Observational Study

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# Blunt traumatic diaphragmatic rupture

## Single-center experience with 38 patients

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**Abstract**

Blunt traumatic diaphragmatic rupture (BTDR) is uncommon, but is associated with high rates of morbidity and mortality. The purpose of this study was to present our experience with management of this injury. Medical records of 38 patients with BTDR who were treated in our hospital from January 2001 to June 2016 were analyzed retrospectively. The sex, age, cause of injury, location of rupture, mode of diagnosis, time to diagnosis, the presence of herniation and bowel perforation, the presence of preoperative shock and intubation, Injury Severity Score (ISS), associated injuries, comorbidity, the operative procedure, morbidity and mortality, and the predictive factors affecting the outcome of BTDR were evaluated. There were 32 men (84.2%) and 6 women (15.8%) with a mean age of 51.2 years (range 18–84 years). The diagnosis could be preoperatively established in 28 patients (73.7%) with a plain chest X-ray or computed tomography scan. Rupture of diaphragm was left-sided in 31 patients (81.6%), right-sided in 6 (15.8%), and bilateral in 1 (2.6%). Sixteen patients had preoperative shock (systolic blood pressure <90 mm Hg, heart rate >120/min). Initial operative approaches were laparotomy in 22 patients (57.9%) and thoracotomy in 16 (42.1%). Eleven required additional exploration. The rate of additional exploration was higher in patients who initially underwent thoracotomy than laparotomy (56.2% vs 9.1%, $P=.003$). Patients who underwent additional exploration had a significantly longer operation time (330 minutes vs 237.5 minutes, $P=.012$), and a significantly higher morbidity rate (72.7% vs 22.2%, $P=.008$). Overall mortality was observed in 6 patients (15.8%). The mortality was associated with right-sided TDR ($P=.042$) and preoperative shock ($P=.003$). Neither ISS nor delay in diagnosis posed a statistically significant risk to the outcome of patients. Intra-abdominal organ injuries are more common than intrathoracic injuries in patients with BTDR, indicating that laparotomy should be the initial approach in these patients. Preoperative shock and right-sided TDR are predictive of mortality after BTDR.

**Abbreviations:** BTDR = blunt traumatic diaphragmatic rupture, CT = computed tomography, DIC = disseminated intravascular coagulation, ISS = Injury Severity Score, TDR = traumatic diaphragmatic rupture.

**Keywords:** blunt, laparotomy, outcome, traumatic diaphragmatic rupture

### 1. Introduction

Traumatic diaphragmatic rupture (TDR) occurs in approximately 1% to 7% of patients with major blunt trauma, including in 10% to 15% of patients with trauma that results in penetration of the lower chest.[1] The mechanisms underlying blunt and penetrating diaphragmatic rupture are completely different. Because blunt TDR (BTDR) is usually caused by momentary high energy damage and is associated with life-threatening injuries, it is generally considered to be a marker of severe trauma.[1] The mechanism by which blunt trauma causes diaphragmatic rupture may include shearing of a stretched diaphragm, avulsion from a muscular insertion point, or increased abdominal pressure that exceeds the bursting pressure of the diaphragm.[2,3] Because there are no specific clinical or physical findings suggestive of TDR, the diagnosis of a diaphragmatic injury can be difficult, especially if accompanied by other severe injuries. Therefore, a high index of suspicion is most helpful in diagnosing this entity. Although many studies have assessed TDR, including penetrating and blunt trauma, fewer have analyzed BTDR alone. The study about BTDR is important because BTDR is a different entity from the penetrating TDR. This retrospective study evaluated the experience of our hospital with the management of patients with BTDR, including its incidence, modes of diagnosis, operative treatments, postoperative outcomes, and factors predictive of patient outcomes.

### 2. Methods

The medical records and radiographs of 51 patients who presented with TDR in our hospital between January 2001 and June 2016 were reviewed retrospectively. Of the 51 patients, 13 had penetrating injury of the diaphragm and were excluded. Factors evaluated included patient sex, age, cause of injury, location (right, left, or bilateral), mode of diagnosis, time to diagnosis, occurrence of herniation and bowel perforation, occurrence of preoperative shock and intubation, Injury Severity Score (ISS), associated injuries, underlying diseases, operation time and procedure, morbidity and mortality, and factors predictive of patient outcomes. All analyses were performed using SPSS 20 (SPSS, Chicago, IL). Continuous variables were compared using Mann–Whitney $U$ test, and differences between categorical variables were assessed using the $\chi^2$ test. A $P$ value

Editor: Goran Augustin.

The authors have no funding and conflicts of interest to disclose.

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Medicine (2018) 97:41(e12849)

Received: 3 October 2017 / Accepted: 21 September 2018

http://dx.doi.org/10.1097/MD.0000000000012849

$<.05$ was considered statistically significant. Because this was a retrospective study and not a trial or prospective observational research, we had an exemption from ethical approval and patient's consent was waived.

## 3. Results

During the study period, 38 patients were diagnosed with BTDR. These 38 patients included 32 men (84.2%) and 6 women (15.8%), ranging in age from 18 to 84 years (mean 51.2 years). The causes of injury included motor vehicle collisions (n=15, 39.5%), pedestrians struck by automobiles (n=12, 31.6%), motorcycle or cultivator collisions (n=5, 13.1%), work-related accidents (n=4, 10.5%), and falls from heights (n=2, 5.3%). TDR was left-sided in 31 patients (81.6%), right-sided in 6 (15.8%), and bilateral in 1 (2.6%).

Preoperative diagnostic methods included plain chest X-ray, and computed tomography (CT) scans of the chest and upper abdomen. Plain chest X-rays were diagnostic of TDR in 20 (52.6%) of the 38 patients and the diagnostic rate of CT was 73.7% (28/38 patients). TDR was diagnosed in $<24$ hours in 26 patients (68.4%). In the remaining 12 patients, diagnostic delay ranged from 1 to 28 days. Ten patients (26.3%) were diagnosed intraoperatively, and 28 (73.7%) were diagnosed preoperatively.

Sixteen patients had preoperative shock (systolic blood pressure $<90$ mm Hg, heart rate $>120$/min). Eight patients underwent preoperative endotracheal intubation owing to dyspnea. Mean ISS was $25.9 \pm 8.3$. Most patients had multiple significant injuries associated with BTDR, including rib fracture (n=28, 73.7%), extremity injury (n=16, 42.1%), liver injury (n=14, 36.8%), spleen injury (n=10, 26.3%), gastrointestinal injury (n=10, 26.3%), and pelvic fracture (n=10, 26.3%) (Table 1). Eight patients had underlying disease, including hypertension, diabetes mellitus, pulmonary tuberculosis, chronic obstructive pulmonary disease, and osteoarthritis.

Initial operative approaches were laparotomy in 22 patients (57.9%) and thoracotomy in 16 (42.1%). Of the 22 patients who initially underwent laparotomy, 2 required additional thoracotomy. Of the 16 patients who initially underwent thoracotomy, 9 required additional laparotomy (Table 2). The rate of additional exploration was higher in patients who initially underwent thoracotomy than laparotomy (56.2% vs 9.1%, $P$=.003). Patients who underwent additional exploration had a significantly longer operation time (330 minutes vs 237.5 minutes, $P$=.012), and a significantly higher morbidity rate (72.7% vs 22.2%, $P$=.008). Twenty-nine patients (76.3%) had visceral herniation involving the small intestine, stomach, and/or spleen, and 4patients (10.5%) had gastrointestinal perforations. Blunt traumatic diaphragmatic injuries were repaired directly in 36 patients (94.7%), whereas Prolene mesh was used for repair of the diaphragmatic defect in 2 patients (5.3%).

Twenty-six patients (68.4%) required mechanical ventilation postoperatively, 14 for a short period ($\leq$3 days) and 12 for a prolonged period of time. Fourteen patients (36.8%) experienced postoperative complications (Table 3). Postoperative pulmonary complications occurred in 8 patients, including pneumonia in 6 and atelectasis in 2. Other complications included 2 patients each with sepsis, disseminated intravascular coagulation (DIC), and wound infection; and 1 patient each with central line infection, cerebral infarction, acute renal failure, and postoperative intestinal obstruction. Six patients (15.8%) died, 4 of hemorrhagic shock and 2 of sepsis. Mortality was significantly associated with right-sided diaphragmatic rupture ($P$=.042) and preoperative shock ($P$=.003). Neither ISS nor delay in diagnosis was significantly associated with patient outcomes (Table 4).

**Table 1**

**Associated injuries.**

| Type of injury | No. of cases (%) |
|---|---|
| Rib fractures | 28 (73.7) |
| Extremity fracture | 16 (42.1) |
| Liver injury | 14 (36.8) |
| Spleen injury | 10 (26.3) |
| Pelvic fracture | 10 (26.3) |
| Gastrointestinal injury | 10 (26.3) |
| Spine injury | 9 (23.7) |
| Head injury | 7 (18.4) |
| Kidney injury | 5 (13.2) |
| Thoracic aorta injury | 4 (10.5) |
| Bladder injury | 2 (5.3) |
| Lung injury | 1 (2.6) |

**Table 2**

**Operative approach.**

| Initial approach | Additional approach | No. of cases | Op time (mean ± SD) | Mortality |
|---|---|---|---|---|
| Laparotomy | | 20 | 265.3 ± 86.9 | 3 |
| Laparotomy | Thoracotomy | 2 | 407.5 ± 60.1 | 1 |
| Thoracotomy | | 7 | 162 ± 23.6 | 1 |
| Thoracotomy | Laparotomy | 9 | 312.8 ± 122.7 | 1 |

SD = standard deviation.

## 4. Discussion

TDR is caused by blunt or penetrating thoracoabdominal trauma. A large collective review reported that 75% of diaphragmatic injuries are caused by blunt trauma and 25% by penetrating trauma.[4] In our series, 74.5% of TDRs were associated with blunt trauma, with the main cause of blunt trauma being road accidents (84.2%).

Most diaphragmatic ruptures in patients, who experience blunt abdominal trauma, occur on the posterolateral part of the left diaphragm. This area, which is derived from the pleuroperitoneal membrane, is the weakest portion structurally. The right diaphragm is congenitally stronger than the left and is partially protected by the liver, which can distribute pressure over a larger area. The rate of left-sided TDR after blunt trauma has

**Table 3**

**Postoperative complications.**

| Complications | No. cases (%) |
|---|---|
| Pneumonia | 6 (15.8) |
| Atelectasis | 2 (5.3) |
| Wound infection | 2 (5.3) |
| Disseminated intravascular coagulation | 2 (5.3) |
| Sepsis | 2 (5.3) |
| Cerebral infarction | 1 (2.6) |
| Acute renal failure | 1 (2.6) |
| Postoperative intestinal obstruction | 1 (2.6) |
| Central line infection | 1 (2.6) |

**Table 4**

**Risk factors influencing outcomes.**

| Risk factors | Survivors (n = 32) | Nonsurvivors (n = 6) | *P* |
|---|---|---|---|
| Age, y mean ± SD | 52.5 ± 18.4 | 39.0 ± 14.5 | .147 |
| | 27 (84.4%) | 5 (83.3%) | 1.000 |
| Laterality (right:left:both) | 3:28:1 | 3:3:0 | .042 |
| Preoperative intubation | 6 (18.8%) | 2 (33.3%) | .587 |
| Preoperative shock (SBP <90, HR >120) | 10 (31.2%) | 6 (100%) | .003 |
| Injury severity score | 25.2 ± 8.3 | 29.8 ± 7.8 | .147 |
| Delayed operation (>24 hour) | 11 (34.4%) | 1 (16.7%) | .643 |
| Operation time, min | 260.7 ± 105.6 | 287.5 ± 109.6 | .506 |
| Gastrointestinal perforation | 4 (12.5%) | 0 (0%) | 1.000 |
| Visceral herniation | 25 (78.1%) | 4 (66.7%) | .618 |
| Underlying disease | 6 (18.8%) | 2 (33.3%) | .587 |

HR = heart rate, SBP = systolic blood pressure, SD = standard deviation.

been reported to range from 68% to 87%.[4–6] Similarly, in our study, 31 (81.6%) of the 38 patients experienced left-sided TDR.

Patients with TDR require immediate surgical treatment, due to the high morbidity and mortality rates associated with this injury.[6] Diagnostic methods that have been reported useful in the evaluation of TDR include plain chest X-ray, upper GI contrast study, fluoroscopic evaluation of diaphragmatic motion, ultrasound, CT scan, laparoscopy, and video-assisted thoracic surgery. The most commonly used diagnostic modalities, chest X-ray and CT scan, are diagnostic in 30% to 50% of patients.[1,7,8] CT scans have been reported to have a sensitivity of 61% to 87% and a specificity of 72% to 100%[7,8] and to be the optimal diagnostic modality in resuscitated stable patients. In evaluating patients at admission, we found that CT scans of the chest and upper abdomen had a sensitivity of 73.7%, whereas plain chest X-rays had a sensitivity of 21.1%. Ten patients (26.3%) were diagnosed with TDR intraoperatively, whereas 12 patients (31.6%) were diagnosed >24 hours after admission. However, delayed diagnosis did not affect mortality, suggesting that TDR itself does not affect patient outcomes.

Associated injuries in our patient cohort were similar to those observed previously.[9] Rib fractures and abdominal solid organ injuries were far more common than hollow viscus injuries in patients with BTDR. We also found that lung parenchymal laceration was rare, despite many rib fractures. In addition, injuries to intra-abdominal organs (liver, 36.8%; spleen, 26.3%; kidney, 13.2%) and hollow viscus injuries (10 patients, 26.3%) were more frequent than injuries to the lung parenchyma (1 patient, 2.6%), suggesting the necessity of intra-abdominal exploration in patients with BTDR. Injuries to the thoracic aorta, indicating a significant acceleration-deceleration force, were observed in 4 patients (10.5%). This association and the risk of missed diagnosis indicate the need to evaluate the thoracic aorta, by methods such as CT angiography, in patients with diaphragmatic injury.

Surgical approaches can include thoracotomy and/or laparotomy. Laparotomy is recommended for patients with acute BTDR because it allows exploration of the intra-abdominal organs for associated injuries.[3,4] Thoracotomy may be necessary for

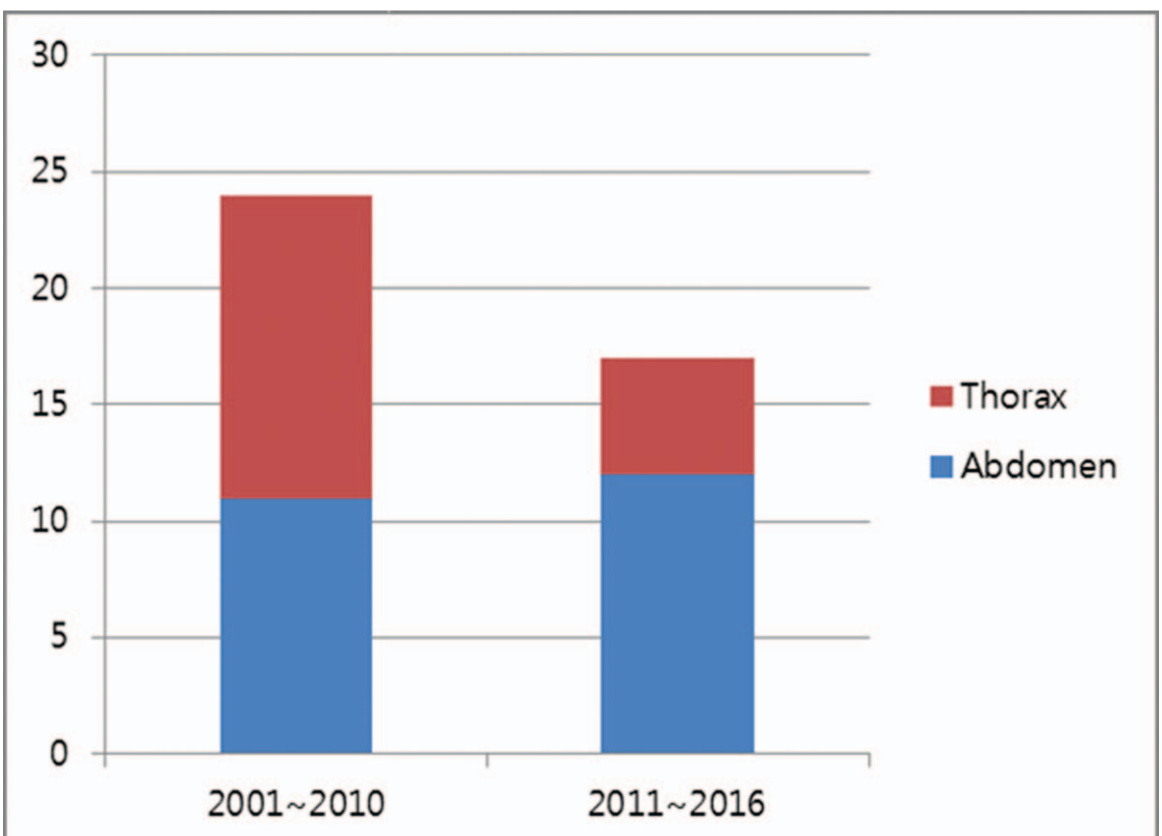


**Figure 1.** The change of initial approach according to period.

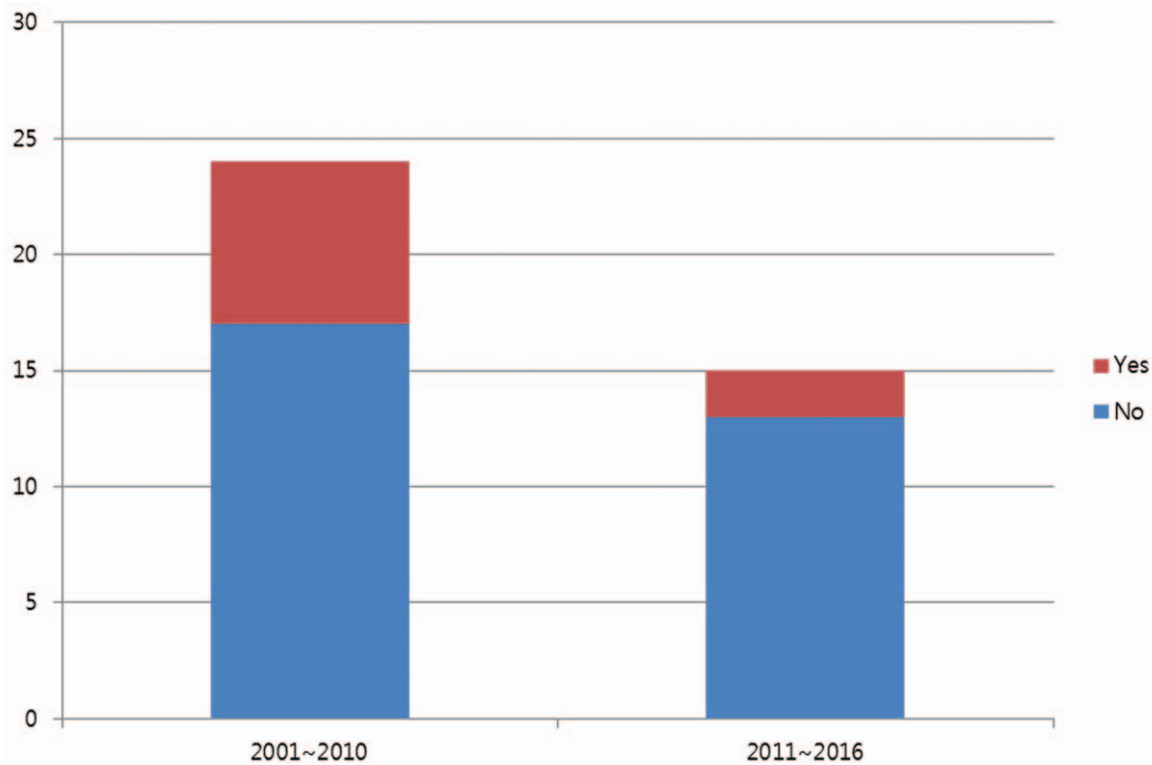


**Figure 2.** The change of additional exploration rate according to period.

patients with chronic injury, to safely separate adhesions between abdominal organs and pleura.[10] Before these conceptions were established in our hospital, thoracotomy was performed more frequently, with many of these patients requiring additional laparotomy to explore intra-abdominal combined injuries (Figs. 1 and 2). The rate of additional exploration was higher in patients who initially underwent thoracotomy than laparotomy. Additional exploration was associated with a significantly longer operation time (330 minutes vs 237.5 minutes, $P=.012$) and a significantly higher morbidity rate (72.7% vs 22.2%, $P=.008$). These results indicate that laparotomy should be the initial approach in patients with BTDR.

Mortality rates of 1% to 28% have been reported in patients with TDR, usually due to associated injuries.[11,12] Predictors of mortality have included age, ISS, and hemodynamic state.[12–14] In our series, the overall mortality rate was 15.8%, with right-sided TDR ($P=0.042$) and preoperative shock ($P=0.003$) being significantly prognostic for mortality. This result suggests that the incidence of severe liver injury in patients with right-sided TDR is high.

In conclusion, our findings demonstrate that intra-abdominal organ injuries are more common than intrathoracic injuries in patients with BTDR, indicating that laparotomy should be the initial approach in these patients, and predictive factors of mortality after BTDR are preoperative shock and right-sided TDR. However, this study has a number of limitations, which should be noted, including its small sample size, selection bias, and retrospective design, thus a multicenter study or larger study should be conducted in future.

## Author contributions

**Conceptualization:** Kyoung Hoon Lim, Jinyoung Park.
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