Diaphragmatic Injury in Patients with Penetrating Thoracoabdominal Injuries without Shock or Acute Abdomen at Admission: A cross-sectional study

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Tabla de contenido

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Abstract

Introduction

Penetrating Thoracoabdominal Injuries (PTAI) are associated with diaphragmatic injuries and subsequent complications. This study aimed to describe the prevalence of diaphragmatic injuries in patients with PTAI without signs of shock or acute abdomen at admission.

Materials and Methods

A cross-sectional, single-centered study was conducted in Bogotá, Colombia. The study included all patients with PTAI who underwent surgical exploration and were admitted without signs of shock or acute abdomen, between January 2019 and August 2021. Indications for surgical exploration included: presence of left thoracoabdominal wound, hemo or pneumothorax in pre-surgical imaging, abdominal pain, hypotension or anemia.

Results

A total of 284 patients were included in the final analysis. The median age was 29 years [IQR 22-33], with 269 patients (94.7%) being males. Out of these, 268 (94.3%) patients experienced stabbing as the mechanism of injury. The prevalence of diaphragmatic injuries diagnosed during surgical exploration was 15.1% (43 patients). There were 183 patients with left-side PTAI and 115 patients with right-side PTAI. The prevalence of right diaphragmatic injury was 25.2% (29 patients), while for left diaphragmatic injury it was 8.1% (15 patients). Only 1 patient presented with bilateral diaphragmatic injury.

Conclusions

The prevalence of diaphragmatic injuries in patients with PTAI, without signs of shock or acute abdomen upon admission, was 15.1%. However, the prevalence was 25.2% in right PTAI and 8.1% in left PTAI. These findings suggest that surgical exploration of

the diaphragm in cases of PTAI should be performed regardless of the side of the wound.

Keywords: Diaphragmatic, Traumatic

Introduction

Penetrating thoracoabdominal injuries (PTAI) are a challenge for the general surgeon, as injuries may occur in the abdominal or thoracic region and may require different surgical approaches. Also, diaphragmatic injuries may be unnoticed in the initial assessment, leading to significant long-term complications. Routinely, patients with stable hemodynamics and left thoracoabdominal wounds undergo surgical exploration. In contrast, for patients with right-sided PTAI, surgical intervention is indicated only when there is high suspicion of thoracic or intraabdominal injury [1,2].

The diagnosis of diaphragmatic injury in the context of PTAI has not been adequately established through diagnostic imaging [2]. Its presentation can lead to complications such as diaphragmatic herniation with strangulation of intraabdominal organs over a course of days or even years [2,3].

Computed tomography can detect extensive diaphragmatic injuries with intraabdominal content in 37.8% of the cases. This lack of a radiological gold standard for identifying diaphragmatic injuries in the trauma context [3,4] makes surgical approach an essential part of the diagnosis and management of PTAI [2].

In patients with PTAI, there is no global consensus on surgical exploration, often reserved for symptomatic patients. However, it has been noted that approximately 25% to 48% of patients with this type of injury may have a normal physical examination despite having an unsuspected diaphragmatic injury [5,6].

Usually, right PTAIs are not surgically explored, a justification for this is the presence of the liver as a protective mechanism against herniation. Nonetheless, reports of hepatic herniation in the presence of unnoticed right diaphragmatic injuries exist [7,8].

This study aimed to describe the prevalence of diaphragmatic injuries and intraoperative findings in PTAI patients admitted without signs of shock or acute abdomen.

Materials and Methods

A cross-sectional study was conducted. Electronic records of all patients who were admitted to the Emergency Department of a high-complexity hospital in Bogotá, Colombia, between January 2019 and August 2021, with PTAI were reviewed. This study was reviewed and approved by the institution's Ethics Committee (Acta 6-2021). The STROBE guideline was used to ensure proper reporting of methods, results, and discussion (SDC 1) [9].

All consecutive patients' electronic records of those who were admitted to the Emergency Department with PTAI were reviewed, patients 18 years of age or older without signs of shock or acute abdomen at admission who underwent surgical exploration, were included in the analysis.

The anterior thoracoabdominal region is delimited superiorly by the intermammary line, inferiorly by the margin of the last rib and laterally by the anterior axillary line in both sides, it is considered left or right according to its location from the midsternal line. The posterior thoracoabdominal region is delimited superiorly by the interscapular line, inferiorly by the posterior margin of the last rib and laterally by the posterior axillary line in both sides, it is considered left or right according to its location from the vertebral line. The right and left lateral thoracoabdominal regions are defined from the anterior axillary line to the posterior axillary line (Figure 1 and 2).

The surgical decision at admission, the patients included in this study did not present shock defined as systolic blood pressure < 90 millimeters of mercury (mmHg), evident clinical signs of hypoperfusion (alteration of consciousness, capillary refill >5 seconds, tachycardia >120 beats per minute (bpm)), or signs of acute abdomen (board-like abdomen, positive rebound sign). Additionally, patients did not exhibit any other

indications for emergency surgery (vascular injury, evident signs of hemo or pneumothorax, or cardiac tamponade). Patients were eligible to undergo surgical exploration based on the institutional clinical guidelines' criteria: all left-sided PTAI, evidence of hemo or pneumothorax on X-ray, onset of abdominal pain or signs of acute abdomen, systolic blood pressure <90mmHg, and/or anemia (a drop in hemoglobin >2g/dL within the first 24 hours of observation). The surgical approach was determined by the location of the wound and surgical indication. Patients who had right-sided wounds and the presence of hemo or pneumothorax underwent thoracoscopy and subsequent closed thoracostomy. Intraoperative findings determined conversion to thoracotomy (defined by massive hemothorax production) and/or laparotomy. Sternotomy could also be considered based on the presence of a positive pericardial window and the location of the wound.

Demographic variables such as age and gender were analyzed. Furthermore, the location of the wounds was categorized into regions within the thoracoabdominal area, classified by its laterality (right or left), anterior, posterior, or lateral within the described boundaries. The identification of imaging findings such as pneumothorax, hemothorax, and pneumoperitoneum was made by chest X-ray, taken in the first 6 hours after admission. Surgical approaches for all patients, as well as intraoperative findings, were documented. In-hospital stay, postoperative complications, and mortality were also analyzed.

This study exhibits selection bias as it is retrospective and single-centered. However, it represents one of the largest cohorts published for patients with thoracoabdominal injuries.

Due to the descriptive nature of the study, sample size calculation was not performed. All consecutive patients meeting the inclusion criteria were included.

The primary outcome assessed was the documentation of diaphragmatic injury, identified intraoperatively through different surgical approaches.

This study was presented and approved by the institution's Ethics Committee (Acta 6-2021) and performed in line with the principles of the Declaration of Helsinki. The 284 subjects who were included in the study signed informed consent forms for participation and publication of the results approved by the committee.

Statistical Analysis:

A description of demographic, clinical and surgical findings' variables was made as well as the description of patients with and without diaphragmatic injury. The distribution was assessed using the Shapiro-Wilk test. Categorical variables were described as proportions, and continuous variables were presented according to their normality, with medians and their corresponding interquartile range (IQR). In an exploratory way, a bivariate analysis was made for the outcome of diaphragmatic injury. There was no missing data among the interest variables. Analyses were conducted using RStudio version 4.1.

Results

A total of 284 patients were included in the final analysis according to the inclusion criteria. The median age was 29.12 [IQR 22-33] years, 269 (94.7%) were men and the median of in-hospital stay was 4.15 [IQR 2-5] days (Table 1).

It was observed that most patients had wounds on the left side 183 (64.4%), compared to the right side 115 (40.5%), and only 14 patients (4.9%) had bilateral wounds. Additionally, a total of 314 wounds were identified, of which 121 (38.5%) were on the right side and 193 (61.5%) on the left side.

Diaphragmatic wounds were evident in 43 patients (15.1%), with bilateral involvement in one patient. Furthermore, there were 30 patients (10.6%) with multiple thoracoabdominal wounds, among whom 16 (5.6%) had unilateral wounds, 6 (2.1%) only on the left side, and 10 (3.5%) only on the right side. Regarding the localization of wounds on each side, it was found that there were more posterior wounds, comprising 56 (46.2%) and 111 (57.5%) on the right and left sides, respectively. Similarly, lateral face wounds were fewer on both sides, with 23 (19%) on the right side and 34 (17.6%) on the left side. Regarding the mechanism of injury, the majority were caused by stab wounds (94.3%), while only 5.6% were caused by gunshot wounds. However, gunshot wounds were associated with a higher incidence of diaphragmatic injury (25%) compared to stab wounds (14.5%).

The x-ray documented findings in 109 patients (38%), with the primary finding being pneumothorax in 72 patients (25%). Among these, contained pneumothorax was the initial diagnosis in 18 patients (6.3%), while contained hemothorax was observed in 12 patients (4.2%). The most common initial surgical approach for managing this cohort was laparoscopy in 197 patients (69%), followed by laparotomy in 38 patients (13%), and thoracoscopy in 32 patients (11%) with the main surgical finding being solid organ injury in 67 patients (23%), followed by hemoperitoneum in 48 patients (16.9%). Thoracostomy was made in 160 patients (56%), pericardial window in 46 patients (16%), converted laparotomy in 23 patients (8%) and sternotomy in 4 patients (1.4%) according to the patients' requirement.

Postoperative complications were documented in 21 patients (7.3%), including early surgical reintervention in 11 patients (3.8%), pneumothorax in 7 patients (2.4%), bleeding in 5 patients (1.7%) and infection in 2 patients (0.07%). There were 2 deaths

(0.07%) in this cohort. The average length of in-hospital stay for this cohort was 4.15 [2-5] days.

Table 2 describes the characteristics of patients with and without diaphragmatic injury, it was identified that patients with right PTAI presented a greater number of diaphragmatic injuries, with 29 patients (25.2%) compared to those with left sided PTAI, 15 patients (8.1%).

Among patients with bilateral wounds, only 1 presented bilateral diaphragmatic injury. Only 15 patients (13.7%) with positive findings on x-ray presented diaphragmatic injuries, of which 14 (19.4%) also had pneumothorax. Patients with more complications were those without diaphragmatic injury, 15 (71.4%), compared to those with it, 6 (28.5%). Mortality did not differ between both groups; however, patients with diaphragmatic injuries had a longer in-hospital stay, with a mean of 4.86 days [3-6.5].

Discussion

This cohort represents one of the largest cohorts published in the literature on thoracoabdominal trauma [1,2,5,10–13]. Similar to multiple prior publications, our cohort exhibits a male predominance and a higher incidence of injuries caused by stabbing objects, particularly left thoracoabdominal wounds [1,4,5,12]. However, in our study, the most frequently injured quadrant is the left posterior thoracoabdominal area (57.05%), contrasting with previous reports that showed a higher proportion in anterior injuries [10], agreeing with the findings of Bautista-Parada IR et al. [5].

Alizade et al. [14] reported in their retrospective study the use of magnetic resonance imaging (MRI) for detecting diaphragmatic injuries compared to surgical exploration in a total of 43 patients. They identified a calculated sensitivity of 100% and specificity of 94%, with a positive predictive value of 86% and negative predictive value of 100%.

Further investigation into the role of MRI in detecting diaphragmatic injuries due to trauma is warranted, as well as evaluating its effectiveness in detecting small wounds. It is important to note the disparity in access to MRI facilities in our setting, particularly in trauma centers such as our institution where this diagnostic tool is not routinely used for this indication.

Regarding the rate of diaphragmatic injuries, our study shows a decrease in the incidence of diaphragmatic injuries in PTAI compared to Bautista-Parada IR et al. [5] which included 112 patients with thoracoabdominal wounds, documenting a diaphragmatic injury rate of 27.6%. Concerning other injured organs, these same authors identified hepatic injury in 9.8% of the cases, followed by spleen (6.25%) and colon (6.25%) injuries. In comparison, our study, find hepatic injury in 8.8% of patients, followed by hollow viscus injury (7.0%), and pulmonary injury (6.33%) being first three organs most commonly involved in thoracoabdominal trauma. Other reported rates of diaphragmatic injury reach up to 42% [11].

Proposing an expectant management approach, even in the presence of firearm injuries, presents itself as an alternative, with a reported rate of negative laparotomies of 33% [15].

The minimally invasive procedures such as laparoscopy and thoracoscopy have shown to be safer [2,13,16], indicating their appropriate utility in both diagnosing and treating diaphragmatic injuries. In our study, laparoscopic repair was documented in 14 cases (4.92%) and thoracoscopic repair in 2 cases (0.70%). Additionally, Koto et al. [10] reported the use of laparoscopy in cases of thoracoabdominal wounds with peritonitis, recommending its application alongside recognition of adequate expertise in this technique. This approach led to the successful management of intra-abdominal organ injuries in 93.3% of 83 hemodynamically stable patients [10].

This study has limitations due to its retrospective nature, being single centered, and that those patients with right PTAI who did not exhibit clinical deterioration (shock, abnormal x-ray findings, or acute abdomen), were not included, potentially leading to an underestimation of the true prevalence of right thoracoabdominal injuries. The main strength of this paper is the sample size and the strict follow up of surgical approach criteria.

We identified diaphragmatic injuries in a quarter of patients with right PTAI, with a possibility of long-term complications. This raises an additional controversy in the trauma field: Should we surgically manage right thoracoabdominal wounds? There is currently no scientific support or global consensus to answer this question definitively. However, considering our institutional experience, with a considerable prevalence of diaphragmatic injuries with potentially long-term complication, solid organ injuries and hollow viscus injuries, it is suggested that surgical exploration of the diaphragm in cases of PTAI should be performed regardless of the side of the wound.

Conclusions

The prevalence of diaphragmatic injuries in patients with PTAI, without signs of shock or acute abdomen upon admission, was 15.1%. However, the prevalence was 25.2% in right PTAI and 8.1% in left PTAI. These findings suggest that surgical exploration of the diaphragm in cases of PTAI should be performed regardless of the side of the wound.

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Annexes

Variable	**n (%)**
Sex	
Male	269 (94.7%)
Female	15 (6%)
Age mean [IQR]	29.12 [22-33]*
Patients with	
Thoracoabdominal injuries	284
Right thoracoabdominal injuries	115 (40.5%)
Left thoracoabdominal injuries	183 (64.4%)
Bilateral thoracoabdominal injuries	14 (4.9%)
Diaphragmatic injury	43 (15.1%)
Bilateral diaphragmatic injury	1 (0.003%)
Multiple thoracoabdominal injuries	30 (10.6%)
Multiple unilateral thoracoabdominal injuries	16 (5.6%)
Right multiple unilateral thoracoabdominal injuries	6 (2.1%)
Left multiple unilateral thoracoabdominal injuries	10 (3.5%)
Thoracoabdominal injuries	
Total	314
Right	121 (38.5%)
Left	193 (61.5%)
Right thoracoabdominal injuries	
Total	121 (38.5%)
Anterior	42 (34.7%)
Posterior	56 (46.2%)
Lateral	23 (19%)
Left thoracoabdominal injuries	
Total	193 (61.4%)
Anterior	48 (24.8%)
Posterior	111 (57.5%)
Lateral	34 (17.6%)
Mechanism	
Gun shot	16 (5.6%)
Stab weapon	268 (94.3%)

Initial X ray	
Positive findings	109 (38%)
Pneumothorax	72 (25%)
Hemothorax	24 (8%)
Pneumoperitoneum	1 (0,7%)
Initial diagnosis	
Contained pneumothorax	18 (6.3%)
Contained Hemothorax	12 (4.2%)
Contained hemopneumothorax	8 (2.8%)
Initial surgical approach	
Thoracoscopy	32(11%)
Thoracotomy	16(5.6%)
Laparoscopy	197 (69%)
Laparotomy	38 (13%)
Other surgical requirements	
Thoracostomy	160 (56%)
Pericardial window	46 (16%)
Converted Laparotomy	23 (8%)
Sternotomy	4 (1.4%)
Intraoperative findings	
Hemothorax > 500 ml	27 (9.5%)
Positive pericardial window:	5 (1.7%)
Cardiac injury	1 (0.3%)
Hemoperitoneum	48 (16.9%)
Solid organ injury	67 (23%)
Hepatic injury	25 (8.8 %)
Lung injury	18 (6.3%)
Vascular injury	16 (5.6%)
Hollow viscus injury	20 (7%)
Diaphragmatic injury	43 (15%)
Surgical treatment	
Laparoscopic phrenorraphy	14 (4.9%)
Open thoracic phrenorraphy	4 (1.4%)
Open abdominal phrenorraphy	23 (8.1%)
VATS phrenorraphy	2 (0.7%)
Pneumorraphy	14 (4.9%)
Lung lobectomy	1 (0.3%)
Postoperative complications	**21 (7.3%)**
Bleeding	5 (1.7%)
Infection	2 (0.07%)
Pneumonia	1 (0.03%)
Pneumothorax	7 (2.4%)
Clotted pneumothorax	5 (1,7%)
Early surgical reintervention	11 (3.8%)
Mortality	2 (0.07)
In-hospital LOS mean [IQR]	4.15 [2-5]*

Table 1. General Characteristics. IQR: interquartile range, VATS: Video-assisted thoracoscopic surgery, LOS: length of stay
*Quantitative variables are presented as mean and IQR

Variable	Diaphragmatic injury (n=43)	No diaphragmatic injury (n=241)
Sex n (%)		
Male	43 (15.9%)	226 (84%)
Female	0 (0%)	15 (100%)
Age Mean [IQR]	27.2 [20.5 – 31.5]	29.47 [23-33]
Region n of patients(%)		
Right thoracoabdominal	29 (25.2%)	86 (74.7%)
Anterior	14 (33.3%)	28 (66.6%)
Posterior	9 (16%)	47 (83.9%)
Lateral	8 (34.7%)	15 (65.2%)
Left thoracoabdominal	15 (8.1%)	168 (91.8%)
Anterior	7 (14.5%)	41 (85.4%)
Posterior	4 (3.6%)	107 (96.3%)
Lateral	8 (23.5%)	26 (76.4%)
Bilateral thoracoabdominal	1 (2.3%)	13 (5.3%)
Mechanism n (%)		
Gun shot	4 (25%)	12 (75%)
Stab weapon	39 (14.5%)	229 (85.4%)
Initial X ray n (%)		
Positive findings	15 (13.7%)	94 (86.2%)
Pneumothorax	14 (19.4%)	58 (80.5%)
Hemothorax	3 (12.5%)	21 (87.5%)
Hemopneumothorax	2 (11.1%)	16 (88.8%)
Pneumoperitoneum	0	2 (100%)
Initial diagnosis n (%)		
Contained pneumothorax	3 (16.6%)	15 (83.3%)
Contained Hemothorax	1 (8.3%)	11 (91.6%)
Contained hemopneumothorax	1 (12.5%)	7 (87.5%)
Surgical approach n (%)		
Thoracosthomy	36 (22.5%)	124(77.5%)
Thoracoscopy	4 (12.5%)	28 (87.5%)
Thoracotomy	2 (12.5%)	14(87.5%)
Sternotomy	2 (50%)	2 (50%)
Laparoscopy	32 (16.2%)	165(83.7%)
Laparotomy	15 (39.4%)	23 (60.5%)
Converted Laparotomy	16 (69.5%)	7 (30.4%)
Pericardial window	10 (21.7%)	36 (78.2%)
Intraoperative findings n (%)		
Hemothorax > 500 ml	3 (11.1%)	24 (88.8%)
Positive pericardial window	2 (40%)	3 (60%)
Cardiac injury	1 (100%)	0
Hemoperitoneum	25 (52%)	23 (47.9%)
Solid organ injury	31 (46.2%)	36 (53.7%)
Hepatic injury	16 (64%)	9 (36 %)
Lung injury	3 (16.6%)	15 (83.3%)
Vascular injury	2 (12.5%)	14 (87.5%)
Hollow viscus injury	9 (45 %)	11 (55%)

Surgical treatment n (%)		
Laparoscopic phrenorraphy	14 (100%)	0
Open thoracic phrenorraphy	4 (100%)	0
Open abdominal phrenorraphy	23(100%)	0
VATS phrenorraphy	2 (100%)	0
Pneumorraphy	2 (14.2%)	12 (85.7%)
Lung lobectomy	0	1 (100%)
Postoperative complications n (%)	**6 (28.5%)**	**15 (71.4%)**
Bleeding	2 (40%)	3(60%)
Infection	1 (50%)	1 (50%)
Pneumonia	0	1 (100%)
Pneumothorax	2 (28.5%)	5 (71.4%)
Clotted pneumothorax	0	5 (100%)
Early surgical reintervention	3 (27.2%)	8 (72.7%)
Mortality n (%)	1(50%)	1(50%)
In Hospital LOS Mean [IQR]	4.86 [3-6.5]	4.03 [2-4.25]

Table 2. Diaphragmatic injury. IQR: interquartile range, VATS: Video-assisted thoracoscopic surgery, LOS: length of stay

Figure 1. Anterior and lateral PTAI. A) Left side B) Right side. 1: midsternal line, 2: left anterior axillary line, 3: left midaxillary line, 4: left posterior axillary line, 5: right posterior axillary line, 6: right midaxillary line, 7: right anterior axillary line, 8: intermammary line, 9: anterior lower margin of the last rib line. PTAI: penetrating thoracoabdominal injury

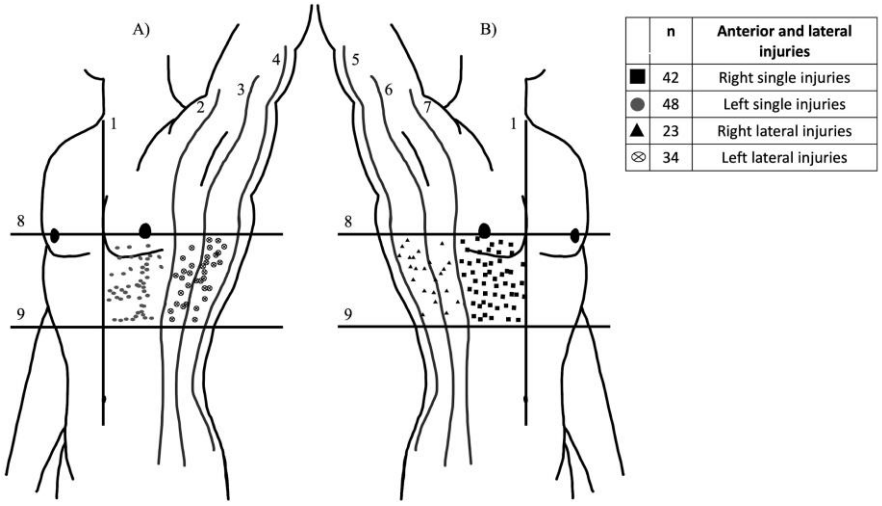

Figure 2. Posterior PTAI. 10: vertebral line, 11: interscapular line, 12: posterior lower margin of the last rib line. PTAI: penetrating thoracoabdominal injury

	n	Posterior injuries
●	56	Right single injuries
■	111	Left single injuries