



The silent threat: A retrospective study of right-sided traumatic diaphragmatic hernias in a university hospital

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ABSTRACT

Objective: In hospital attendance, 75% of diaphragmatic hernias occur on left as opposed to 25% on the right side. Right side hernias are associated with abdominal injuries, mainly the liver. However, right-side injuries are frequently underdiagnosed due to the complexity of associated injuries and high mortality rates. The aim of this study was to perform a retrospective analysis of records from our clinical experience to investigate demographics, TM, diagnosis, morbidity, and mortality associated with right sided TDH. These findings may provide insights into improving the clinical management of patients with this serious injury, potentially reducing morbidity and mortality rates.

Material and Methods: Retrospective analysis of the medical records of patients from the trauma database of the Division of Trauma Surgery at University of Campinas in 32-year period was performed. Only records of patients with right sided TDH were included in the analysis.

Results: Blunt trauma was the most common mechanism. Diagnoses were made by laparotomy in eight cases, all these cases were hemodynamically unstable. TDH grade III injury occurred in most cases followed by grade IV. Liver injuries were present in almost all cases, most of them high grade, followed by colon and small bowel. Extra-abdominal associated injuries with a predominance of femur fractures, pelvic fractures and hemothorax. Post-operative complications were associated with length of stay in intensive care unit. Pneumonia was the most frequent complication. The overall mortality rate was 16%.

Conclusion: Most diagnoses were performed through laparotomy and not by radiologic exams, due to hemodynamic instability on admission. There is underdiagnosis of right-side TDH due to the high-energy trauma mechanism with high grade associated injuries and mortality on pre-hospital.

Keywords: Trauma, abdominal injuries, diaphragm, diaphragmatic hernia

INTRODUCTION

Traumatic diaphragmatic hernia (TDH) is defined as the protrusion of abdominal structures through an injured diaphragm into the thoracic cavity. TDH is most often caused by blunt trauma (BT) because it involves a more severe trauma mechanism (TM). However, its actual incidence may be slightly higher than expected due to underdiagnosis (1). The diagnosis of diaphragmatic injury is challenging for the surgeon and depends on a high index of suspicion, TM and interpretation of radiological images. In hospital care, 75% of TDH occur on the left versus 25% on the right (2-4). Explanation for this fact involves three mechanisms. First, the existence of an area of muscle weakness at the embryonic fusion area on the left posterolateral diaphragm. Next, the liver attributes a protective effect to the diaphragm on the right during sudden increases in intra-abdominal pressure, and finally, the underdiagnosis of patients with right diaphragmatic rupture due to the severity of associated injuries, mainly liver damage. On the other hand, in the literature, there is a higher incidence of TDH on the right side in the autopsies, demonstrating severity of the associated injuries (5,6). For the diagnosis of the initial phase, the awareness of these factors is mandatory for the surgeon, when these go unnoticed in trauma patients, this serious injury remains unidentified leading to significant mortality and morbidity. Trauma care is a global challenge for public health authorities. The aim of this study was to perform a retrospective analysis of records from our clinical experience to investigate demographics, TM, diagnosis, morbidity, and mortality associated with right sided TDH. These findings may provide insights into improving the clinical management of patients with this serious injury, potentially reducing morbidity and mortality rates.

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MATERIAL and METHODS

This is a retrospective study based on a retrospectively collected database from the medical records of patients of the Division of Trauma Surgery (DCT) at University of Campinas between January 1990 and July 2022. The metropolitan area of Campinas has a population of 3.5 million, encompassing 21 cities. Clinics Hospital of Campinas is a referral hospital for the population using the public health system in this region. It is a like a level 1 trauma center with 420 beds, specific trauma floor with 16 beds dedicated to low complexity injuries, and intensive care unit (ICU) only for polytrauma with 10 beds for patients with high complexity injuries.

The records of 425 patients with diaphragmatic injury by blunt or penetrating trauma (PT) were evaluated. Fifty-five patients with herniation were evaluated and 12 patients with exclusive right sided TDH were analyzed for demographic data, mechanism (BT or PT), hemodynamic status at admission [unstable patients are those with a systolic blood pressure (SBP) <90 mmHg], grade of the injury, herniated organs, diagnostic methods (preoperative and intraoperatively), the interval between diagnosis and surgery (less than 24 h), length of stay (LES) in the ICU and trauma floor, associated injuries, morbidity, and mortality. Trauma scores were calculated using the injury severity score (ISS).

Diaphragm injury was graded according to the American Association for the Surgery of Trauma (AAST) injury scale (7) as follows: grade I, diaphragm contusion; grade II, laceration less than or equal to 2 cm; grade III, laceration greater than 2 cm

and less than 10 cm; grade IV, laceration greater than 10 cm, with tissue loss less than or equal to 25 cm²; and grade V, laceration with tissue loss greater than 25 cm². Patients with left side hernias, grade I injuries, congenital defects, hiatal hernias, chronic and delayed traumatic hernias for more than 14 days were excluded.

Trauma surgery institutional protocol for the treatment of TDH, after the diagnosis, entails surgical exploration, which uses laparotomy, preferable in unstable or high-grade injuries, or laparoscopy (Figure 1). After recognizing TDH, the injury is treated by repairing defects with an interrupted nonabsorbable suture, such as polypropylene, in open surgery. In laparoscopy, injury is treated with polyglactin uninterrupted suture. Further, an ipsilateral chest tube or a nasogastric tube may be placed at the site of the injury for drainage (Figure 2). Descriptive statistics were used to analyze the data, with continuous variables expressed as means and categorical data expressed as frequencies and percentages. The results are presented in tables, which provide a clear and concise overview of the key findings of the study. Approval for the study was obtained from the University of Campinas and Institutional Review Board without restriction (Protocol No: 2.692.996, Date: 06.05.2018 and 5.892.808, Date: 02.14.2023).

RESULTS

Right-sided TDH were predominant in young males (75%). The most common mechanism of trauma was BT, accounting eight (67%) cases. Of these, motor vehicle collisions were the most common, accounting for seven (87%) cases, followed by

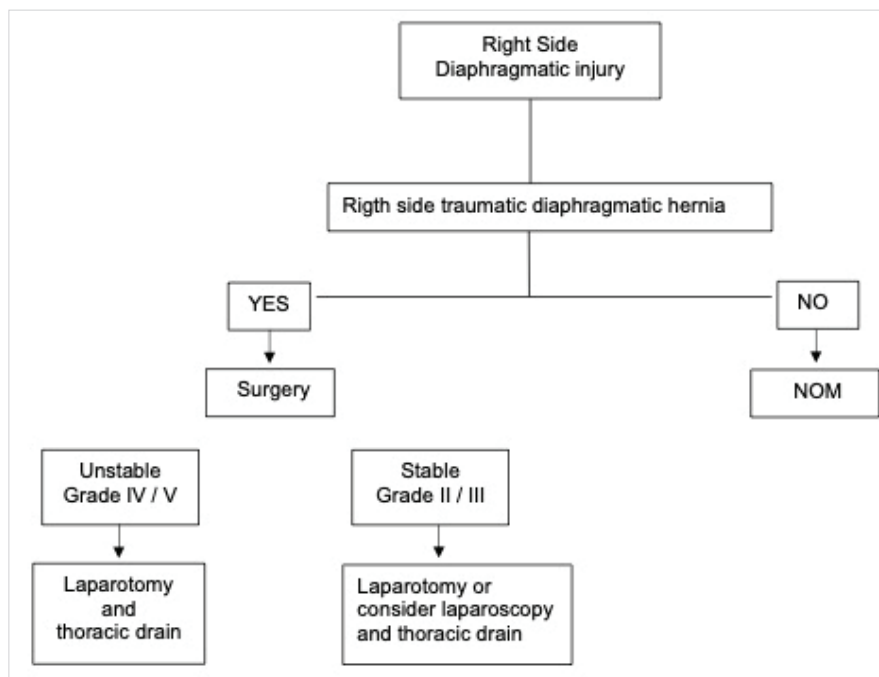


Figure 1. Institutional protocol.

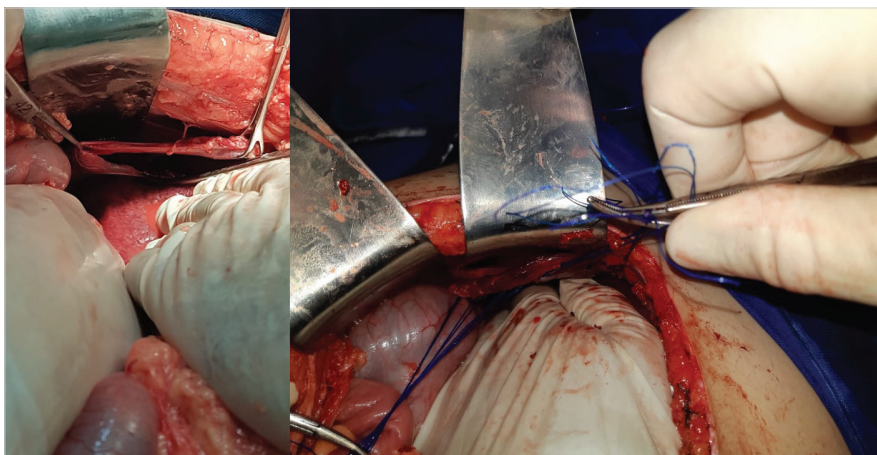


Figure 2. Grade III right side diaphragmatic injury on trauma laparotomy.

pedestrians hit by car in one (13%). All vehicle occupants were drivers, and in 80% of cases, the collision occurred on the right side of the vehicle compartment. In PT, three (75%) suffered a gunshot wound (GSW) and one (25%) from a stab wound (SW). Diaphragmatic grade III injury occurred in six cases (50%), grade IV in four (33%) and grade V in two (17%). Liver in eight patients (67%) was the most herniated organ, followed by the stomach with three (25%) and small bowel with one case (8%). Description between BT vs. PT analyses is shown in Table 1.

Eleven cases underwent laparotomy, one case with BT and stable clinical condition, was started with laparoscopy and had to be converted to laparotomy during the procedure due to technical difficulties (Figure 3). Two cases underwent laparotomy with thoracotomy.

Associated injuries were present in 11 out of 12 cases (92%). Liver injuries were the most common, occurring in 11 cases (92%), with a predominance of grade III and IV injuries. Colon injuries were present in four cases (36%) and small bowel injuries in two cases (18%), both predominantly grade II injuries. Extra-abdominal associated injuries were also observed in 10 cases (83%), with a predominance of femur fractures (40%). Hemothorax and open book pelvic fracture was observed in three cases each (30%). Associated injuries are summarized in.

In eight cases (67%), the diagnosis was made intraoperatively during laparotomy due to hemodynamic instability. Only four cases (33%) were able to undergo imaging exams prior to surgery due to their stable condition. Preoperative diagnosis was made in four cases (33%), with two based on chest radiography (CXR) (50%) and the other two with multi-slice computed tomography (CT). CXR showed common abnormal findings such as elevation of the right diaphragm, intrathoracic abdominal structures, and pulmonary contusion with rib fractures in all cases (Figure 4). CT showed herniation of abdominal contents and hump sign, as well as indirect findings

such as pulmonary contusion with rib fractures and mediastinal shift (Figures 5).

Postoperative complications occurred in six patients (50%). Pneumonia was the most frequent complication in BT (four cases, 50%) while, in PT, abdominal cavity abscess was present in two (50%). Mean LES in ICU was 13 and trauma floor were 18 days. ICU patients are commonly associated with prolonged mechanical ventilation and are three times more likely to undergo tracheostomy. An ISS greater than 15 was found in nine cases (75%) and greater than 25 in three, mostly observed associated with BT, as well as the cases with hemodynamic instability, which for the most part (six cases, 75%) were BT with liver injury. Overall mortality was two cases (17%), one BT and the other PT, both with hemorrhagic shock. Both were unstable during primary survey, high grade liver injury with hemothorax and ISS greater than 25, requiring massive transfusion during admission.

DISCUSSION

Comprehending the distinctions between blunt and penetrating trauma in relation to diaphragmatic injury is imperative. There is limited literature available on right sided TDH. Most of the right-side diaphragmatic injuries in our survey were caused by BT. Penetrating wounds often result in small defects, with occult injuries remaining silent before symptoms appear. On the other hand, BT commonly leads to large linear ruptures with immediate herniation. In our survey, BT with right side TDH grade III injury occurred in most cases followed by grade IV, with immediate herniation. Our study demonstrated that 67% of right-side TDH resulted from BT, which is strongly correlated with the high incidence of traffic injuries in the metropolitan region of Campinas. Specifically, 87% those hernias were caused by motor vehicle collisions, whereas 13% resulted from pedestrian hit by car.

Table 1. Description between BT vs PT analyses

	Penetrating	Blunt
Deaths	4 (33%)	8 (67%)
Male	4 (33%)	5 (42%)
Female	0	3 (25%)
Age		
<18 y	0	0
18-29 y	2 (16.6%)	2 (16.6%)
30-59 y	2 (16.6%)	6 (50%)
>60 y	0	0
SBP on admission		
< 90 mmHg	1 (25%)	6 (75%)
> 90 mmHg	3 (75%)	2 (25%)
Diagnosis		
CXR	1 (25%)	1 (12.5%)
CT	0	2 (25%)
Laparotomy	3 (75%)	4 (50%)
Laparoscopy	0	1 (12.5%)
Herniated organ		
Liver	2 (50%)	6 (75%)
Stomach	2 (50%)	1 (12.5%)
Small bowel	0	1 (12.5%)
Grade of injury		
III	3 (75%)	3 (37.5%)
IV	1 (25%)	3 (37.5%)
V	0	2 (25%)
ISS		
<25	4 (100%)	5 (62.5%)
>25	0	3 (37.5%)
Complications		
Infection	0	4 (50%)
Thrombosis	0	2 (25%)
Abscess	2 (50%)	0

According to Rodriguez-Morales et al., the diagnosis of TDH should be based on trauma kinematics and clinical assessment (3). Kearney et al. have demonstrated that lateral collisions can increase the risk of ipsilateral diaphragmatic hernia up to threefold (8). Despite the challenges in data collection, our study found that all vehicle occupants were drivers and in 80% of cases, the collision occurred on the right side of the vehicle passenger compartment, consistent with Kearney’s proposed pattern. These findings underscore the importance of early recognition of diaphragmatic injuries in trauma patients, particularly in lateral collisions. Our findings are like Brown and Richardson’s, regarding the organ that is typically herniated, it is

not surprising that the liver is the most affected in the majority of cases, given its proximity (4).

Intrahospital studies have shown that left-sided TDH account for 75% of cases, whereas right-sided account for 25% (6,9,10). This disparity involves three mechanisms. Firstly, Lucido and Wall demonstrated in 1963 the existence of a muscular weakness area in the embryonic fusion point in the postero-lateral left diaphragm (11). Secondly, the liver provides a protective effect to the right diaphragm during sudden increases in intra-abdominal pressure. Finally, there is an underdiagnosis of patients with right diaphragmatic rupture (1,5,6,9,10,12).

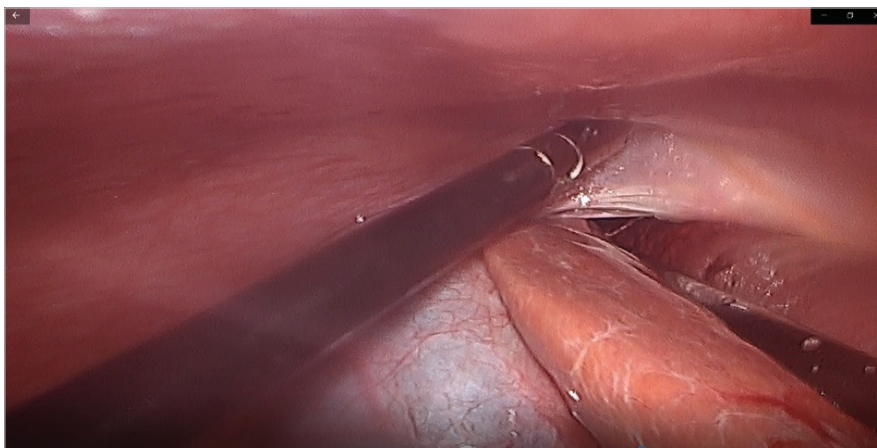


Figure 3. Diaphragmatic injury site on the laparoscopy.

Currently, intrahospital diagnosis of right-sided post-traumatic diaphragmatic hernias in severe blunt trauma patients is possible due to improvements in trauma systems. Including the efficient pre-hospital teams that stabilize and scoop to run patients to trauma center, trained trauma teams consisting of surgeons or emergency physicians in the trauma bay, 24/7 blood bank availability, and equipment such as CT, improved the accuracy of images facilitating their accurate interpretation by experienced radiologists. These advancements have led to an increase in the diagnosis of right-sided diaphragmatic hernias, which were previously underdiagnosed.

A study by Aun et al. compared two groups, one of which consisted of 97 cases of diaphragmatic hernias treated surgically and the other included 146 cases evaluated in 12,276 consecutive autopsies of patients without medical care (5). Autopsy group showed a higher incidence of right-sided diaphragmatic ruptures (49.6%) compared to the hospitalized group (14.4%). Additionally, the autopsied group had a greater number of associated injuries and more severe injuries,

including orthopedic and pelvic trauma, traumatic brain injury, and high-grade liver injuries. Shock was the main cause of death in over 80% of the autopsy group in contrast to the 15% in the hospitalized. The study concluded that patients with right-sided diaphragmatic hernias have severe injuries are quickly deadly.

Similarly, to Aun, Desforges have stated that there is a higher pre-hospital mortality rate in patients with right sided hemidiaphragm rupture, which is attributed to higher kinetics needed to produce an injury, typically associated with significant vascular tears in the inferior vena cava or hepatic veins (13). Boulanger et al. have observed that right-sided post-traumatic diaphragmatic hernias are more severe due to the greater number of associated injuries and found that all cases of right-side diaphragmatic hernia has associated abdominal injuries (6). Our findings demonstrate that associated injuries were present in almost all cases (92%), with high-grade liver injuries being the most common. Extra-abdominal associated injuries were observed, with a predominance of femur fractures and “open book” pelvic fractures. These results support the existing literature that emphasizes the severity of injuries resulting from high-energy mechanisms (6). Additionally, 67% of patients underwent intraoperative diagnoses by laparotomy, mainly due to hemodynamic instability. Only 33% were stable enough to undergo for imaging exam. These findings underscore the need for prompt surgical intervention in cases of right-sided diaphragmatic hernias. Moreover, like Boulanger we also observed higher injury severity scores ($ISS > 25$) in blunt trauma (6). Therefore, the presence of TDH following BT should alert the surgeon to the likelihood of associated solid-organ and pelvic injuries.

Awareness for the diagnosis of diaphragmatic injuries is crucial. Aronoff et al. have reported that physical examination is disappointing for diagnosing these injuries after blunt trauma, as it can only identify 44% of cases (10). We attribute the low

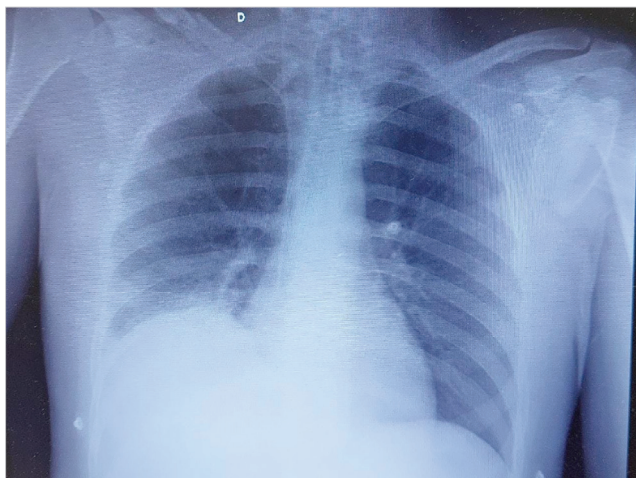


Figure 4. CXR abnormal findings (elevated diaphragm).

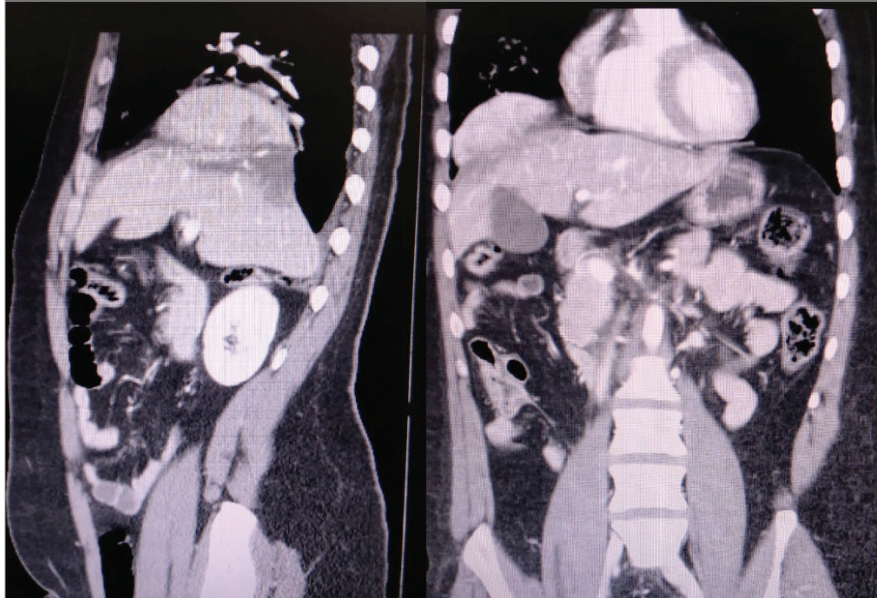


Figure 5. CT Hump sign.

sensitivity to three factors: first, lack of familiarity of surgeons with the disease; second, the low specificity of physical examination, which is often performed in a noisy trauma bay, making it difficult to perform assessment; and third, as patients with diaphragmatic hernias usually have associated injuries, hemodynamic shock or ventilatory compromise may divert the attention of the examiner.

CXR has limited diagnostic value. Gelman et al. have reported that the most sensitive radiographic finding for diagnosis is a 5 cm elevation of the diaphragmatic dome, seen in 61% of cases, followed by intrathoracic abdominal viscera in 45% although most radiographs are normal (14). CT has enhanced diagnostic accuracy and allowed for nonoperative management of hemodynamically stable polytrauma patients. The sensitivity of CT for blunt traumatic diaphragmatic injury ranges from 71 to 82%, with specificity ranging from 75 to 100%, while in penetrating trauma, sensitivity is 86 to 94% and specificity is 79 to 96% (15-18). Coronal and sagittal reformations contribute to the diagnostic accuracy, improving sensitivity and specificity. Our survey assessed the preoperative imaging methods for patients with some hemodynamic stability. CXR and CT were used to diagnose half of the patients each. The most frequent findings on CXR were right-sided diaphragm elevation of 5 cm and rib fractures. On the other hand, CT revealed abdominal viscera into the thorax, the "hump sign" and indirect findings such as pulmonary contusion, mediastinal shift, and rib fractures. However, it should be highlighted that due to most trauma patients arriving at the trauma bay unstable, the diagnosis by laparotomy remains the most performed method. Early diagnosis and surgical repair are mandatory to avoid catastrophic sequelae (19).

Despite the advantages of imaging modalities such as CT, the decision to perform a laparotomy was based on the associated abdominal injuries and hemodynamic status. In the context of blunt trauma and the possibility of associated injuries, hemodynamic and ventilatory instability may occur, questioning the role of laparoscopy. However, since the first report of the use of laparoscopy as a diagnostic and therapeutic tool, there has been a significant advancement in the technique. The experience of surgeons in elective procedures on the diaphragm, such as hiatal hernias, has made laparoscopy feasible in well-selected cases with appropriate devices that facilitate suturing. Our series involved one case in which diagnostic laparoscopy was used to diagnosis, this can be explained by inexperienced laparoscopic surgeons, but this, there was no differences observed in outcomes despite the treatment method.

Complications after surgery are not the same for penetrating and blunt injuries (20). In our study, many complications were associated with respiratory causes and not necessarily attributed to the diaphragmatic hernia. All survivors with BT had a significant length of stay in the trauma floor and intensive care unit, with a longer duration of mechanical ventilation, reflecting the severity and multiplicity of injuries, this observation can be explained by the fact that pneumonia was the most common complication, especially due to its association with mechanical ventilation.

Zazour et al. have reported a mortality rate of 21%, with higher mortality in patients with right-sided diaphragmatic injuries (21). Boulanger et al. have found a mortality rate of 41%, while our study had an overall mortality of 17%, with one PT and one BT resulting in death (6). All deaths had high grade liver and

lung laceration, evolved with the lethal triad. Early mortality is mainly related to the associated injuries rather than the diaphragmatic hernia and post operation complications. Therefore, post-traumatic diaphragmatic hernia serves as a marker for serious and lethal injuries.

The retrospective design of this study introduces some limitations. There is a possibility of biases due to changes in perspectives and tendencies in patient assessment when analyzing existing data. Additionally, data collection was relied on reviewing charts at the participating institution, which may have resulted in errors or omissions.

CONCLUSION

Diagnosis is often made via laparotomy due to hemodynamic instability. Most cases presented associated injuries indicating high-energy trauma, with the liver being the most herniated and injured in right-sided diaphragmatic hernias. The lethal triad was the main cause of death.

Ethics Committee Approval: This study was approved by University of Campinas and Institutional Review Board (Protocol No: 2.692.996, Date: 06.05.2018 and 5.892.808, Date: 02.14.2023).

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Author Contributions: Concept - VK, GPF; Design - VK; Supervision - VK; Data Collection and/or Processing - VK, TRAC; Analysis and/or Interpretation - ESH, TRAC; Literature Search - GPF; Writing Manuscript - VK, TRAC; Critical Reviews - ESH, GPF.

Conflict of Interest: The authors have no conflicts of interest to declare.

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**ORİJİNAL ÇALIŞMA-ÖZET**

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Sessiz tehdit: Bir üniversite hastanesinde sağ taraflı travmatik diyafram hernileri üzerine retrospektif bir çalışma

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ÖZET

Giriş ve Amaç: Hastaneye başvuruda diyafragma fıtıklarının %75'i solda, %25'i ise sağ tarafta meydana gelir. Sağ taraftaki fıtıklar, başta karaciğer olmak üzere karın yaralanmalarıyla ilişkilidir. Bununla birlikte, sağ taraftaki yaralanmalar, ilgili yaralanmaların karmaşıklığı ve yüksek ölüm oranları nedeniyle sıklıkla eksik teşhis edilmektedir. Bu çalışmanın amacı, sağ taraflı TDH ile ilişkili demografik özellikler, TM, tanı, morbidite ve mortaliteyi araştırmak için klinik deneyimlerimizden elde edilen kayıtların retrospektif bir analizini yapmaktır. Bu bulgular, bu ciddi yaralanmaya sahip hastaların klinik yönetiminin iyileştirilmesi ve potansiyel olarak morbidite ve mortalite oranlarının azaltılması konusunda fikir verebilir.

Gereç ve Yöntem: Campinas Üniversitesi Travma Cerrahisi Anabilim Dalı travma veri tabanından 32 yıllık dönemdeki hastaların tıbbi kayıtlarının retrospektif analizi yapıldı. Analize sadece sağ taraflı TDH'li hastaların kayıtları dahil edildi.

Bulgular: Künt travma en sık görülen mekanizmaydı. Sekiz olguda tanı laparotomi ile konuldu, bu olguların tümünün hemodinamikleri stabil değildi. Çoğu vakada TDH derece III yaralanma meydana geldi ve bunu derece IV izledi. Çoğu yüksek dereceli olmak üzere hemen hemen tüm vakalarda karaciğer yaralanmaları mevcuttu ve bunu kolon ve ince bağırsak takip ediyordu. Femur kırıkları, pelvik kırıklar ve hemotoraksın ağırlıklı olduğu karın dışı ilişkili yaralanmalar. Ameliyat sonrası komplikasyonlar yoğun bakım ünitesinde kalış süresiyle ilişkiliydi. Pnömoni en sık görülen komplikasyondur. Genel ölüm oranı yüzde 16 oldu.

Sonuç: Başvuru anında hemodinamik dengesizlik nedeniyle tanıların çoğu radyolojik incelemelerle değil laparotomi yoluyla konuldu. Yüksek enerjili travma mekanizması nedeniyle, hastane öncesi yüksek dereceli yaralanma ve mortalite nedeniyle sağ taraf TDH tanısı yetersiz konulmaktadır.

Anahtar Kelimeler: Travma, karın yaralanmaları, diyafram, diyafram hernisi

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