

Diagnosis, treatment, and management of traumatic diaphragmatic rupture: A multi-center study

Travmatik diyafram rüptürünün tanısı, tedavisi ve yönetimi: Çok merkezli çalışma

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ABSTRACT

Background: This study aims to evaluate the diagnosis, surgical outcomes, and prognosis of patients with traumatic diaphragmatic rupture and discuss recent advancements in diagnostic technologies.

Methods: Between January 2014 and January 2024, a total of 35 patients (27 males, 8 females; mean age: 45.3±14.2 years; range, 13 to 68 years) who underwent diaphragmatic repair for traumatic diaphragmatic rupture in three centers were retrospectively analyzed. Data including demographic characteristics of the patients, medical history, type of trauma, clinical findings, diagnostic methods used preoperatively, preoperative interventions, the establishment of an intraoperative diagnosis, associated organ injuries, side of the diaphragmatic rupture, type of surgical procedure, postoperative complications, and length of hospital stay were recorded.

Results: Among the cases, penetrating trauma was the most common mechanism (62.9%). Among the 25 patients who underwent computed tomography, a preoperative diagnosis of diaphragmatic rupture was established in 14 (56%). The median defect size in the diaphragm was 5.7 cm in blunt trauma cases and 4.04 cm in penetrating trauma cases. The morbidity rate was 40%, and the mortality rate was 5.7%. The length of hospital stays for the surgically treated patients ranged from 4 to 16 days. Comparing the laparotomy and thoracotomy groups, the laparotomy group had a longer hospital stay (p=0.017) and had statistically significant data in terms of participation in multidisciplinary surgery (p=0.001).

Conclusion: Diaphragmatic rupture should be considered in cases involving high-energy blunt trauma, particularly when multiple lower rib fractures, liver lacerations, or splenic lacerations are present, or in patients with a history of penetrating trauma to the thoracoabdominal region. As delays in diagnosis and treatment may increase morbidity and mortality, early recognition and prompt management are essential. The choice of surgical procedure should be guided by the presence or absence of concomitant injuries.

Keywords: Multidisciplinary, radiological imaging, surgery, traumatic diaphragmatic rupture.

ÖZ

Amaç: Bu çalışmada, travmatik diyafram rüptürü olan hastaların tanısı, cerrahi sonuçları ve prognozu değerlendirildi ve tanı teknolojilerindeki son gelişmeler irdelendi.

Çalışma planı: Ocak 2014 - Ocak 2024 tarihleri arasında üç farklı merkezde travmatik diyafram rüptürü nedeniyle ameliyat edilen toplam 35 hasta (27 erkek, 8 kadın; ort. yaş: 45.3±14.2 yıl; dağılım, 13-68 yıl) retrospektif olarak incelendi. Hastaların demografik özellikleri, tıbbi öyküsü, travma türü, klinik bulguları, ameliyat öncesi kullanılan tanı yöntemleri, ameliyat öncesi girişimler, ameliyat sırası konulan tanı, ilişkili organ hasarları, diyafram rüptürünün yeri, cerrahi işlem türü, ameliyat sonrası komplikasyonlar ve hastanede kalış süresi dahil olmak üzere veriler kaydedildi.

Bulgular: Olgular arasında penetran travma en sık görülen mekanizmaydı (%62.9). Bilgisayarlı tomografi çekilen 25 hastanın 14'üne (%56) ameliyat öncesi diyafram rüptürü tanısı konuldu. Künt travmalarda diyaframadaki median defekt çapı 5.7 cm iken, penetran travmalarda 4.04 cm idi. Morbidite oranı %40 ve mortalite oranı %5.7 idi. Cerrahi uygulanan hastaların ameliyat sonrası hastanede kalış süreleri 4 ila 16 gün arasında değişiklik gösterdi. Laparotomi ve torakotomi grupları karşılaştırıldığında, laparotomi grubunun hastanede kalış süresi istatistiksel olarak anlamlı düzeyde daha uzundu (p=0.017) ve multidisipliner cerrahiye katılım açısından istatistiksel olarak anlamlı verilere sahipti (p=0.001).

Sonuç: Yüksek enerjili künt travmalara eşlik eden, özellikle çoklu alt seviye kosta fraktürleri, karaciğer ve dalak laserasyonları veya torakoabdominal bölgeye penetran travma öyküsü ile başvurularda diyafram rüptürü akla gelmelidir. Tanı ve tedavideki gecikmeler morbidite ve mortaliteyi artırabileceğinden, erken tanı ve hızlı tedavi esastır. Cerrahi işlem seçimi, eşlik eden yaralanmaların varlığına veya yokluğuna göre şekillenmelidir.

Anahtar sözcükler: Multidisipliner, radyolojik görüntüleme, cerrahi, travmatik diyafram rüptürü.

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Traumatic diaphragmatic rupture (TDR) is a rare, but severe injury which occurs following blunt or penetrating trauma to the thoracoabdominal region.^[1] It is observed in 8% of high-energy blunt traumas and in 10 to 15% of penetrating traumas.^[2,3] Traumatic diaphragmatic rupture predominantly affects the left side of the diaphragm (80 to 90%).^[4,5] Despite advancements in diagnostic imaging, TDR remains underdiagnosed in 9 to 41% of cases.^[3,6] Associated organ injuries often obscure the presence of TDR, resulting in a missed diagnosis.^[4]

Various imaging modalities, including chest radiography, computed tomography (CT), ultrasonography, magnetic resonance imaging, diagnostic peritoneal lavage, laparoscopy, and thoracoscopy, play key roles in identifying diaphragmatic defects.^[7,8] Once diagnosed, primary repair should be performed using non-absorbable sutures or patches, depending on defect size and location.^[3] Traumatic diaphragmatic rupture may manifest itself with a severe clinical manifestation or may continue its course silently without any clinical indication. If it has a silent course, it can make it very difficult for physicians to diagnose TDR.^[9] Although TDR may not cause morbidity in the acute phase, undiagnosed TDR can lead to clinical conditions with high morbidity and mortality in the late period, such as pneumonia, pleural effusion, empyema, cardiac tamponade, herniation, and strangulation.^[3,10] Therefore, correct diagnosis in the early period is of critical importance.

In the present study, we aimed to evaluate the diagnostic challenges, treatment approaches, and current management strategies for TDR and to discuss the latest technological advancements and the increasing availability of imaging modalities.

PATIENTS AND METHODS

This multi-center, retrospective study was conducted at Karadeniz Technical University Faculty of Medicine, Departments of Thoracic Surgery between January 2014 and January 2024. Consecutive Caucasian patients who were diagnosed with TDR and underwent surgical treatment were included. Seventeen additional patients who underwent surgery for TDR, but did not meet the inclusion criteria, delayed chronic TDR patients and had incomplete hospital records were excluded. Finally, a total of 35 patients (27 males, 8 females; mean age: 45.3±14.2 years; range, 13 to 68 years) who underwent diaphragmatic repair for TDR were included in the study. Written informed consent was obtained

from each patient. The study protocol was approved by the Karadeniz Technical University Faculty of Medicine Scientific Research Ethics Committee (Date: 07.03.2025, No: 2025/21). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient data were analyzed based on demographic characteristics, medical history, type of trauma, clinical findings, diagnostic methods used preoperatively, preoperative interventions, the establishment of an intraoperative diagnosis, associated organ injuries, side of the diaphragmatic rupture, type of surgical procedure, postoperative complications, and length of hospital stay.

Surgical approach and timing

The choice between laparotomy and thoracotomy varied according to the type and location of the injury and the surgeon's preference. Median laparotomy was the first choice for penetrating injuries to the abdomen and thoracotomy was the first choice for penetrating injuries to the thorax. Both approaches were combined in five patients. Patients who were operated late in the surgical removal process were taken into operation considering the increase in complications developing due to trauma during follow-up. Diaphragmatic injury was detected in these patients in the intraoperative period. The algorithm applied to TDR patients from the moment of initial presentation is shown in Figure 1.

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 25.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD) or median (min-max), while categorical variables were expressed in number and frequency. The chi-square test was used to test whether there was a relationship between two independent classification variables. A *p* value of <0.05 was considered statistically significant.

RESULTS

Among the 35 patients, 22 sustained diaphragmatic ruptures due to penetrating trauma, while 13 incurred injuries from blunt trauma. Of the penetrating injuries, 11 were caused by firearm trauma and 11 by sharp or cutting instrument injuries. Among the blunt trauma cases, seven resulted from falls, and six were caused by motor vehicle accidents. The diaphragm was injured on the left side in 22 patients,

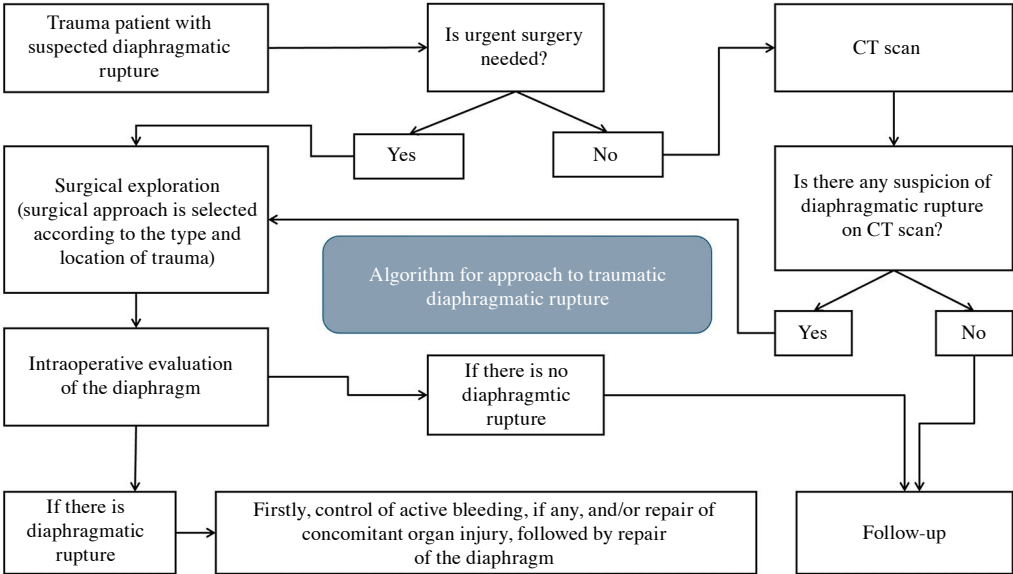


Figure 1. Study flowchart.
CT: Computed tomography.

on the right side in 13 patients. The mean body mass index (BMI) of the patients was 31.4 kg/m².

A suspicion of TDR was noted on the posteroanterior chest radiograph in 11 patients and on thoracic CT in 14 patients (Figures 2a-c). Preoperative findings included hematoma in 23, gastrointestinal perforation in six, organ herniation in three, free intraperitoneal fluid in two, and both hematoma and gastrointestinal perforation in one patient. In addition, TDR was diagnosed intraoperatively in 21 (60%) patients and preoperatively in 14 (40%) patients.

Surgery was performed on the day of admission in 26 (74.2%) patients and on the following day in nine (25.8%) patients. Intraoperative findings revealed that TDR was located on the left side in 22 (62.9%) patients and on the right side in 13 (37.1%) patients. The median rupture defect diameter was 5.7 (range, 2 to 10) cm in blunt trauma cases and 4.04 (range, 1 to 10) cm in penetrating trauma cases, with an overall median of 4.6 (range, 1 to 10) cm.

For the treatment of TDR, a median laparotomy incision was used in 16 (45%) patients and a

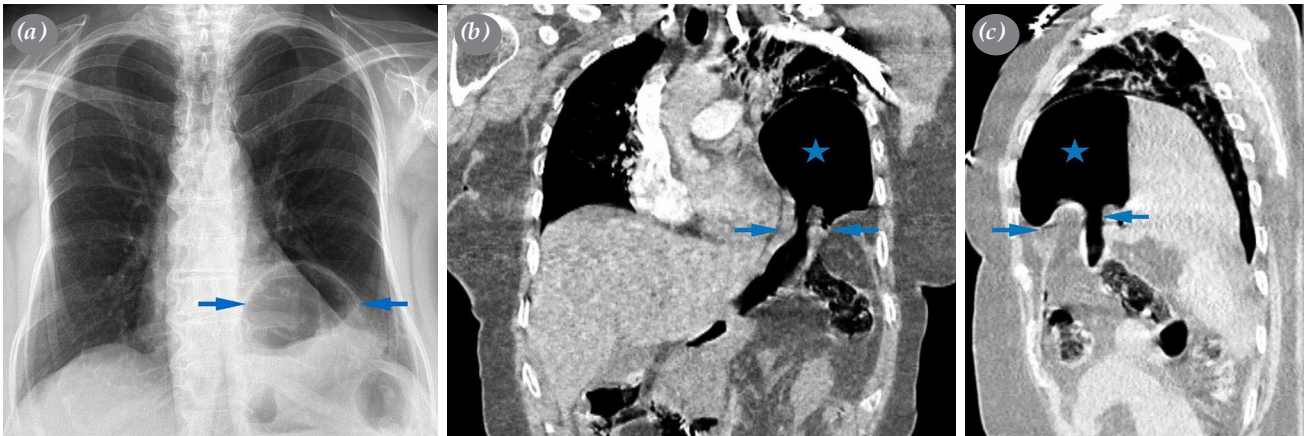


Figure 2. (a) Blue arrows show gastric herniation behind the heart in the left hemithorax on the PA chest radiograph after TDR. In the coronal section (b) and sagittal section (c) of the thoracic computed tomography showing gastric herniation in the left hemithorax after TDR, blue arrows indicate the ruptured diaphragm, and blue star indicates the herniated stomach.

PA: Posteranterior; TDR: Traumatic diaphragmatic rupture.

thoracotomy incision was used in 14 (40%) patients. Both incision types were used in five (15%) patients. The surgical method used in all cases was simple TDR repair (Figure 3a-c). In addition to TDR, 32 (92%) patients had concomitant intrathoracic or intraabdominal organ injuries. The most common intraabdominal injury was liver trauma, observed in 12 (34%) patients. Table 1 presents the clinical characteristics of the patients and their associated organ injuries. One (2.8%) patient with an intrathoracic hematoma, one (2.8%) with an intraabdominal abscess, one (2.8%) with gastric perforation, and one (2.8%) with intraabdominal hemorrhage and bile leakage required reoperation.

Postoperative complications developed in 14 (40%) patients who underwent surgery for TDR. Pulmonary complications (pneumonia and hematoma) were most frequently observed (Table 1). No deaths occurred in the postoperative period; however, two patients died in the perioperative period, resulting in an overall mortality rate of 5.7%. These patients, who presented with hypovolemic shock and multiple organ injuries (particularly liver and splenic lacerations), succumbed to massive hemorrhage. The median length of stay in the intensive care unit was 3.5 (range, 0 to 17) days, while the mean ward stay was 9.5 (range, 1 to 28) days. The median length of hospital stay was 13 (range, 3 to 39) days. The mean length of hospital stay was 14.5 ± 8.1 days among patients who underwent only median laparotomy ($n=16$) and 8.2 ± 4.6 days among those who underwent only thoracotomy ($n=14$).

Comparing laparotomy and thoracotomy groups, three factors were found to be statistically significant: involvement of multiple disciplines in the operation ($p=0.001$), length of stay in the ward ($p=0.014$) and total length of hospital stay ($p=0.017$) (Table 2).

According to preoperative CT scans, TDR was identified in eight patients (61%) with blunt trauma and in six (27%) patients with penetrating trauma, indicating a statistically significant difference ($p=0.046$) (Table 3).

DISCUSSION

In the present study, we evaluated the diagnostic challenges, treatment approaches, and current management strategies for TDR. This study underlines five key points: (i) Patients with blunt trauma were considerably older; (ii) Among patients who underwent CT imaging, a preoperative diagnosis of diaphragmatic rupture was established in 56% of cases, while 60% were diagnosed intraoperatively; (iii) Left diaphragmatic ruptures were observed in 85% of blunt trauma cases compared to 50% of penetrating trauma. The median diaphragmatic defect size was 5.7 cm in blunt trauma and 4.04 cm in penetrating trauma cases; (iv) A median laparotomy was performed in 45% of patients and a thoracotomy in 40%. All cases were managed by primary repair using non-absorbable sutures, without the use of mesh; and (v) Associated organ injuries were present in 92% of patients with blunt trauma.

Diaphragmatic ruptures are more common in young adults and males.^[11] Patients sustaining blunt

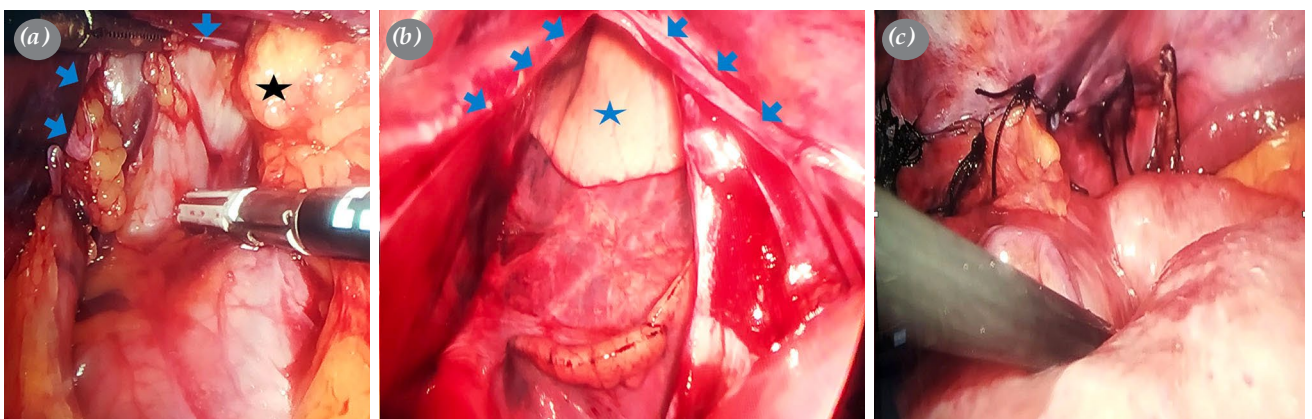


Figure 3. (a) In the median laparotomy performed after TDR, intestinal and gastric herniation is shown with black star, and ruptured diaphragm is shown with blue arrows. (b) After reduction of the gastric and intestinal organs into the abdomen, the basal part of the lung is shown with a blue star, and the ruptured diaphragm is shown with blue arrows. (c) Image showing primary repair of the diaphragm after reduction of organs by laparotomy for intestinal and gastric herniation after TDR.

TDR: Traumatic diaphragmatic rupture.

Table 1. Clinical characteristics of patients, associated organ injuries, postoperative complications, and treatments

	n	%	Mean±SD	Treatment
Age (year)			45.3±14.2	
Body mass index (kg/m ²)			31.4±4.8	
Sex				
Male	27	77		
Female	8	23		
Trauma type				
Blunt	13	37		
Fall from height	7	20		
Motor vehicle accidents	6	17		
Penetrating	22	63		
Sharp instrument injury	11	31.5		
Firearm injury	11	31.5		
Time of diagnosis				
Preoperative	14	40		
Intraoperative	21	60		
Diaphragmatic rupture side				
Right	13	37		
Left	22	63		
Mean diaphragmatic rupture defect diameter (cm)			4.6±2.4	
Blunt			5.7±2.5	
Penetrating			4.04±2.25	
Surgical procedure				
Laparotomy	16	45		
Thoracotomy	14	40		
Both	5	15		
Associated organ injury				
Multiple rib fractures	14	40		Stabilization in 3, follow-up in 11
Liver laceration	12	34		3 surgical repairs, 9 follow-ups
Lung laceration	10	28		Surgical repair
Splenic laceration	9	25		Splenectomy in 4, follow-up in 5
Bowel perforation	9	25		Surgical repair
Gastric perforation	7	20		Surgical repair
Kidney laceration	5	14		Nephrectomy in 1, follow-up in 4
Postoperative complications				
Pneumonia	5	14		Medical treatment
Wound site infection	4	11		Medical treatment and debridement
Hematoma	1	2.8		Follow-up with warm saline irrigation
Hematoma + wound site infection	1	2.8		Reoperation
Intra-abdominal abscess	1	2.8		Reoperation
Intra-abdominal hemorrhage + bile leakage	1	2.8		Reoperation
Stomach perforation	1	2.8		Reoperation

SD: Standard deviation.

trauma tend to be older, with a median age of 44 years, compared to a median age of 31 years for penetrating injuries. Tokgöz *et al.*^[31] reported a mean age of 37.6 (range, 20 to 65) years, while Mergan İliklerden

et al.^[12] reported a median age of 35 (range, 18 to 61) years. In the present study, the mean age of all patients was 45.3±14.4 (range, 20 to 71) years, with a median age of 51.6 years in the blunt trauma group

Table 2. Parameters showing differences between the surgical procedure groups

	Laparotomy (n=16)			Thoracotomy (n=14)			p
	n	%	Mean±SD	n	%	Mean±SD	
Age (year)			45.9±16.7			46.8±13.1	0.878
BMI (kg/m ²)			31.8±3.3			31.8±7.2	0.975
Involvement of multiple disciplines	16	45		6	17		0.001
Length of stay in the ward (day)			11.1±6.2			6.1±3.9	0.014
Total length of hospital stay (day)			14.5±8.1			8.2±4.6	0.017

SD: Standard deviation; * Five patients who underwent both laparotomy and thoracotomy were excluded from the groups.

Table 3. Parameters showing difference between trauma groups

	Blunt (n=13)			Penetrating (n=22)			p
	n	%	Mean±SD	n	%	Mean±SD	
Age (year)			51.6±15.1			42.3±13.5	0.075
BMI (kg/m ²)			32.4±6.4			31.2±3.5	0.506
Involve-ment of multiple disciplines	8	61		19	86		0.103
Detection on preoper-ative CT	8	61		6	27		0.046
Length of stay in the ward (day)			7.9±2.5			11.6±8.2	0.074
Total length of hospital stay (day)			10.6±2.6			15.9±11.5	0.064

SD: Standard deviation; CT: Computed tomography.

Table 4. Comparison of the advantages and disadvantages of laparotomy and thoracotomy

	Laparotomy	Thoracotomy
Advantages	• Ease of intervention in intraabdominal organ damage and hemorrhage • Easy manipulation of intraabdominal organ herniations in acute trauma • Possibility of exploration of both sides of the diaphragm	• Ease of intervention in thoracic cavity injuries • Exploration and ease of repair of isolated right diaphragmatic injuries
Disadvantages	• Exploration and repair of isolated right diaphragmatic injuries is difficult due to liver • Manipulation of herniated organs is difficult due to adhesions in the thorax in the repair of patients with delayed diagnosis of chronic diaphragmatic rupture	• Intraabdominal organ damage and hemorrhage are very difficult to intervene • Need for double lumen intubation • Whichever hemithorax is approached, that diaphragm can be evaluated. The opposite diaphragm cannot be explored.

and 42.3 years in the penetrating trauma group. Furthermore, a male-to-female ratio of 5:1 was observed, which aligns with the existing literature indicating a higher prevalence in males. The higher incidence of penetrating injuries in males may be attributed to their greater involvement in activities associated with criminal behavior. Moreover, the

mean ages in both the blunt and penetrating trauma groups in this study were higher than those reported in previous studies. This may be explained by the predominance of a middle-aged population in the region and sociodemographic factors which result in older individuals remaining actively engaged in outdoor work.

Approximately 75% of TDRs occur on the left side.^[12] The left medial and posterolateral portions of the diaphragm are embryologically weaker, rendering left hemidiaphragmatic ruptures more common than those on the right.^[3,13] Additionally, the sudden increase in intraabdominal pressure during high-energy trauma is partially absorbed by the liver, which exerts a protective effect on the right hemidiaphragm.^[15,7] In the present study, consistent with the literature, left diaphragmatic ruptures were the most frequent (62.9% vs. 37.1%). Left-sided ruptures were present in nearly all blunt trauma cases, whereas in penetrating trauma cases the distribution was approximately equal.

The diagnosis of diaphragmatic ruptures following high-energy trauma is often delayed due to the lack of specific clinical findings. Partial damage occurring in any layer of the diaphragmatic muscle, or the delayed rupture of an infected diaphragm, may occur several days after the initial injury. Furthermore, the prominence of symptoms related to multiple rib fractures and lacerations of the liver and spleen can mask the diagnosis.^[1] Previous studies have reported missed diagnosis rates ranging from 7 to 66%.^[11,14] Therefore, it is crucial to maintain a high index of suspicion for TDR in cases with associated organ injuries or a history of penetrating trauma.^[1] In this study, the diagnosis was initially missed in nine cases (25.7%), with diagnosis established only after the appearance of findings such as hematoma, hemorrhage, progressive herniation, and obstruction. Five of these cases resulted from blunt trauma and four from penetrating trauma. Consistent with the literature, it was diagnosed on average 3 ± 2.2 (range, 1 to 8) days after the injury. Patients were followed, as multiple organ injuries masked TDR and the injury could not be detected radiologically. Over time, factors such as the persistence of hemorrhagic fluid during chest tube follow-up, the development of secondary atelectasis from hematoma, progressive dyspnea, or the emergence of herniation due to increasing intraabdominal pressure eventually prompted the diagnosis. Although these symptoms may raise suspicion of diaphragmatic rupture, their absence in the acute phase can lead to delayed recognition.

In patients with stable vital signs, CT imaging is a valuable tool for detecting diaphragmatic ruptures. Compared to conventional CT, multi-slice helical CT has the advantages of significantly shorter imaging time, minimization of artefacts caused by respiratory movements, improved image quality

and the ability to obtain thinner slice images.^[15,16] Furthermore, the use of specialized digital software allows axial images to be reconstructed into coronal, sagittal and oblique planes, helping to identify difficult anatomical structures or injuries.^[15,16] With the widespread availability of multi-slice helical CT scanners in emergency departments, studies have demonstrated a sensitivity of 40 to 77% and specificity up to 100%.^[17-19] Of note, CT can directly visualize a diaphragmatic defect or indirectly suggest its presence through the herniation of intraabdominal organs.^[12] A recent study reported a detection rate of 44% for TDR via CT in a series of 126 patients with penetrating trauma.^[20] In this study, CT imaging was performed in 25 (71.5%) patients to evaluate diaphragmatic rupture. In the remaining 10 (28.5%), CT was not performed due to severe hemodynamic instability, and multiple organ injuries, and these patients were taken directly for emergency surgery. Among the patients who underwent CT, diaphragmatic rupture was identified in 56% of cases. However, when the patients were divided and compared according to the type of trauma, eight (61%) patients with blunt trauma and six (27%) patients with penetrating trauma were found, indicating a statistically significant difference. The reason for this is that the diaphragm is damaged at a larger diameter after high-energy transfer in blunt trauma and the pressure in the abdominal cavity during trauma increases the susceptibility of organs to herniation. For this reason, we believe that the diagnosis of penetrating traumas becomes more difficult due to the fact that the findings that would help to make the diagnosis are relatively less common in addition to the disruption of the integrity of the diaphragm suggestive of diaphragmatic rupture on CT. The findings in the present study, which reflect current data, appear to be higher than previously reported rates, suggesting that advancements in CT technology have improved the diagnostic process for TDR. However, these detection rates remain suboptimal. This may be explained by the fact that injuries to the right hemidiaphragm, particularly those with a rupture defect diameter of <4 cm, may not be accompanied by the herniation of intraabdominal organs, thereby masking the injury.

Penetrating injuries often result in smaller diaphragmatic defects, whereas blunt trauma tends to produce larger defects.^[12] The occurrence of herniation depends on the defect's diameter and the physical characteristics of the adjacent organs.^[4] In this study, the median rupture defect diameter

was 5.7 cm in blunt trauma cases and 4.04 cm in penetrating trauma cases. These findings are consistent with the literature. The higher energy transfer in blunt trauma is likely transmitted from the intraabdominal organs to the diaphragm, creating a blast effect that results in larger defects. In contrast, in penetrating injuries the defect size is directly proportional to the surface area of the penetrating object, thereby resulting in a smaller average defect size.

There is substantial literature on patients undergoing surgery for suspected diaphragmatic rupture and subsequently receiving a diagnosis intraoperatively. Zeybek et al.^[11] reported an intraoperative diagnosis rate of 36%, Tarladaçalışır et al.^[21] reported 40%, and Mihos et al.^[7] reported 74%. The intraoperative diagnosis rate in the literature varies considerably. In this study, 21 patients (60%) received the diagnosis intraoperatively, which falls within the range reported in previous studies. In these cases, the prominent symptoms of associated organ injuries often obscured the presence of a diaphragmatic rupture, which was then identified during surgery, accounting for the relatively high intraoperative detection rate. In addition, we attribute the high intraoperative diagnosis to the fact that the damage to the diaphragm was on the right side, the damage was small in diameter, and accordingly, the diaphragmatic integrity disorder could not be completely selected on CT. In addition, we believe that indirect findings such as herniation of intraabdominal organs that may occur in diaphragmatic rupture were not observed.

Intraoperative direct visualization of the diaphragm would allow the diagnosis and management of TDR. Since the diaphragm can be observed from both the thorax and abdomen, TDR management can be achieved from both cavities.^[18] Such patients can be difficult to manage, as the surgeon may be faced with the dilemma of which management to choose. Opening multiple body cavities is associated with increased morbidity and mortality rates. Inappropriate choice of surgical procedure delays the management of damaged internal organs, which is associated with increased mortality.^[22] Both approach techniques have their own advantages and disadvantages (Table 4). Clinical assessment of patients before the surgeon's choice of procedure and decision making accordingly is of critical importance. It would be more useful for the surgeon to assess the diaphragm from

the cavity containing suspected hemorrhage and/or accompanying serious injuries.^[18] In high-energy blunt trauma or penetrating trauma to the abdomen, the correct approach is laparotomy for high-grade liver, spleen or gastrointestinal tract injuries. In this way, the possibility of herniation of any intraabdominal organ is reduced and direct examination of the intraabdominal organs for potential injury can be performed. In patients with blunt trauma, the surgical approach is often through the abdomen. In the approach to be applied, priority should be given to control of bleeding and gastrointestinal system injury, if any, and then diaphragm repair should be performed.^[18] Thoracotomy should be considered in penetrating injuries to the thorax, displaced costal fractures at the lower levels of blunt trauma, hemothorax, massive air leakage and lung expansion defects. In this way, damage in the thoracic cavity, lacerations in the lung parenchyma can be easily controlled and the diaphragm can be explored. We believe that the most optimal choice of surgical method depends on the experience of the surgeon depending on the accompanying organ damages. In our study, the effect of the surgical approach on intraoperative diagnosis was compared. Half (50%) of 16 patients who underwent laparotomy were diagnosed intraoperatively, while 10 (71%) of 14 patients who underwent thoracotomy were diagnosed intraoperatively, indicating no statistically significant difference. In two of the five cases in which combined approach was used, laparotomy was first performed, but the patient was additionally approached by thoracotomy due to massive bleeding from the thorax. In three patients, thoracotomy was initially chosen, but due to the detection of gastrointestinal content and bleeding from the abdomen, a median laparotomy was performed. Thoracotomy approach accounted for 40% of all patients. The high rate of thoracotomy compared to laparotomy is attributed to the fact that the majority of penetrating traumas involve the thorax. The type and location of the injury influences the surgeon's approach, suggesting that the rate of thoracotomy is increased.

Minimally invasive surgery is safely used for both diagnosis and treatment of various diseases of the diaphragm.^[23] Recent studies have indicated that video-assisted thoracoscopic surgery is effective for both diagnosing and treating TDRs. In particular, a thoracoscopic approach applied to the right hemithorax offers the dual advantage of evaluating the right hemidiaphragm and thoroughly exploring the thoracic cavity.^[12,24]

This facilitates the identification and management of concomitant intrathoracic injuries. Furthermore, in the aftermath of high-energy blunt and penetrating thoracoabdominal traumas, laparoscopy provides the opportunity to assess both intraabdominal organs and the diaphragm.^[12,25] If necessary, a combination of these approaches may be used. In this study, stable patients with a delayed diagnosis might have been managed with minimally invasive techniques. We believe that the early application of minimally invasive methods in hemodynamically stable patients with suspected TDR would be advantageous. Increased surgeon confidence and decisiveness in this approach may lead to further improvements in patient outcomes.

Both penetrating and blunt traumas are frequently accompanied by injuries to other organs.^[26] In cases of diaphragmatic rupture due to blunt trauma, additional intraabdominal injuries are identified in 50 to 80% of cases. The most common associated organ injuries are spleen, liver, and hollow organs.^[3] In penetrating ruptures, this rate may increase to 80 to 95%.^[7,11] Specifically, lung injuries are most common in penetrating trauma, whereas blunt trauma is more frequently associated with fractures of the ribs, sternum, clavicle, and vertebrae.^[11] In this study, the most common thoracic injury accompanying diaphragmatic rupture was multiple rib fractures (40%). Regarding intraabdominal organs, the liver was affected in 34% of cases, the spleen and intestines in 25% cases, and the kidneys in 14% cases. Additionally, three patients had no associated organ injuries. Notably, 92% of patients with diaphragmatic rupture resulting from blunt trauma had associated organ injuries, indicating that exposure to high-energy trauma often results in multiple organ damage.

Comparing the length of hospital stay of the laparotomy and thoracotomy patients, the length of hospital stay of the laparotomy group was statistically significantly longer. We believe that the reason for this significant difference in our study is that the patients in this group had multiple organ damage, and their discharge processes were prolonged due to repair operations performed after gastrointestinal tract injuries. Similarly, we observed that the laparotomy group had significant statistical data in terms of multidisciplinary participation. We attribute this to the inevitability of multiple organ damage in case of any injury, as the abdominal cavity contains multiple organs. Thus, the need for

a multidisciplinary approach in abdominal injuries should be kept in mind before the operation.

Morbidity and mortality associated with diaphragmatic ruptures are associated with concurrent thoracic and intraabdominal organ injuries. Reported morbidity and mortality rates vary between 40 and 60% and 3.6 and 41%, respectively.^[11,27] In this study, the overall morbidity rate was 37%. Two patients died in the perioperative period due to massive hemorrhage, while no deaths occurred postoperatively, yielding an overall mortality rate of 5.7%. Both figures are consistent with those in the literature. Pulmonary complications were the most frequently encountered. Pain arising from both the diaphragmatic injury with accompanying multiple rib fractures and the surgical intervention may lead patients to intentionally reduce their depth of ventilation, suppress coughing, and avoid effective respiratory physiotherapy. Consequently, this may result in respiratory complications such as atelectasis and pneumonia. To prevent these complications, it is imperative not only to implement effective analgesia and administer mucolytic agents, but also to engage patients in active respiratory physiotherapy, postural drainage, deep breathing exercises, spirometry, and early mobilization. In our clinic, in order to prevent these complications, we attach importance to providing analgesia with an epidural catheter when necessary to provide effective analgesia, mobilization exercises for active respiratory movements and ensuring mobilization as much as possible in the postoperative period. In this study, five patients (14%) experienced serious pulmonary complications, predominantly atelectasis and pneumonia. Therefore, ensuring optimal pain control is critical to maximize patient compliance and to facilitate the essential components of an uneventful postoperative recovery following thoracic surgery.

The main limitations to this study its retrospective design and relatively small sample size. Further large-scale, prospective studies are needed to confirm these findings.

In conclusion, in patients presenting with high-energy blunt trauma accompanied by multiple rib fractures or a history of penetrating trauma to the thoracoabdominal region, diaphragmatic rupture must always be considered. The use of modern multi-slice helical computed tomography combined with careful evaluation of the diaphragm in all planes by both radiologists and surgeons can considerably

improve diagnostic accuracy. As delays in diagnosis and treatment may increase morbidity and mortality, early recognition and prompt management are essential. The choice of surgical procedure should be guided by the presence or absence of concomitant injuries. In patients requiring emergency surgical exploration, direct intraoperative visualization of the diaphragm is essential. Furthermore, depending on the surgeon's experience and the patient's stability, minimally invasive surgical techniques may be considered.

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