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Management of Patients with Traumatic Rupture of the Diaphragm

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Background: Traumatic rupture of the diaphragm is an unusual type of trauma. In addition, it is difficult to diagnose because it can be accompanied by injuries to other organs. If it is not detected early, the mortality rate can increase due to serious complications. Diaphragmatic rupture is an important indicator of the severity of the trauma. The aim of this study was to investigate the factors affecting the incidence of complications and mortality in patients who had surgery to treat traumatic rupture of the diaphragm. ***Materials and Methods:*** The subjects were patients who had undergone a diaphragmatic rupture by blunt trauma or stab wounds except patients who were transferred to other hospitals within 3 days of hospitalization, from January 2000 to December 2007. This study was a retrospective study. 43 patients were hospitalized, and 40 patients were included during the study period. Among them, 28 were male, 12 were female, and the average age was 42 (from 18 to 80). Outcome predictive factors including hypoxia, ventilator application days, revised trauma score (RTS), injury severity score (ISS), age, herniated organs, complications, and the mortality rate were investigated. ***Results:*** Causes of trauma included motor vehicle crashes for 20 patients (50%), falls for 10 (25%), stab wounds for 8 (20%), and agricultural machinery accidents for 2 (5%). Most of the patients (36 patients; 90%) had wound sites on the left. Diagnosis was performed within 12 hours for most patients. The diaphragmatic rupture was diagnosed preoperatively in 27 patients (70%) and in 12 patients (30%) during other surgeries. For surgical treatment, thoracotomy was performed in 14 patients (35%), laparotomy in 11 (27.5%), and a surgery combining thoracotomy and laparotomy in 15 patients (37.5%). Herniated organs in the thoracic cavity included the stomach for 23 patients (57.5%), the omentum for 15 patients (37.5%), the colon for 10 patients (25%), and the spleen for 6 patients (15%). Accompanying surgeries included splenectomy for 13 patients (32.5%), lung suture for 6 patients (15%), and liver suture for 5 patients (12.5%). The average hospital stay was 47.80±56.72 days, and the period of ventilation was 3.90±5.8 days. The average ISS was 35.90±16.81 (11～75), and the average RTS was 6.46±1.88 (1.02～7.84). The mortality rate was 17.5% (7 patients). Factors affecting complications were stomach hernia and age. Factors affecting the mortality rate were ISS and RTS. ***Conclusion:*** There are no typical symptoms of the traumatic rupture of the diaphragm by blunt trauma. Nor are there any special methods of diagnosis; in fact, it is difficult to diagnose because it accompanies injuries to other organs. Stab wounds are also not easy to diagnose, though they are relatively easy to diagnose compared to blunt trauma because the accompanying injuries are more limited. Suture of the diaphragm can be performed through the chest, the abdomen, or the thoracoabdomen. These surgical methods are chosen based on accompanying organ injuries. When there are many organ injuries, there are a great number of complications. Significant factors affecting the complication rate were stomach hernia and age. ISS and RTS were significant as factors affecting the mortality rate. In the case of severe trauma such as pelvic fractures, frequent physical examinations and chest X-rays are necessary to confirm traumatic rupture of the diaphragm because it does not have specific symptoms, and there are no clear diagnosis methods. Complications and the mortality rate should be reduced with early diagnosis and with treatment by confirming diaphragmatic rupture in the thoracic cavity and the

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abdomen during surgery.

Key words: 1. Diaphragm
2. Trauma
3. Thoracotomy
4. Rupture

INTRODUCTION

The diaphragm is an important muscle for respiration. Functional damage of the diaphragm is caused by diaphragmatic rupture. Moreover, respiratory distress occurs by atelectasis and mediastinal displacement, which are caused by the herniation of intraperitoneal organs into the intrathoracic cavity. However, diaphragmatic rupture by blunt wounds is difficult to diagnose because of unstable vital signs in the ER, and it accompanies other injuries in the chest, abdomen, and extremities. There are few cases of stab wounds by firearm accidents in Korea. Instead, stab wounds by knives or sharp objects are frequent, and the accompanying injuries to other organs are limited to the chest and the abdomen. Thus, a straightforward diagnosis can be performed. Diaphragmatic rupture is diagnosed by chest X-ray, computed tomography (CT), abdominal angiography, and ultrasound. However, the diagnosis is not easy because its specificity and sensitivity are low. Shah et al. [1] reported that 43.5% cases of diaphragmatic rupture were diagnosed presurgically, 41.4% during surgery or autopsy, and 14.6% postsurgically. It is reported that 77～95% of cases of diaphragmatic rupture were caused by blunt wounds, and 12.3% were caused by stab wounds [2]. Another study showed that the morbidity of diaphragmatic rupture was low, at 0.8～1.6%, though it has been concluded that the morbidity rate is likely higher than reported statistics because it is difficult to compile accurate statistics on diaphragmatic rupture by chest radiographs and other findings [3]. Diaphragmatic rupture by blunt wounds is an indicator of the severity of injury because it generally accompanies injuries to other organs. To treat diaphragmatic rupture in the early stage, the diaphragm is sutured, and the accompanying injuries in other organs are treated by laparotomy, thoracotomy, or a combination of laparotomy and thoracotomy. However, thoracotomy is recommended when late-stage diagnosis is performed. Thus, this study investigated the factors affecting the complications of and mortality rate from diaphragmatic rupture by blunt trauma and stab wounds.

MATERIALS AND METHODS

In this study, 40 out of 43 patients who underwent surgery for the traumatic rupture of the diaphragm between January 2000 and December 2007 in the Thoracic Surgery Department of Samsung Changwon Medical Center of Sungkyunkwan University were included. The 3 patients during that period who were transferred to other hospitals within 3 days of hospitalization were excluded. This study was a retrospective study.

To investigate factors affecting the complication and mortality rates, initial medical records of the Emergency Medical Center, simple chest X-rays, and chest computed tomography findings were reviewed to obtain the following information: sex, age, causes of trauma, locations of trauma, hemopneumothorax, intrathoracic injuries such as stab wounds to the lung, injuries to the abdominal organs, herniated organs, accompanying injuries to other organs, periods of ICU stay, number of ventilator application days, hospitalization days, injury severity score (ISS), revised trauma score (RTS), complications, and mortality rate.

All patients were hospitalized through the Emergency Medical Center. Chest CT and abdominal ultrasound were performed for diagnosis after stabilizing the patients' vital signs with the following treatments: administration of fluids, blood transfusion, and vasopressors; ventilation; and insertion of intubation and a chest tube. A physical examination, simple chest X-ray, chest CT, and abdominal ultrasound were

performed in patients who had stable vital signs. If diaphragm rupture was diagnosed, thoracotomy and laparotomy were performed based on intrathoracic and abdominal injuries. The diaphragm was restored by simple interrupted suture or double layer suture methods with nonabsorbable suture materials. Intubation was removed when patients had respiration without assistance and stable vital signs after surgery. However, patients who had weak self respiration and unstable vital signs had ventilators applied in the ICU. Outpatient follow-up was performed within 3 months for most patients. However, long-term follow up was not observed because of the characteristics of trauma treatment.

The chi-square test was used for categorical variables, and the Mann-Whitney test was used for continuous variables in univariate analysis. Multiple logistic regression analysis was performed in multivariate analysis. All data are shown as means±standard deviation. $p<0.05$ was considered statistically significant. Data analysis was performed by SPSS 12.0K for Windows®.

RESULTS

Patients were aged 18 to 90; the average age was 42.0±14.5. Among them, 28 (27%) were male and 12 (30%) were female. Causes of the diaphragmatic rupture were mostly motor vehicle crashes, with 20 cases (50%); falls during work, with 10 cases (25%); stab wounds, with 8 cases (20%); and tractor accidents in agricultural areas, with 2 cases (5%). Most cases (n=36; 90%) of diaphragmatic rupture were located on the left side. There were 18 (45%) hypotension cases by other accompanying organ injuries, and 16 (40%) hypoxia cases by diaphragmatic rupture, atelectasis, or lung injury. 37 cases (92.5%) were diagnosed within 12 hours, 2 cases within 24 hours, and one case within 72 hours. 28 cases (70%) were diagnosed presurgically, and the other cases were found during other surgeries for hemothorax, hemoperitoneum, etc. As for surgical methods, thoracotomy (n=14; 35%) and laparotomy (n=11; 27.5%) were performed , and these methods were chosen based on the type of organ injury (Table 1). The diaphragm was restored by a simple interrupted suture and double layer suture with nonabsorbable suture materials. Herniation of organs in the intra-abdominal cavity mostly occurred in left side injuries. The herniated organs were the stomach in 23 cases (57.5%), omentum in 15 cases (37.5%), colon in 10 cases (25%), spleen in 6 cases (15%), and liver in 5 cases (12.5%). Accompanying surgeries were splenectomy in 13 cases (43.5%), lung suture in 6 cases (15%), liver suture in 5 cases (12.5%), nephrectomy in 4 cases (10%), and omentoplasty in 4 cases (10%).

Accompanying injuries in other organs were hemopneumothorax in 23 cases (57.5%), abdominal injuries including hemoperitoneum and retroperitoneal hematoma in 16 cases (40%), and extremity injuries including femoral fractures and scapular fractures in 12 cases (30%). An ISS score, representing the severity of trauma, of over 16 was assigned to 36 of

Table 1. Clinical characteristics of patients with traumatic diaphragmatic rupture

Characteristics	No. (%)
Age	52.8±14.5 (18～80)
Gender	
Male	28 (70)
Female	12 (30)
Mechanism of trauma	
Motor vehicle accident	
In car	12 (30)
Pedestrian	8 (20)
Fall	10 (25)
Stab wound	8 (20)
Cultivator accident (agricultural)	2 (5.0)
Hypotension	
Yes	18 (45)
No	22 (55)
Hypoxemia	
Yes	16 (40)
No	24 (60)
Laterality	
Left	36 (90)
Right	4 (10)
Diagnosis at operation	
Yes	28 (70)
No	12 (30)
Diagnosis time	
＜12 hour	37 (92.5)
＞12 hour	3 (7.5)
Operation	
Thoracotomy	14 (35)
Laparotomy	11 (27.5)
Combination	15 (37.5)

Table 2. Associated injuries, injury severity scores (ISS), and revised trauma scores (RTS)

Associated injuries/ISS/RTS	No. (%)
Thoracic injuries	23 (57.5)
Abdominal injuries	16 (40)
Extremity injuries	12 (30)
Pelvic bone fractures	9 (22.5)
Head injuries	4 (10)
Spine injuries	1 (2.5)
Injury severity score	35.90±16.81
0～15	4 (10)
16～29	12 (30)
30～75	24 (60)
Revised trauma score	6.46±1.88
＜8	40 (100)

Table 3. Complications and outcomes in the management of diaphragmatic rupture

Complications	No. (%)
Pulmonary	
Pleural effusion	5 (12.5)
Pneumonia	2 (5.0)
ARDS	3 (7.5)
Empyema	1 (2.5)
Atelectasis	1 (2.5)
Non-pulmonary complications	
Ileus	4 (10)
Wound infection	4 (10)
DIC	3 (7.5)
Compartment syndrome	2 (5.0)
Gastrointestinal bleeding	1 (2.5)
Arrhythmia	1 (2.5)
Delirium	1 (2.5)
Outcomes	
Hospital days	47.80±56.72 (2～255)
ICU days	11.90±15.23 (1～71)
Ventilator days	3.90±5.83 (0～25)
Operation time	186.35±91.56
Deaths	7 (17.5%)

ARDS=Acute respiratory distress syndrome; DIC=Disseminate intravascular coagulation; ICU=Intensive care unit.

the cases (90%), and the RTS score, representing indicators of severity, was under 8 in all 40 cases (Table 2). The average length of hospitalization was relatively long, at 47.80±56.72 days (2～255 days) for the following reasons: extensive accompanying injuries in other organs, a long period of insertion of the chest tube due to an extended period needed for drainage of the pleural fluid, delayed recovery because of poor oral feeding due to abdominal complications, and an extended rehabilitation period due to extremity fractures. The average ICU stay was 11.90±15.233 days (1～71 days). In 24 (60%) cases, ventilation was applied for respiratory failure or unstable vital signs, and the average application period was 3.90±5.83 days (0～25 days). Complications were divided into thoracic related complications and non-thoracic complications. Thoracic related complications were pleural effusion in 5 cases (12.5%), and other complications were pneumonia and acute respiratory failure. Non-thoracic complications included 4 cases (10%) of paralytic ileus and 4 cases

Table 4. Factors for complications

Factor	p-value
Age	＜0.05
ISS	NS
RTS	NS
Hospital days	NS
ICUt days	NS
Ventilator days	NS
Diagnosis time	NS
Transfusion	NS
Operation time	NS
Stomach herniation	＜0.05
Rupture size	NS

ISS=Injury severity score; RTS=Revised trauma score; ICU=Intensive care unit.

Table 5. Factors associated with mortality

Factor	p-value
GE	NS
ISS	＜0.05
RTS	＜0.05
Hospital days	NS
ICUt days	NS
Ventilator days	NS
Diagnosis time	NS
Transfusion	NS
Operation time	NS
Stomach herniation	NS
Rupture size	NS

ISS=Injury severity score; RTS=Revised trauma score; ICU=Intensive care unit.

(10%) of wound infection; however, most cases were treated conservatively. The mortality rate was high, at 17.5% (7 cases). Causes of death were respiratory failure in 3 cases (5.7%), hypovolemic shock in 2 cases (5%), and multiple organ failure in 2 cases (5%) (Table 3).

Stomach hernia and age were the factors affecting the presence of complications that were statistically significant ($p < 0.05$) (Table 4). ISS and RTS were the factors affecting the mortality rate that were statistically significant ($p < 0.05$) (Table 5).

DISCUSSION

The diaphragm plays an important role in separating the chest from the abdomen, and it is also an essential muscle for breathing. Thus, careful observation is necessary, because diaphragmatic rupture affects the chest and the abdomen, and this can have serious results. Diaphragmatic rupture is caused by blunt trauma in 0.8～7% of cases and stab wounds in 10～15% of cases [4], while 90% of cases occur on the left side [5]. Desforges et al. [6] reported that the reasons for such a high percentage of diaphragmatic rupture cases on the left side were the following: the liver buffered external forces applied to the abdomen or flank and delivered to the diaphragm through the intra-abdominal organs, the diaphragm is naturally stronger on the right side than on the left side, and the detection of diaphragmatic rupture on the right side is more difficult than detection on the left side. In this study, the diaphragmatic rupture was on the left side in 90% of the cases. Rupture of the diaphragm often occurs in young people who participate in many social activities. The most frequent cause is a motor vehicle crash (86% of which are car accidents, 11% of which are pedestrian accidents, and 3% of which are motorcycle accidents), while other causes of blunt trauma are falls and assault [7]. Stab wounds are caused by firearm accidents, knives, and sharp objects. Although there are no specific symptoms leading directly to the diagnosis of diaphragmatic rupture, there are symptoms that indicate the possibility, such as abdominal pain, shortness of breath, chest pain, and hematuria. Signs of diaphragmatic rupture can also include abdominal tenderness and decreased breathing sounds [8]. Accompanying injuries to other organs occurred in 94% of cases, including 72～79% of cases with intra-abdominal injuries and 81% with extra-abdominal injuries. Pelvic fracture was the most frequent accompany injury. Injuries to the liver and spleen were frequent intra-abdominal injuries, and extra-abdominal injuries included injuries to the bladder, ribs, lung, brain, intestines, kidney, and major vessels [9]. Diagnosis methods include plan chest roentgenogram, CT-scan, magnetic resonance imaging, gastrointestinal contrast studies, ultrasound, fluoroscopy, thoracoscopy, and laparoscopy. However, there are no methods with high sensitivity or specificity. So far, there is no gold-standard diagnostic test. Plan CXR is a useful method for diagnosing diaphragmatic rupture, and its sensitivity for diaphragmatic rupture with herniation is over 94% and without herniation is 30～60% [10]. To diagnose diaphragmatic rupture by CXR, pictures are taken at 6-hour intervals with or without dye after insertion of a nasogastric tube [11]. Specificity for diaphragmatic rupture by CT is high in patients with blunt wounds; specificity and sensitivity are increased by helical CT in particular [12]. Specificity and sensitivity for diaphragmatic rupture by thoracoscopy are almost 100%, and thoracoscopy is used for restoration of the diaphragm as well. However, it can only be used in patients with stable vital signs [13]. In this study, thoracoscopy was used in 2 cases. Operation time was long because the visual field was too narrow, and the surgeon's experience using thoracoscopy was limited. However, the outcome of thoracoscopy should improve with repeated trials. We plan to use thoracoscopy in the future in patients with stable vital signs. Diaphragmatic rupture is found during 27.2% of emergency operations for hemothorax or hemoperitonium without enough time for preoperative tests because of patients' unstable vital signs [14]. In this study, the diaphragmatic rupture was not diagnosed, even though it was suspected, in 30% of patients (12 cases). The diaphragm was restored during emergency surgery for other organ injuries. Diaphragmatic rupture should be suspected in patients with other organ injuries because there are no specific symptoms or diagnostic methods. Surgery is necessary for treatment, and an immediate operation is needed if it is diagnosed in the early stage. The surgery can be performed through the chest, abdomen, or thoracoabdomen, and the priority of the surgery is decided based on the urgency of pathologic processes. The left side of the

diaphragm is restored easily in laparotomy with severe abdominal injuries. However, additional thoracotomy may be needed because injuries on the right side could be hidden by the liver [15]. Thoracotomy is recommended over laparotomy to restore the diaphragm in the late stage [16]. In this study, surgical methods were chosen by the severity of the thoracic or abdominal injuries, and the choice of method was similar in cases of thoracotomy and laparotomy. Surgeries through the thoracoabdomen were mostly performed to treat organ injuries in the chest and abdomen. Nonabsorbable surgical suture materials were used to restore the diaphragm. However, absorbable surgical suture materials were sometimes used [16]. The diaphragm was restored by simple interrupted suture or double layer suture with nonabsorbable surgical suture.

Post operative complications were found in 11～62.9% of cases, and the most frequent complications were lung-related. It is known that significant factors for the occurrence of complications are the severity of injuries, accompanying injuries, hemodynamic status during hospitalized stays, and diagnosis time [17]. In this study, age and stomach hernia were significant factors for the occurrence of complications. The mortality rate from diaphragmatic rupture varies from 1% to 28%, and the mortality rate from accompanying injuries is higher than from the diaphragmatic rupture itself. Factors expected to increase the mortality rate are the following: age over 55, major comorbid illness, and the number and severity of associated injuries to major body systems along with central nervous, cardiovascular, and intra-abdominal injuries. In this study, the statistically significant factors affecting the mortality rate were ISS and RTS.

CONCLUSION

Diaphragmatic rupture is likely to occur more often than the statistical data reflects because there are no typical symptoms of it, no specific methods for diagnosis, and many cases are not detected. Diaphragmatic rupture occurs most often in young people who have high social activity, and it has increased with the increasing rate of motor vehicle crashes. Most injuries occur by blunt wounds and are found on the left side. Early diagnosis is most important, but evaluations of diaphragmatic rupture are not easy because diaphragmatic rupture often accompanies injuries to other organs, and intensive care such as a ventilator is necessary due to unstable vital signs. In this study, diaphragmatic rupture was found and treated during other surgeries in around 30% of cases. If a diaphragm injury is diagnosed in the early stage, surgery for diaphragm restoration should be performed through the chest, the abdomen, or the thoracoabdomen quickly. If it is diagnosed late or it is found in a chronic condition, surgery through the chest is recommended. Death by diaphragmatic rupture alone is rare, and the main cases of death are hypovolemic shock and acute respiratory failure caused by accompanying injuries to other organs. In a previous study, the mortality rate was reported to be quite high, at 28%. In the present study, it is also relatively high, at 17%. The mortality rate is high in patients with a high ISS score and low RTS score. Thus, the mortality rate can be reduced by early diagnosis and treatment. The limitations of this study were that the subjects included only trauma patients and long-term follow up could not be performed. Moreover, the number of subjects was not large enough. Thus, debates on the factors shaping complication and mortality rates remain. To conclude, this study should be helpful in managing patients with traumatic rupture of the diaphragm.

REFERENCES

1. Shah R, Sabanathan S, Mearns AJ, Choudhiry AK. *Traumatic rupture of the diaphragm.* Ann Thoracic Surg 1995;60: 1444-9.
2. Mihos P, Poataris K, Gakidis J, et al. *Traumatic rupture of the diaphragm: experience with 65 patients.* Injury 2003;34: 169-72.
3. Troop B, Myers RM, Agarwal N. *Early recognition of diaphragmatic injuries from blunt trauma.* Ann Emerg Med 1985;14:97-101.
4. Meyers BF, McCabe CJ. *Traumatic diaphragmatic hernia: occult marker of serious injury.* Ann Surg 1933;218:783-90.
5. Wiencek RG, Wilson RF, Steger Z. *Acute injuries of the diaphragm: an analysis of 165cases.* J Thorac Cardiovascular Surg 1986;92:989-93.
6. Desforges G, Strieder JW, Lynch JP, et al. *Traumatic rupture od diaphragm.* J Thorac Surg 1957;34:779.
7. Boulanger BR, Milzman DP, Rosati C, Rodriguez A. *A comparison of right and left blunt traumatic diaphragmatic rup-*

ture. J Trauma 1993;35:255-60.
8. Sukul DM, Kata E, Johannes EJ. *Sixty-three cases of traumatic injury of diaphragm.* Injury 1991;22:303-6.
9. Athanassiadi K, Kalavrouzotis G, Athanassiou M, et al. *Blunt diaphrarmatic rupture.* Eur J Cardiothorac Surg 1995; 15:469-74.
10. Hanna W, Ferri L, Fata P, Razek T, Mulder D. *The current status of traumatic diaphragmatic injury: lessons learned from 105 patients over 13 years.* Ann Thorac Surg 2008;85: 1044-8.
11. Reda E, Ebrahim A, Ehab M. *Blunt traumatic diaphragmatic rupture: a retrospective observational study of 46 patients.* Interact Cardiovasc Thorac Surg 2009;9:45-9.
12. Nchimi J, Szapiro D, Ghaye B, et al. *Helical CT of blunt diaphragmatic rupture.* AJR 2005;184:24-30.
13. Navarro J, Cuesta J, Alaron J, et al. *Traumatic rupture of the diaphragm.* Arch Bronchoneumol 2008;44:197-203.
14. Roa G, Madoff HR. *Bilateral rupture of diaphragm with delayed strangulation.* Chest 1989;95:244-5.
15. Ilgefritz FM, Stewart DE. *Blunt trauma of the diaphragm: a 15-county private hospital experience.* Am Surg 1992;58:334-9.
16. Bryant LR, Schechter FG, Rees R, Albert HM. *Bilateral diaphragmatic rupture due to blunt trauma: a rare injury.* J Trauma 1978;18:280-2.
17. Boulanger BR, Milzman DP, Rosati C, Rodriquez A. *A comparison of right and left blunt traumatic rupture.* J Trauma 1993;35:255-60.