (28.3%), and 48 bilateral and 10 central tendon cases (4.5%). Over 94% of the 926 cases we reviewed had other organs injured at the time of TRD (Tables 2A-D). Twenty-seven of the 32 articles reviewing 1223 cases tabulated a mortality of 21.6% (Tables 2A-D).

In Table 3 the *penetrating TRDs* are tabulated by side, with 188 left-sided (50%), 158 right-sided (42%), and 30 bilateral (8%). The side of the TRD was not specified in 82 penetrating cases.

TABLE 2A

Review of articles from the 1990's which provided statistics for both *penetrating and blunt* TRD (n = 342 cases)

Author	*Area of Training*	*Period*	*Total # Cases*	*Total # Left (%)*	*Total # Right (%)*	*Total # Bilateral (%)*	*Total # Central (%)*	*Multiple Injuries # (%)*	*Mortality # (%)*
Boulanger 1993	Surg	1986–1991	80	59 (74)	16 (20)	5 (6)	0	80 (100)	33 (41)
Brandt 1992	Ped Surg	1972–1990	13	10 (77)	3 (23)	0	0	9 (69)	2 (15)
Ilgenfritz 1992	Surg	1983–1989	52	39 (75)	12 (23)	1 (2)	0	52 (100)	7 (13)
Pagliarello 1992	Surg	1986–1990	43	32 (74)	8 (19)	3 (7)	0	40 (93)	13 (30)
McHugh 1991	Rad	1978–1988	9	7 (78)	2 (22)	0	0	?*	?
Chen 1991	Surg	1979–1989	62	41 (66.1)	20 (32.3)	1 (1.6)	0	62 (100)	14 (22.6)
Gelman 1991	Rad/Surg	1983–1989	50	44 (88)	6 (12)	0	0	42 (84)	?
Voeller 1990	Surg	1983–1988	33	19 (58)	13 (39)	1 (3)	0	33 (100)	8 (24)

* Data not provided

TABLE 2B

Review of articles from the 1980's which provided statistics for both *penetrating and blunt* TRD (n = 588 cases)

Author	*Area of Training*	*Period*	*Total # Cases*	*Total # Left (%)*	*Total # Right (%)*	*Total # Bilateral (%)*	*Total # Central (%)*	*Multiple Injuries # (%)*	*Mortality # (%)*
Sharma 1989	Surg	1976–1988	28	20 (72)	8 (28)	0	0	22 (79)	2 (9)
Van Vugt 1989	Surg	1977–1988	28	?*	?	?	?	28 (100)	8 (28.6)
Kearney 1989	Surg	?	76	60 (78.9)	13 (17.1)	3 (4.0)	0	?	42 (51)
Jamous 1989	Surg	?	6	2 (33.3)	2 (33.3)	0	2 (33.3)	?	?
Beal 1988	Surg	1986–1987	37	24 (65)	11 (30)	2 (5)	0	36 (97)	15 (41)
Flancbaum 1988	Surg	1984–1986	9	7 (78)	1 (11)	0	1 (11)	9 (100)	1 (11)
Freixinet 1987	Surg	1978–1985	33	20 (61)	13 (39)	0	0	?	6 (18)
Harms 1987	Surg	1977–1987	26	19 (73)	7 (27)	0	0	20 (77)	1 (4)
Rodriguez 1986	Surg	1974–1983	60	39 (65)	18 (30)	1 (2)	2 (3)	?	16 (27)
Wiencek 1986	Surg	1980–1985	165	78 (47.3)	62 (37.6)	25 (15)	0	157 (95)	22 (13)
Morgan 1986	Surg	1979–1984	44	33 (75)	8 (18)	1 (2.5)	2 (4.5)	44 (100)	9 (20.4)
Beauchamp 1984	Surg	1970–1981	24	20 (83)	3 (13)	0	1 (4)	20 (83)	3 (13)
Ball 1982	Rad	Several years	42†	33 (79)	9 (21)	0	0	?	?
Ward 1981	Surg	1976–1979	16	12 (75)	4 (25)	0	0	16 (100)	4 (25)

* Data not provided

† 42 total cases = 17 penetrating + 19 blunt + 6 iatrogenic

TABLE 2C

Review of articles from the 1970's which provided statistics for both *penetrating and blunt* TRD (n = 316 cases)

Author	*Area of Training*	*Period*	*Total # Cases*	*Total # Left (%)*	*Total # Right (%)*	*Total # Bilateral (%)*	*Total # Central (%)*	*Multiple Injuries # (%)*	*Mortality # (%)*
Fataar 1979	Rad	1966–1976	47	40 (85)	7 (15)	0	0	?*	2 (4)
Estrera 1979	Surg	1973–1978	62	34 (54.8)	27 (43.6)	1 (1.6)	0	?	10 (15)
Freeman 1976	Surg	1964–1976	38	24 (63)	13 (34)	1 (3)	0	38 (100)	14 (37)
McCune 1976	Surg	1954–1976	27	21 (78)	6 (22)	0	0	?	6 (22)
Wise 1973	Surg	1962–1971	110	68 (62)	40 (36)	2 (2)	0	100 (91)	15 (14)
Andrus 1970	Surg	1939–1970	32	26 (81)	5 (16)	1 (3)	0	30 (94)	5 (16)

* Data not provided

TABLE 2D

Review of articles from before 1970 which provided statistics for both *penetrating and blunt* TRD (n = 99 cases)

Author	*Area of Training*	*Period*	*Total # Cases*	*Total # Left (%)*	*Total # Right (%)*	*Total # Bilateral (%)*	*Total # Central (%)*	*Multiple Injuries # (%)*	*Mortality # (%)*
Ebert 1967	Surg	1926–1965	53	?*	?	?	?	?	2 (4)
Desforges 1957	Surg	1950's	16	15 (94)	1 (6)	0	0	15 (94)	3 (19)
Peck 1957	Rad	1945–1957	21	0	21 (100)	0	0	12 (60)	?
Carter 1951	Surg/Rad	1932–1947	9	7 (78)	0	0	2 (22)	5 (56)	1 (11)

* Data not provided

TABLE 2E

Historical review of 32 articles (1345 cases) of *blunt and penetrating* TRD (n = 1345 cases)

	Before 1970	*1970s*	*1980s*	*1990s*	*Totals*
Authors	Ebert, Desforges*, Peck, Carter	Fataar, Estera, Freeman*, McCune*, Wise, Andrus*	Sharma, Van Vugt*, Kearney*, Jamous*, Beal*, Flancbaum*, Freixinet, Harms*, Rodriguez*, Wiencek, Morgan*, Beauchamp, Ball, Ward*	Boulanger*, Brandt, Ilgenfritz*, Pagliarello, McHugh*, Chen, Gelman*, Voeller*	All 32 articles
Penetrating # (%)	37 (37.4)	160 (50.6)	199 (33.8)	62 (18.1)	458 (34.1)
Blunt # (%)	62 (62.6)	156 (49.4)	389 (66.2)	280 (81.9)	887 (65.9)
Total Cases	99 (7.4)	316 (23.5)	588 (43.7)	342 (25.4)	1345
Left # (%)	22 (47.8)	213 (67.4)	367 (64.8)	251 (73.4)	853 (67.2)
Right # (%)	22 (47.8)	98 (31.0)	159 (28.1)	80 (23.4)	359 (28.3)
Bilateral and Central # (%)	2 (4.4)	5 (1.6)	40 (7.1)	11 (3.2)	58 (4.5)
Total Cases	46 (3.6)	316 (24.9)	566 (44.6)	342 (26.9)	1270

* Eighteen authors who presented only blunt TRD (total 639 of 887 cases)

TABLE 3

Review of 13 articles from 1951 to 1992 which provided statistics for *penetrating* TRD (n = 458 cases*)

Author	*# Cases (%)*†	*# Left (%)*	*# Right (%)*	*# Bilateral (%)*	*# Central (%)*
Brandt 1992	8 (62)	5 (63)	3 (37)	0	0
Pagliarello 1992	9 (21)	4 (44.5)	4 (44.5)	1 (11)	0
Chen 1991	45 (73)	27 (60)	17 (38)	1 (2)	0
Sharma 1989	9 (32)	4 (45)	5 (55)	0	0
Freixinet 1987	19 (58)	7 (37)	12 (63)	0	0
Wiencek 1986	154 (93)	71 (46)	58 (38)	25 (16)	0
Ball 1982	17 (40)	?‡	?	0	0
Fataar 1979	36 (77)	?	?	0	0
Estrera 1979	39 (63)	20 (51.3)	18 (46.1)	1 (2.6)	0
Wise 1973	85 (88)	46 (54)	37 (44)	2 (2)	0
Ebert 1967	29 (55)	?	?	?	?
Peck 1957	4 (19)	0	4 (100)	0	0
Carter 1951	4 (44)	4 (100)	0	0	0

* Side specified in only 376 cases = 188 left + 158 right + 30 bilateral; side not specified in 82 cases
† Percent of total cases
‡ Data not provided

In the cases of *blunt TRD*, Table 4A presents a summary of our 32 articles, giving case numbers and percentages for left-sided TRDs, right-sided TRDs, and bilateral and central TRDs. Table 4B summarizes those statistics: 606 left-sided (73.1%), 195 right-sided (23.5%), and 18 bilateral and 10 central tendon (3.4%). The side of TRD was not specified in 58 cases of blunt trauma.

Table 5 summarizes from each of the 32 articles the main features of blunt TRD, namely: (a) their location, (b) the time to diagnosis, (c) how the diagnosis was made, and (d) recommendations the authors may have for making this diagnosis. Only 25% of the authors accurately and specifically described the laceration (Table 5). We encountered terms such as "stellate" or "linear" and many that were 8–11 cm in length (2, 3, 11, 14–17). The time to diagnosis of less than 24 hours was accomplished in 87% of cases; 81% were diagnosed in less than 12 hours, whereas 77% were diagnosed in less than 6 hours (Table 5). From 30 articles, the diagnosis of TRD was reportedly made by chest radiography (Table 5) on average 50% of the time and during surgery 47% of the time. Other radiologic studies were used 3% of the time to confirm the diagnosis. Less specifically, from these articles chest

TABLE 4A

Review of 32 articles from 1951 to 1993 providing statistics for *blunt* TRD (n = 887 cases)

Author	*# Cases (%)*	*# Left (%)*	*# Right (%)*	*# Bilateral (%)*	*# Central (%)*
Boulanger 1993	80 (100)	59 (74)	16 (20)	5 (6)	0
Brandt 1992	5 (38)	5 (100)	0	0	0
Ilgenfritz 1992	52 (100)	39 (75)	12 (23)	1 (2)	0
Pagliarello 1992	34 (79)	28 (82)	4 (12)	2 (6)	0
McHugh 1991	9 (100)	7 (78)	2 (22)	0	0
Chen 1991	17 (27)	6 (35)	11 (65)	0	0
Gelman 1991	50 (100)	44 (88)	6 (12)	0	0
Voeller 1990	33 (100)	19 (58)	13 (39)	1 (3)	0
Sharma 1989	19 (68)	16 (84)	3 (16)	0	0
Van Vugt 1989	28 (100)	?*	?	?	?
Kearney 1989	76 (100)	60 (78.9)	13 (17.1)	3 (4.0)	0
Jamous 1989	6 (100)	2 (33.3)	2 (33.3)	0	2 (33.3)
Beal 1988	37 (100)	24 (65)	11 (30)	2 (5)	0
Flancbaum 1988	9 (100)	7 (78)	1 (11)	0	1 (11)
Freixinet 1987	14 (42)	13 (93)	1 (7)	0	0
Harms 1987	26 (100)	19 (73)	7 (27)	0	0
Rodriguez 1986	60 (100)	39 (65)	18 (30)	1 (2)	2 (3)
Wiencek 1986	11 (7)	7 (64)	4 (36)	0	0
Morgan 1986	44 (100)	33 (75)	8 (18)	1 (2.5)	2 (4.5)
Beauchamp 1984	24 (75)	20 (83)	3 (13)	0	1 (4)
Ball 1982	19 (45)	?	?	0	0
Ward 1981	16 (100)	12 (75)	4 (25)	0	0
Fataar 1979	11 (23)	?	?	0	0
Estrera 1979	23 (37)	14 (61)	9 (39)	0	0
Freeman 1976	38 (100)	24 (63)	13 (34)	1 (3)	0
McCune 1976	27 (100)	21 (78)	6 (22)	0	0
Wise 1973	25 (22)	22 (88)	3 (22)	0	0
Andrus 1970	32 (100)	26 (81)	5 (16)	1 (3)	0
Ebert 1967	24 (45)	22 (92)	2 (8)	0	0
Desforges 1957	16 (100)	15 (94)	1 (6)	0	0
Peck 1957	17 (81)	0	17 (100)	0	0
Carter 1951	5 (56)	3 (60)	0	0	2 (40)

* Data not provided

radiographs were felt to be abnormal in 77% of the cases. Our review uncovered 33 cases (3.6%) where CT was used (1, 6, 9, 23, 24, 26, 31, 38, 39), and of these, 6 were considered diagnostic (18.2%). A few reports of the use of MRI in the diagnosis are included (23, 40–42). Daum-Kowalski et al. (41) used it to successfully diagnose TRD. Boulanger et al. (40) used MRI five times in highly suggestive TRD patients; it diagnosed two true-positives and confirmed three surgically proven true-negatives. Most authors recommend a high index of suspicion, nasogastric tube placement, and serial chest radiographs to monitor the patient's course (Table 5), for herniation may lag significantly behind rupture and does not necessarily occur simultaneously.

Discussion of articles

In dividing our cases by decades, we looked for trends from the literature in the number of cases of penetrating and blunt TRD, side involved, associated injuries, mortality, location of rupture, and time to diagnosis (Tables 2E and 5). Four articles before 1970 (Table 2E) provided a total of 99 cases, 37 of them due to penetrating injury and 62 due to blunt trauma. One article (21) provided 17 right-sided TRD cases (17% of all cases for this period), skewing statistically the relative incidence of left compared to right-sided TRD in that decade. Since we were concerned more with the blunt ruptures (Table 4B), we calculated the side

TABLE 4B

Historical review of 32 articles of *blunt* TRD (n = 829 cases*)

Date	*Before 1970*	*1970s*	*1980s*	*1990s*	*Totals*
Authors	Ebert, Desforges, Peck, Carter	Fataar, Estera, Freeman, McCune, Wise, Andrus	Sharma, Van Vugt, Kearney, Jamous, Beal, Flancbaum, Freixinet, Harms, Rodriguez, Wiencek, Morgan, Beauchamp, Ball, Ward	Boulanger, Brandt, Ilgenfritz, Pagliarello, McHugh, Chen, Gelman, Voeller	All 32 articles
Left # (%)	40 (64.5)	107 (73.8)	252 (73.7)	207 (73.9)	606 (73.1)
Right # (%)	20 (32.3)	36 (24.8)	75 (21.9)	64 (22.9)	195 (23.5)
Bilateral # (%)	2 (3.2)	2 (1.4)	15 (4.4)	9 (3.2)	28 (3.4)
Total Cases	62 (7.5)	145 (17.5)	342 (41.2)	280 (33.8)	829

* Side not specified in 58 cases of blunt TRD; therefore, 887 − 58 = 829 cases

TABLE 5

Summary of 32-article review from 1951 to 1993 which provided location, time to diagnosis and how diagnosis made for *blunt* TRDs along with authors' final diagnostic recommendations

Author	*Location of TRD*	*Time to Diagnosis*	*How Diagnosis Made*	*Authors' Recommendations*
Boulanger 1993	Randomly presented	80% <4 hours 99% <24 hours	22 chest x-ray diagnosis (27.5%) 52 surgical diagnosis (65%) 6 CT or MR (7.5%)	High index of suspicion Chest x-ray
Brandt 1992	?*	<24 hours	60% chest x-ray diagnosis 20% barium swallow diagnosis (abnormal CXR† also) 20% surgical diagnosis	High index of suspicion Chest x-ray (most important), serial
Ilgenfritz 1992	48% dome 30% lateral 4% hiatus 18% unknown	73% <4 hours 19% 4–12 hours 8% 12 hours to 3 weeks	50% chest x-ray diagnosis 50% surgical diagnosis 1 CT: nondiagnostic	High index of suspicion Chest x-ray
Pagliarello 1992	?	Mean = 7 hours All <12 hours except 1?	62% chest x-ray diagnosis 38% surgical diagnosis 2 CT: 1 diagnostic + 1 nondiagnostic	Chest x-ray best Not CT
McHugh 1991	?	1–16 years Mainly 1–6 years +16 Mean = 4.3 years	100% chest x-ray abnormal (delay) 2 fluoroscopy: diagnostic 6 barium swallow: diagnostic 2 ultrasound: 1 diagnostic + 1 nondiagnostic	Chest x-ray + barium swallow (delayed) High index of suspicion Liver-spleen scan (right)
Chen 1991	?	<24 hours	Chest x-ray: 71% diagnostic, 100% abnormal 11 CT: 6 blunt + 5 penetrating; 7 left + 4 right; all 11 nondiagnostic 1 upper GI: diagnostic 2 fluoroscopy: both diagnostic	Chest x-ray Not CT

(Continues)

TABLE 5—Continued

Author	*Location of TRD*	*Time to Diagnosis*	*How Diagnosis Made*	*Authors' Recommendations*
Gelman 1991	?	98% <2–5 hours	Chest x-ray: 52% diagnostic, 86% abnormal 7 CT: 1 diagnostic + 6 nondiagnostic 2 MR: both diagnostic 1 fluoroscopy: diagnostic 2 upper GI: both diagnostic 1 ultrasound: nondiagnostic 46% surgical diagnosis	High index of suspicion Chest x-ray MR excellent Not CT
Voeller 1990	?	88% immediate 12% 8–96 hours	Chest x-ray: 27% diagnostic, 85% abnormal 4 CT: all 4 nondiagnostic 1 barium swallow: nondiagnostic Chest x-ray abnormal 78% right	Chest x-ray early + late Others not beneficial High index of suspicion If admission chest x-ray normal, follow-up chest x-rays
Sharma 1989	Left posterolateral most common 38% esophageal hiatus upward + anterolateral	<4 hours	Chest x-ray 41% diagnosis 2 CT: 1 diagnostic + 1 nondiagnostic	?
Van Vugt 1989	?	82% <24 hours 18% > 24 hours to 8 years	Chest x-ray 50% diagnosis Surgical 39% diagnosis Autopsy 11% diagnosis	Chest x-ray + high index of suspicion best (NGT[‡]) Upper GI CT urgent cases Laparotomy or thoracotomy
Kearney 1989	32% dome 14% posterior 2% lateral/medial 52% unknown	?	?	High index of suspicion Chest x-ray Not CT Liver-spleen scan (right)
Jamous 1989	?	?	Chest x-ray 66.6% diagnosis 1 CT: diagnostic (right) 1 surgical diagnosis	?
Beal 1988	?	?	36 abnormal chest x-ray (97.3%) 15 chest x-ray: diagnostic (40.5%) 22 surgical: diagnostic (59.5%)	Chest x-ray
Flancbaum 1988	?	<4 hours	Chest x-ray: 44% diagnostic, 89% abnormal 44% surgical diagnosis 2 CT: 1 diagnostic + 1 nondiagnostic	High index of suspicion Chest x-ray
Freininet 1987	?	?	25 chest x-ray: diagnostic (75.8%) 8 surgical: diagnostic (24.2%)	Chest x-ray
Harms 1987	?	69.2% <48 hours	8 chest x-ray: diagnostic (30.8%) 10 surgical: diagnostic (38.5%)	High index of suspicion Chest x-ray More CT
Rodriguez 1986	?	96.7% <24 hours	24 chest x-ray: diagnostic (40%)	High index of suspicion Chest x-ray
Wiencek 1986	?	?	Chest x-ray: 18% diagnostic, 100% abnormal	High index of suspicion, chest x-ray
Morgan 1986	?	93% <6 hours 7% at 3–5 days	Chest x-ray: 32% diagnostic, 92% abnormal 11% DPL[§] fluid from chest tube 5% upper GI diagnostic 2% CT: diagnostic 50% surgical diagnosis	High index of suspicion Chest x-ray best DPL Upper GI CT

(*Continues*)

TABLE 5—Continued

Author	*Location of TRD*	*Time to Diagnosis*	*How Diagnosis Made*	*Authors' Recommendations*
Beauchamp 1984	?	83.3% <72 hours	15 chest x-ray: diagnostic (62.5%) 5 surgical: diagnostic (20.8%)	High index of suspicion Chest x-ray Liver-spleen for right
Ball 1982	?	Acute phase (<14 days) 47% Interval phase (>14 days–strangulation) 26.5% Obstructive phase 26.5%	Acute phase: serial chest x-ray: 100% diagnostic Interval phase: Radiography 57% diagnostic, 43% nondiagnostic Obstructive phase: Radiography 56% diagnostic, 39% nondiagnostic 1 pneumoperitoneum: diagnostic	High index of suspicion Chest x-ray best (serial); also barium, liver-spleen scan (right)
Ward 1981	53% left posterolateral 24% right lateral 18% left anterolateral 5% left dome	94% <24 hours 6% at 5 weeks	Chest x-ray 19% diagnosis 1 chest x-ray + fluoroscopy diagnosis 4 angio: 3 diagnostic + 1 nondiagnostic 4 surgical diagnosis 1 pneumothorax	No consistent way to diagnose
Fataar 1979	?	?	?	High index of suspicion Chest x-ray Barium studies
Estrera 1979	No particular pattern	44% within a few hours 61% <24 hours 39% >24 hours to weeks	Chest x-ray: 61% diagnosis + 39% nondiagnostic; 100% abnormal	High index of suspicion, chest x-ray: serial (best)
Freeman 1976	?	?	12 chest x-ray: diagnostic (38.7%) 19 surgical: diagnostic (50%)	
McCune 1976	?	44.4% <6 hours	24 chest x-ray: abnormal (88.9%) 20 chest x-ray: diagnostic (74.1%)	High index of suspicion Chest x-ray
Wise 1973	?	92.7% <24 hours	?	Chest x-ray Barium studies
Andrus 1970	Dome or posterior most common Left dome most common	47% <7 days	Chest x-ray: initial 81% diagnosis, serial 100% diagnosis 1 Barium swallow + fluoroscopy: diagnostic (after CXR diagnosis; delayed case) 2 other barium studies diagnostic in delayed cases 1 pneumoperitoneum: diagnostic	Chest x-ray
Ebert 1967	58% posterocentral area 21% anterior, lateral wall 21% dome left	25% <24 hours 37.5% initial hospital diagnosis 62.5% diagnosis after hospital discharge	Chest x-ray	High index of suspicion Chest x-ray followed by barium Serial CXR
Desforges 1957	Left dome + parapericardial (anterior and medial)	25% <48 hours 25% <5 days 35% <1 month	Serial chest x-ray: 81% diagnostic Chest x-ray + NGT: 6% diagnostic Chest x-ray + barium swallow 13% diagnostic, (100% chest x-ray diagnostic)	High index of suspicion Serial chest x-ray (upright) NGT + barium Not fluoroscopy
Peck 1957	?	18% prompt diagnosis 12% at 3–6 months 29% at 2–2.5 years 29% at 4–10 years 6% at 20 years 6% at 44 years	47% surgical diagnosis 18% pneumoperitoneum: diagnostic 23% unknown 6% chest x-ray + fluoroscopy: diagnostic 6% barium study: diagnostic	High index of suspicion Chest x-ray Also fluoroscopy, barium, and pneumoperitoneum

(*Continues*)

TABLE 5—Continued

Author	*Location of TRD*	*Time to Diagnosis*	*How Diagnosis Made*	*Authors' Recommendations*
Carter 1951	1 dome (20%)	40% < prompt diagnosis	Chest x-ray: 80% diagnostic, 100% abnormal	High index of suspicion
	1 posterolateral (20%)	20% <24 hours	20% surgical diagnosis	Chest x-ray
	1 anterolateral (20%)	20% at 10 weeks	4 barium swallow: 3 diagnostic + 1 nondiagnostic	Barium studies
	2 central tendon (40%)	20% at 11 months		
Summary of all 32 articles		<6 hours:276/359 = 76.9%	Chest x-ray: diagnostic (49.5%)	
		<12 hours:319/393 = 81.2%	Chest x-ray: abnormal (76.9%)	
		<24 hours:496/570 = 87.0%	Surgical diagnosis (46.6%)	

* Data not provided
† Chest radiograph
‡ Nasogastric tube
§ Diagnostic peritoneal lavage

involved as the left side 64.5% of the time and the right 32.2% of the time, and central or bilateral as 3.2%.

Six articles from the 1970s provided an additional 316 cases (Table 2E), but only 156 of these were due to blunt trauma. Because one author (36) failed to provide information about the side ruptured, 11 of our cases had to be excluded, leaving 145 TRDs with sidedness identified (Table 4B). One hundred seven were left-sided (73.8%), 36 were right-sided (24.8%), and 2 were bilateral (1.4%). There were 14 articles from the 1980s providing an additional 588 cases to the literature of blunt and penetrating trauma (Table 2E), of which 389 (66.2%) were from blunt trauma. Two of the original 14 authors (26, 33) did not provide information about the side involved in their cases, leaving 342 cases (Table 4B) from which we identified 252 (73.7%) left-sided, 75 (21.9%) right-sided, and 15 bilateral or central (4.4%). In the 1990s, there were eight articles totaling 342 cases (Table 2E) of which 280 (81.9%) addressed blunt trauma (Table 4B). Of these, left-sided blunt ruptures occurred in 207 (73.9%), whereas right-sided ruptures occurred in 64 (22.9%), and bilateral ruptures occurred in nine (3.2%). Summarizing the experience from the decades, blunt ruptures of the left hemidiaphragm ranged from 64.5% prior to the 1970s to 73.9% in the 1990s with a mean percentage for left-sided ruptures of 73.1% (Table 4B). Right-sided ruptures ranged from 21.9% in the 1980s to 32.3% prior to the 1970s, with a mean of 23.5% over the decades. Bilateral and central ruptures ranged from 1.4% in the 1970s to 4.4% in the 1980s, for a mean of 3.4% for cases over the decades. There clearly are increasing numbers of penetrating *and* blunt trauma cases reported, and marked changes have occurred in surgical skills, diagnostic skills, the availability of emergency medical technicians, and access to trauma centers; each considered, we find these figures remarkably stable. Furthermore, they compare favorably with our 71% left-sided and 29% right-sided figures for the short series we present. For all cases, the ratio of left- to right-sided ruptures appears to be remaining constant at 3.1:1.

Although there were no fatalities in our group, all seven of our cases had multiple injuries, and the review of literature indicates that multiple injuries were present in 94% of 926 cases (Tables 2A-D). In the largest series, mortalities ranged from 17 to 22%, for a mean fatality from 1223 cases of 21.6% (Tables 2A-D). It is important, however, to note that TRD was *not* the cause of the patient's death; other injuries caused the patient's demise (10, 27). Andrus and Morton (10) reported only nine cases from 20,000 autopsies in motor vehicle accidents where TRD was considered a contributing cause of death.

Concerning location of the laceration, Kearney et al. (13) found that frontal and left lateral blunt impacts resulted in more left-sided than right-sided TRDs. They found that frontal impacts resulted in more posterior tears than ones in the dome of the diaphragm. Left or right lateral impacts resulted in more dome than posterior tears, and right lateral impacts resulted in more right than left TRDs. TRD as an isolated injury is rare and may be recognized only when herniation occurs; hence, when the tear is small, the lesion may go unrecognized and untreated. Children, with more pliable torsos, are most likely to suffer such tears.

The time to diagnosis has shortened through the decades so that now 87% are diagnosed within 24 hours, 81% diagnosed in 12 hours, and 77% in less than 6 hours (Table 5). More recent authors have stated that TRD not diagnosed within 24 hours is "significantly delayed" (1). Six of our seven cases were diagnosed within 1–2 hours of admission, probably because our clinicians have a high index of suspicion, better life support assistance, and improved portable chest radiographic technology. Sicker patients also now arrive at our trauma center alive because of improved handling, life support, and transportation. Lives saved remain relatively constant. In the 1970s, less than 13% of 94 cases were diagnosed within 24 hours (Table 5). Before the 1970s, the diagnosis was considered acute if less than 7–14 days from injury (Table 5); now acute diagnosis means 2–24 hours from initial presentation (1, 4–6, 8, 23, 24). The diagnosis of TRD was delayed in one of our right-sided cases (case 7) for more than 24 hours, despite quality chest radiography, CT examination, and experienced trauma surgeons. In 25 articles listed in Table 5 that specified the time required to diagnose TRD, delay was more than 24 hours in about 13% of blunt trauma cases.

DIAGNOSTIC FINDINGS

The initial evaluation in trauma associated with TRD is clinical; penetrating injuries where the missile or stab vectors can be guessed usually suggest the diagnosis. In blunt trauma, the diagnosis should be considered whenever the torso receives a crushing impact. The triad described by Bergqvist et al. (43) consists of diaphragmatic rupture with pelvis and/or spinal fractures in a patient who also has rib fractures; adding head trauma to this list improves the otherwise nonspecific nature by signaling more severe trauma. When a significant volume of abdominal contents herniates into the pleural space, the abdomen may become scaphoid; this is called Gibson's sign (4, 10). Vomiting with a scaphoid abdomen may signal obstruction or strangulation, but this has not been described often with TRD in recent years. The clinician hearing bowel sounds within the thorax and encountering unusual dullness at the lung base must suspect a TRD. Sudden, severe respiratory distress and peritonitis are two additional clinical presentations of TRD that require emergent diagnosis and treatment (44). Elevated central venous pressure in a *hypotensive* patient should make one consider TRD, because TRD reflects many of the signs associated with mediastinal shift: tension pneumothorax, pericardial tamponade, or superior vena cava compression by a mediastinal hematoma (Robert J. Freeark, M.D., personal communication, January 1994; see also discussion notes in Ref. 36).

The chest roentgenogram is usually the first diagnostic study in the injured patient with a ruptured diaphragm; in about 77% of cases, the chest radiograph will provide enough information to suggest TRD (Table 5). The direct diagnostic findings on radiography are the presence of extraneous bowel gas or air-fluid levels within the thorax (Fig. 3A and B). Indirect findings to search for include an unusual appearance of the affected hemidiaphragm; this may be an arcuate shadow along the expected edge of the diaphragm or just a blunted costophrenic angle. Atelectasis is frequently present in torso trauma without TRD, but TRD without herniation must still be considered. Mediastinal shift may be seen without TRD from fluid or air in the pleural space, but TRD with herniated abdominal contents may also be causing it. Ventilator-assisted respiration may delay herniation across the tear because the assisted respiration increases intrathoracic pressure sufficiently to overcome the usual thoracoabdominal gradient. Ancillary plain film findings to seek include presence of fractured lower ribs, pulmonary contusion and laceration, transient pleural effusions that seem apparently to be depending on body position, or the inability to recover peritoneal dialysis fluid in the emergency setting. Diaphragmatic laceration will occasionally extend into the

Figure 3A

Figure 3B

Figure 3A. TRD (iatrogenic) on left 10 years after left nephrectomy with lateral and cephalic bulge that had slowly enlarged; it caused no symptoms. **B.** The TRD contains stomach and colon but neither ring nor beak implying any obstruction.

pericardium; then the clinical issue may be pericardial tamponade, and the chest radiograph may show air-fluid levels within the pericardium. When the chest is the principal target of the trauma rather than the abdomen, and TRD is suspected, one should also search for associated rupture of the aorta (10).

For left-sided TRD, Perlman et al. (19) described placing a long nasogastric tube into the stomach to see whether it passes into the thorax. This method works if enough of the stomach is herniated but will fail if too short a segment of tube is inserted, if herniation has not yet occurred, or when the laceration is right-sided. When it succeeds, the nasogastric tube is seen within the thorax on chest radiography, simplifying the diagnosis and permitting early decompression of the stomach. In our cases (Table 1), 57% had an abnormal chest radiograph, and all but one of these showed the nasogastric tube in the thorax. In our review of 32 articles, 77% of 710 cases had an abnormal chest radiograph, and 50% were considered diagnostic for TRD (Table 5). A 19-article review by Humphreys and Abbuhl (7) reported abnormal chest radiographs in 86.2% of 526 cases, in which 49.4% were considered diagnostic. Most authors (1, 3–6, 8–11, 13, 17, 18, 21, 23–26, 28, 33, 34, 37, 44) considered a high index of suspicion for TRD the most important factor in making the diagnosis preoperatively by chest radiography.

When the clinical diagnosis remains in doubt, a number of procedures may be performed. If a thoracotomy tube is already in place, a small amount of water-soluble vital dye such as methylene blue may be instilled through the peritoneal dialysis catheter and recovered through the thoracotomy tube (25); we surmise that reversing the process will also work. Others have noted that air introduced into the peritoneum can travel across the TRD into the appropriate hemithorax (10, 21); one cause of unexpected pneumothorax at emergency laparotomy may be unrecognized TRD. Ilgenfritz and Stewart (24) have described introducing a radionuclide such as technetium during peritoneal dialysis and scanning the chest; however, routine diagnostic peritoneal lavage may be falsely negative in up to 36% of patients with TRD (4, 35).

Right-sided TRD cases are more difficult to diagnose because the liver frequently blocks abdominal viscera from entering the thorax, and thus fewer diagnostic findings are seen on chest radiographs than in left-sided cases. If herniation occurs, the ectopic location of the liver may be seen on chest radiography, liver-spleen scanning, CT, or MRI scanning. Peck (21) classified right-sided TRD as (a) total herniation of the liver into the thorax, (b) partial herniation of the liver into the thorax—the "mushroom sign," and (c) herniation of both liver and bowel. Another possibility exists but is not frequently diagnosed radiographically: no herniation despite laceration. Figures 4A-C show partial herniation of the liver. At least one group (45) has questioned the advisability of repairing a right-sided TRD which is otherwise asymptomatic. Many surgical authors have commented upon the danger of reducing a herniated liver in right-sided TRD because of the propensity for the herniated liver to tamponade a caval laceration; this caval laceration may bleed uncontrollably when the liver is returned to the abdomen.

Many other radiologic studies may be used in delayed diagnosis of TRD. Contrast by mouth or by rectum may demonstrate stomach, small bowel, or colon within the thorax; some earlier authors believed this a useful tool in delayed diagnosis of TRD. In our experience, the long delays in diagnosis reported in the older literature may predispose to strangulating obstruction; this is no longer commonplace today. Serial chest radiographs and more intense resuscitative measures have prevented most delayed herniation from escaping diagnosis during initial hospitalization (12, 44). Penetrating trauma, with its smaller diaphragmatic laceration, has a propensity for delayed diagnosis, especially in patients denied exploration. Ancillary studies such as radionuclide, barium, ultrasound, or vital dye studies rarely improve the diagnostic clarity when compared with serial chest radiographs, inspected with TRD in mind.

CT may aid in the diagnosis of TRD when the initial chest radiograph is nondiagnostic (8, 26, 34, 44). CT may show omental fat or abdominal viscera posterolateral to the diaphragm or may directly visualize the laceration. If CT does not demonstrate the rent in the diaphragm, it may show fluid in the pleural and peritoneal spaces or lacerations of adjacent organs (liver, lung, spleen) and may highlight the necessity for close evaluation of all fractures adjacent to the diaphragm. Several authors (5, 6, 8, 13, 23, 25) did not find CT useful in diagnosing TRD; other authors (9, 24, 33, 38, 39, 44, 45) recommend it. We believe that CT, with a utilization of only 3.6% from among 918 cases, has not been given enough of a trial to judge its role objectively in diagnosing TRD (30). Current CT technology with fast scanning permits torso evaluation in trauma situations in less than 10 minutes. Spiral scanning with thinner slices may better visualize small peridiaphragmatic hematomas and may permit coronal and sagittal reformation of the diaphragm, the lack of which limits this diagnostic modality. Preliminary studies with MRI indicate that it is an excellent modality for looking at soft tissues in *all* planes (23, 40–42); however, the patient must be stable to undergo this study. MRI is a valuable tool for both the true-positive and true-negative diagnosis of TRD in the stable, complicated patient (40). When MRI access, scanning times, and cost become favorable, this modality may replace multiple serial chest radiographs and CT in acute trauma situations for evaluating TRD and other viscera. For now, we recommend serial chest roentgenograms along with nasogastric tube placement for urgent and continuing evaluation and CT when other organ injury warrants its use (44). Peridiaphragmatic trauma should suggest the possibility of TRD even when herniation is not present.

In the differential consideration of TRD, hiatus hernia, paraesophageal hernia, volvulus of stomach, diaphragmatic eventration, and congenital hernia need consideration. The clinical presentation and any prior radiographs are most useful in differentiating among these entities. If eventration causes symptoms and radiologic signs are sufficiently indistinguishable from TRD, surgery may be warranted. Differentiating atelectasis secondary to TRD from other causes such as contusion, pneumonia, abscess, laceration, or preexisting tumor may require both serial chest radiographs and more sophisticated radiologic studies.

Repair of TRD rarely fails (45), but late complications include obstruction, volvulus, diminished lung function, and, rarely, thoracic splenosis.

Figure 4A Figure 4B Figure 4C

Figure 4A. Anteroposterior chest radiograph of patient with TRD on right with multiple segmental rib fractures and right thoracotomy tube. The right hemidiaphragm is obscured, as is the herniated liver, by the pleural fluid. Note minimal mediastinal shift to left. B. T1-weighted MRI study showing the liver partially herniated into the right thorax. The hemidiaphragmatic edge indents the liver laterally (arrow). C. Parasagittal image of right herniation showing the diaphragm pinching the liver anteriorly and posteriorly (arrows). Formerly called the "mushroom" appearance. (Courtesy of Dr. Theresa McLoud, Massachusetts General Hospital.)

CONCLUSIONS

In the trauma setting, all abnormal hemidiaphragms should stimulate a search for TRD as well as accompanying injuries—pulmonary contusions and lacerations, kidney, liver, splenic lacerations, and pleural collections of air and fluid—because TRD may be present without herniation. When either bowel or a nasogastric tube can be seen above the diaphragm, the diagnosis of TRD can easily be made. Nevertheless, 28 of the 32 articles we reviewed were written by surgeons, who may be biased by surgical diagnosis, and, hence, the true statistical incidence of a positive chest radiograph for TRD (which may be a retrospective analysis) may be different than the reported statistics indicate.

We presented seven cases of TRD from blunt trauma and reviewed the literature on 1345 proven cases of TRD from both blunt and penetrating trauma. The diagnosis of TRD is currently established much more readily than in the past. The distribution of injury has been relatively consistent through the decades. Blunt TRD provides the greater challenge. Seldom is the diagnosis of TRD made without chest radiography, and until herniation occurs, the diagnosis of TRD may only be suggested. Serial chest radiographs along with nasogastric tube placement represent the most reliable, available, and inexpensive preliminary technique for diagnosing and evaluating patients with potential TRD. The use of CT in diagnosing TRD is of uncertain value and may have improved accuracy with the advent of spiral technology. We recommend CT in torso trauma of all kinds, not specifically for the diagnosis of TRD but for the other critical, potentially fatal injuries that may be present. The limited use of MRI with its coronal and sagittal projections shows high accuracy in diagnosing TRD, especially in uncertain cases.

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