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Surgical Management of Thoracic Trauma

Ivonne Alondra León Suárez[1], Morelos Adolfo García Sánchez[2], María de los Ángeles Carmona Alva[3], & José Luis García Hernández[4]

1. Specialist in Surgery. Attached to the Department of Surgery General Hospital "Dr. Rubén Leñero" of the Ministry of Health of Mexico City. Graduated from The National Autonomous University of Mexico. Mexico City. Country Mexico
2. Specialist in General Surgery with a subspecialty in Colorectal Surgery. Attending Surgeon in the Department of Surgery at the "Dr. Rubén Leñero" General Hospital, Ministry of Health of Mexico City. Graduate of the National Autonomous University of Mexico, Mexico City, Mexico
3. Specialist and Holder of the Specialty Course in Surgery, Attached to the Department of Surgery General Hospital "Dr. Rubén Leñero" of the Ministry of Health of Mexico City. Graduated from the National Autonomous University of Mexico. Mexico City. Country Mexico
4. Specialist in Surgery. Attached to the Department of Surgery General Hospital Iztapalapa "Dr. Juan Ramón de la Fuente" of the Ministry of Health of Mexico City. Graduated from The National Autonomous University of Mexico. Mexico City. Country Mexico

Abstract: Introduction: Thoracic trauma represents a critical challenge in emergency medicine and trauma surgery, encompassing a broad spectrum of injuries ranging from minor rib fractures to life-threatening visceral damage. Objective: To describe the clinical experience and outcomes of surgical interventions in patients with thoracic trauma treated at public hospitals within the Ministry of Health. Method: A multicenter, retrospective, longitudinal, observational, and descriptive study was conducted by the General Surgery departments of three secondary-care hospitals. Results: The study included 65 patients, all of whom were male (100%), with a mean age of 35 years (mode: 34; range: 20–68). Regarding the mechanism of injury, 96% of cases were attributed to interpersonal violence. The reported morbidity rate was 63.07% (adjusted to 34%), with a mortality rate of 16.6%. Conclusions: In Mexico, surgical thoracic trauma is predominantly associated with interpersonal violence involving male victims. While the diagnosis is frequently evident due to the nature of the presentation, successful management relies heavily on advanced surgical expertise. Surgeons demonstrate high levels of clinical efficiency and technical proficiency in the resolution of these complex cases.

Keywords: Trauma, Thoracic trauma, Cardiac tamponade, Hemothorax, Pneumothorax, Empyema, Hypovolemic shock.

INTRODUCTION

Thoracic trauma represents a critical challenge in emergency medicine and surgical trauma care, encompassing a broad spectrum of injuries ranging from minor rib fractures to life-threatening visceral damage. Common etiologies include falls, motor vehicle collisions, and interpersonal violence.[1] In polytrauma patients, thoracic trauma is the second most frequent unintentional injury and the third leading cause of death, following traumatic brain and abdominal injuries.[2] It accounts for approximately 15% of all trauma cases and is present in nearly half of polytraumatized patients. Furthermore, it is the second leading cause of mortality after traumatic brain injury, contributing significantly to death in an estimated 25% to 50% of trauma cases.[3] Given its potential for rapid progression, prompt recognition, clinical assessment, and appropriate management are essential to mitigate

complications and improve patient outcomes.[4] Blunt thoracic trauma is characterized by injuries that do not breach skin integrity; this mechanism is prevalent in motor vehicle accidents, falls, and sports-related injuries. Such trauma can lead to severe complications, including hemothorax, pneumothorax, or pulmonary contusions, which result in high morbidity and mortality if not managed in a timely and effective manner.[5] Globally, thoracic trauma is a major public health concern, accounting for 10% to 15% of all traumatic injuries and serving as the direct cause in nearly 25% of all trauma-related deaths.[6] In Mexico, mortality rates associated with interpersonal violence (homicide) are exponentially high within specific demographics. Data from 2024 indicates that assault is the second leading cause of death in the 15–24 age group and the primary cause in the 25–34 age group, falling to sixth place among those aged 45–54. Additionally, accidents remain a significant cause of mortality. [7, 8] The factors that most frequently determine patient survival are the etiology and the temporality of intervention. [9] Currently, thoracic trauma is responsible for approximately one-quarter of all trauma-related deaths, with some estimates reaching as high as 60%.[10] Rib fractures occur in approximately 40% of patients with thoracic trauma. Multiple rib fractures are strongly associated with pneumothorax, hemothorax, flail chest, and pulmonary lesions, all of which can significantly increase mortality rates.[11]

OBJECTIVE

To describe the clinical experience and outcomes of surgical interventions in patients with thoracic trauma treated at public hospitals under the Ministry of Health in Mexico City.

METHODS

This is a multicenter, retrospective, longitudinal, observational, and descriptive study conducted by the General Surgery services of three secondary-care hospitals within the Mexico City Ministry of Health:

1. Iztapalapa General Hospital "Dr. Juan Ramón de la Fuente"
2. Tláhuac General Hospital
3. General Hospital "Dr. Rubén Leñero"

The study period spanned from February 1, 2023, to February 1, 2026, focusing on patients who underwent surgical intervention for thoracic trauma at the aforementioned institutions.

Case records were systematically reviewed to evaluate the following variables: age, sex, etiology (mechanism of injury), type of surgical intervention (emergency, urgent, or elective), operative time, estimated blood loss, length of hospital stay, morbidity, and mortality. Post-operative follow-up was conducted through outpatient consultations.

Data analysis was performed using descriptive statistics, including measures of central tendency and relative frequency distributions, ensuring a high level of confidence in the reported values.

RESULTS

A total of 65 patients were analyzed, all of whom were male (100%). The mean age was 35 years (mode: 34; range: 20–68 years). Regarding the etiology of thoracic trauma, 96% of cases were secondary to interpersonal violence. The most frequent mechanism of injury was penetrating wounds from firearm projectiles, accounting for 27 cases (41.53%), followed by sharp-force injuries in 24 patients (36.92%). Blunt thoracic trauma was the third most common presentation with 13 cases. **See Table 1.**

Table 1: Etiology of Thoracic Trauma in Patients from Three Ministry of Health Hospitals in Mexico City

Etiology of Thoracic Trauma	N	%
Firearm Injuries	27	41.53
Sharp-Force Injuries.	24	36.92
Blunt Thoracic Trauma	13	20
Motor Vehicle Accidents	6	11.11
Occupational Accidents.	3	07.40
Others	1	01.23
Total	74	

Within the study cohort, six patients sustained thoracic trauma from motor vehicle accidents and three from occupational incidents, including one case of crush injury. Although the analysis accounted for overlap in causal factors, the statistical adjustments were calculated based on the actual sample size. Notably, firearm injuries emerged as the predominant mechanism of trauma in this series.

Clinical diagnoses served as the primary surgical indication, and interventions were categorized by urgency as emergent, urgent, priority, or elective. While concomitant injuries to other vital organs were identified, this study focused exclusively on patients requiring a thoracic surgical approach.

According to the findings summarized in **Table 2**, the predominant clinical entity was thoracic trauma associated with rib fractures—occurring either in isolation or in combination with pneumothorax or hemopneumothorax—accounting for 45% of the cohort. Initial clinical suspicion was confirmed via chest X-ray and/or computed tomography (CT). Within this group, three cases of tension pneumothorax were identified, requiring immediate decompression and chest tube thoracostomy in the resuscitation bay, followed by elective surgical fixation in cases of complex multiple rib fractures.

The second most frequent pathology involved pulmonary parenchymal injuries, identified in 17 patients (26%) who presented with hypovolemic shock upon admission. Due to institutional infrastructure limitations regarding immediate diagnostic imaging, management was based on clinical assessment, leading to emergency anterolateral thoracotomy. In these instances, surgical repair (suture repair) of the parenchyma and tributary vessels was performed, achieving effective hemostasis.

In descending order of frequency, 11 cases of cardiac injury (17%) were documented. The diagnostic approach included pericardiocentesis or a pericardial window, with definitive surgical resolution via sternotomy or left anterolateral thoracotomy. Myocardial repair was

successfully achieved without intra-aortic balloon pump (IABP) support, given the limited availability of advanced technological resources. Finally, although a damage control surgery strategy was considered for selected cases, its implementation was restricted by the technical complexity and the critical nature of the injuries. **[12]**

Furthermore, thoracic injuries with concomitant abdominal involvement—clinically referred to as penetrating thoracoabdominal trauma—ranked fourth in incidence. This diagnosis was identified in eight individuals; it should be noted that a ninth case involving a pregnant patient was initially identified but subsequently excluded to maintain the homogeneity of the study sample. In this specific trauma category, firearm injuries predominated, with hypovolemic shock serving as the primary determinant for strategic management. Successful emergency surgical intervention relied on the coordinated response of the anesthesiology and nursing teams, as well as the blood bank.

The diagnostic protocol was based on non-contrast computed tomography, due to the lack of available contrast media or clinical laboratory support at the time of admission. In the emergency setting, simultaneous left thoracotomy and exploratory laparotomy (celiotomy) were performed to address hemoperitoneum, pneumothorax, and hemothorax. The primary objective focused on damage control surgery for vital organs and achieving hemostasis through packing, with subsequent prioritized procedures scheduled in a staged manner. Finally, six patients experienced cardiopulmonary arrest; these individuals responded to resuscitation maneuvers and subsequently developed post-cardiac arrest syndrome. **See Table 2**.

Table 2: Surgical Diagnosis, Diagnostic Imaging, Association with Shock, Type of Surgery, and Surgical Procedures

Surgical Diagnosis	No/%	Diagnostic Studies	Shock Grade	Type of Surgery	Therapeutic Management
Lung Injury	17/26	Clinical/None	IV	Urgent	Pulmonary Suture Repair
Cardiac Injury	11/17	Fast Usg/Tc	IV	Emergent	Cardiac Suture Repair
Diaphragmatic Injury	5/8	Chest X-Ray	II	Urgent	Mesh Repair
Cardiac Tamponade	4/6	Ct	III/IV	Emergent	Cardiac Suture Repair
Greatvassel Injury	3/4	Clinical/Tc	I	Urgent	Packing
Rib Fractures/Pneumothorax/ Hemothorax	29/45	Rib Series/Ct Ct	0	Elective/Na	Surgical Fixation/Chest Tube
Flail Chest.	4/6	Ct	I	Priority	Damage Control
Penetrating Thoracoabdominal Trauma	8/12	Clinical/Tc	III/IV	Emergent	Damage Control
Total	81				

Thoracic trauma involving acute diaphragmatic rupture occurred in 8% of cases, presenting with hemorrhage, Grade II hypovolemic shock, and associated pneumothorax. These patients underwent emergency thoracic surgery aimed at restoring the anatomical and functional integrity of the diaphragm via primary suture repair (raffia) or the use of Teflon mesh, depending on resource availability. Diagnostic support was based on basic imaging, including plain chest X-rays and, in selected instances, non-contrast computed tomography.

Great vessel injuries were analyzed as a distinct category, involving the descending aorta, the aortic arch, the superior and inferior vena cava, and the pulmonary veins. Multivascular involvement was identified in several patients. Successful surgical repair (raffia) was achieved for both the vena cava and the aorta; however, pulmonary vein repair remained a significant technical challenge. In emergency scenarios involving Grade IV hypovolemic shock,**[13]** surgical approaches included bilateral thoracotomy, left anterolateral thoracotomy, and exploratory laparotomy.

Finally, flail chest was identified as another significant surgical diagnosis. Of these patients, four were managed with supportive care, two of whom required mechanical ventilation; notably, these patients did not present with hypovolemic shock. Elective surgical management via rib osteosynthesis was performed in three cases, while one patient was successfully transferred to a tertiary care center for specialized management. **See Table 3.**

Table 3: Grade of Hypovolemic Shock in Patients with Thoracic Trauma

Shock Grade	Number/%
Grade O	07/10.76
Grade I	02/3.07
Grade II	06/09.23
Grade III	03/04.61
Grade IV	47/72.30
Total	65/100

The majority of cases presented with Grade IV hypovolemic shock, with some patients meeting criteria for irreversibility; nevertheless, despite institutional limitations, definitive therapeutic management was achieved. This critical state affected a total of 47 patients (72.30%), representing a notably high incidence. Grade 0 shock followed in frequency, occurring predominantly in cases of flail chest, rib fractures, and simple pneumothorax. It is imperative to specify that these clinical statuses were determined upon admission to the emergency department or the shock trauma bay.

In one specific case, an emergency anterolateral thoracotomy with open-chest cardiac massage was performed. Furthermore, several immediate transfers to the operating room were executed, based exclusively on clinical judgment and the attending surgeon's decision.

Regarding the therapeutic strategies employed, management was individualized and expedited, based on critical clinical decisions made by the attending surgeon to optimize patient outcomes. This comprehensive approach began at the time of prehospital reception and continued through the surgical phase, including vital sign monitoring, initial clinical assessment, chest tube thoracostomy, central venous catheterization, and immediate transfer for emergency surgery. The most frequent surgical procedure was left anterolateral thoracotomy, performed in 42 patients (64.61%), followed by right anterolateral thoracotomy in 11 cases (16.92%). Additionally, two bilateral thoracotomies and two median sternotomies (3.07%) were documented. In cases of flail chest, elective multiple rib osteosynthesis was performed once clinical stability was achieved. **See Figure 1.**

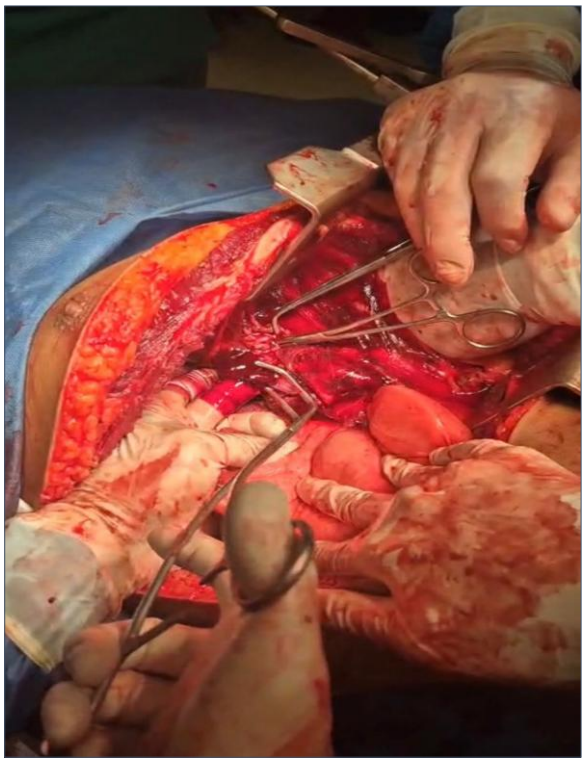

Figure 1: Thoracic surgery via left anterolateral thoracotomy with cardiac exposure and myocardial suture repair.

Cardiac repairs (suturing/raffia) are performed expeditiously, optimizing available resources in the absence of advanced technology, vascular surgeons, or interventional angiologists, and without the support of extracorporeal circulation or hemodynamic services. From a surgical standpoint, these represent high-complexity techniques requiring rapid and efficient exposure to repair muscular defects in a beating heart, with a critical emphasis on preserving the coronary arteries to prevent intraoperative ischemia or myocardial infarction.

Furthermore, in patients with penetrating thoracoabdominal trauma, a simultaneous dual-cavity approach was employed. The primary objective of this strategy was damage control and achieving hemostasis through ligatures, sutures, and packing, in order to stabilize the patient for subsequent scheduled surgeries. These procedures, performed in critical scenarios involving Grade IV hypovolemic shock and multiple organ failure, rely fundamentally on the surgeon's expertise and clinical judgment, constituting life-saving measures intended to preserve the patient's life under extreme conditions.

The mean operative time was 129 minutes (range: 38–191 minutes). Regarding intraoperative blood loss quantified by the anesthesiology service, a mean of 1,830 mL was recorded, with ranges between 40 and 4,200 mL. Forty-three percent of the cohort (n=28) was successfully transferred to the Intensive Care Unit (ICU) for specialized postoperative management, with a mean ICU stay of 14 days (range: 7–17 days). The mean total hospital stay was 23 days (range: 0–51 days). An overall morbidity rate of 63.07% was reported, which was adjusted to 34% considering that patients frequently presented with multiple complications, either simultaneously or sequentially. Detailed postoperative complication findings are presented in **Table 4**.

Table 4: Morbidity in Patients Undergoing Thoracic Surgery for Chest Trauma.

Morbidity Number /%	
Pneumonia	07/10.76
Pleural Effusion	05/07.69
Empyema	11/16.9
Cardiac Sequelae	03/04.61
Brachial Plexus Injury	03/04.61
Spinal Cord Injury	02/03.07
Surgical Site Infection	10/16.92
Total	41/63.07

Infectious processes were identified as the three leading causes of morbidity within the study group. Empyema and pulmonary abscesses ranked first; these conditions required surgical drainage and targeted antibiotic therapy based on specific cultures and sensitivity testing. In refractory cases, secondary surgical interventions such as decortication and/or lobectomy were performed.

The second most frequent complication was surgical site infection, which demanded exhaustive management, including serial debridement/dressings, microbiological cultures, and specific antibiotic regimens. Healthcare-associated pneumonia ranked third in incidence and was managed similarly with culture-guided antimicrobial therapy. Finally, cases of pleural effusion were managed via chest tube drainage, with pleurodesis using povidone-iodine or talc performed in four patients. **See Figure 2**.

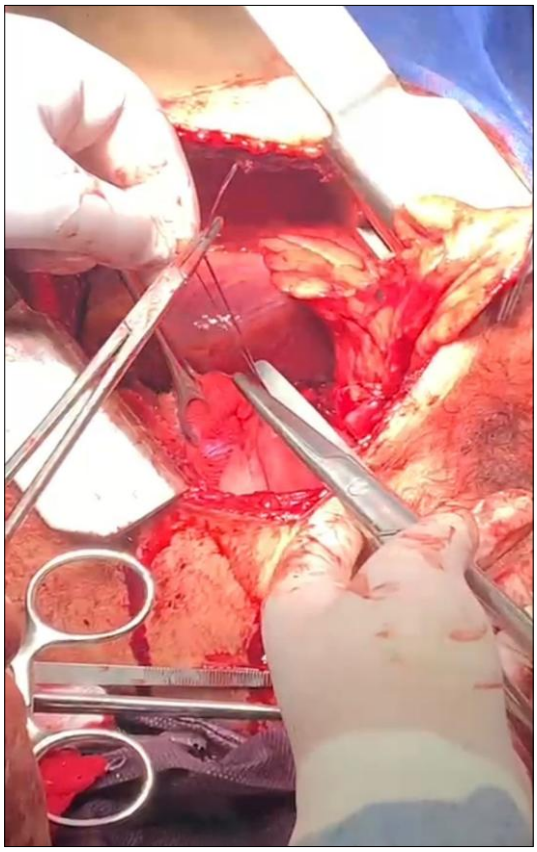

Figure 2: Left anterolateral thoracotomy with surgical repair of the lung parenchyma.

Patients with cardiac sequelae and neurological injuries were referred to tertiary care centers for specialized management by the Cardiology, Spine Surgery, Neurology, and Neurosurgery departments. Postoperative follow-up was conducted for an average of three months through the General Surgery outpatient clinic; however, a 64% loss to follow-up rate was documented.

Mortality rates varied across the participating hospitals, with an overall average of 16.6% (representing seven deaths). It should be noted that this rate does not exceed those reported in national and international medical literature for high-complexity traumatic injuries.

DISCUSSION

The mechanism of injury is driven by the transfer of sufficient kinetic energy to penetrate the cutaneous barrier, skeletal structures, and vital organs. Conversely, blunt thoracic trauma is characterized by internal injuries that do not compromise skin integrity. Both scenarios underscore the lethal potential inherent in the etiology and mechanism of the assault. **[14]**

Regarding etiology, impalement injuries, although rare, present unique diagnostic and surgical challenges due to their unpredictable trajectories and the frequent involvement of multiple organ systems. These cases necessitate meticulous, multidisciplinary management to optimize clinical outcomes. **[15]**

In blunt thoracic trauma, which presents an incidence of 63%, the necessity for cardiopulmonary bypass must be considered in patients with specific injuries. Evidence shows that the most prevalent injuries include cardiac lesions (42%), thoracic aortic injuries (42%), and cardiac tamponade (25%), with a reported mortality rate of 22%.**[16]**

Furthermore, it is essential to assess the vulnerability of each patient based on pre-existing medical conditions. These comorbidities increase the risk of severe injuries that often remain undetected within complex multisystem trauma. A notable example is ankylosing spondylitis, which can present with hemothorax in the absence of rib fractures, or spinal cord injury due to vertebral fractures following low-impact blunt trauma. **[17]** Similarly, Fanconi syndrome a generalized proximal tubular dysfunction leading to hypophosphatemic osteomalacia may predispose patients to spinal and rib fractures even without a significant traumatic history.**[18]**

Another complex scenario involves the association of an open thoracic wound with a pathological sternal fracture, secondary to remote trauma, chronic chest wall infections, malignancy, or sternal osteomyelitis. Such conditions complicate the prevention of complications arising from structural instability of the chest wall. **[19]**

Regrettably, firearm injuries have been documented as the leading cause of death in the pediatric population, with an exceptionally high mortality rate reaching 68% in cases of direct cardiac injury, evidenced by a 24% vs. 1% comparison $P < 0{,}001$.**[20]** Finally, rib fractures remain among the most frequent injuries in trauma patients. Over the last two decades, significant scientific progress has led to the development of multiple rib stabilization systems, including intrathoracic deployment devices. Despite ongoing debate, clear indications for the surgical fixation of rib fractures exist, although no definitive

consensus currently recommends one specific system or surgical approach over another. **[21]**

It is essential to document that the incidence of blunt abdominal injuries resulting from high-energy non-penetrating thoracic impacts is frequently overlooked, which is associated with increased morbidity and mortality. While the diagnosis of penetrating firearm wounds successfully predicts lesion locations by tracing the ballistic trajectory, no similar correlation has been established to date for blunt impacts. **[22]** Furthermore, the severity of combat-related trauma is evident; musculoskeletal injuries represent the greatest medical threat to deployment readiness, accounting for 60% of limited-duty days in 2019. The incidence is primarily distributed across the spinal column (lumbosacral: 30%; cervical: 22%; thoracic: 10%), totaling 62%. Medical attention for these conditions is a priority for the reintegration of active-duty military personnel.**[23]** Additionally, it must be considered that thoracic trauma is a direct cause of pulmonary embolism, a complex and poorly understood phenomenon in trauma settings. Its underlying mechanisms remain largely unknown; it is classified as immediate, early, or late, and can occur even in the absence of deep vein thrombosis. **[24]** Hemorrhagic shock remains one of the leading causes of preventable trauma-related death, especially within the first hours following the injury. Identifying patients who require massive transfusions **[25]** or those at high risk of mortality is crucial for optimizing trauma management. Consequently, therapeutic planning and surgical decision-making have a direct impact on mortality rates. **[26]** Regarding the mechanism of injury, the reviewed literature indicates that sharp-force injuries were the most prevalent, accounting for 23.9% of cases, followed by blunt trauma. Notably, falls from height frequently reported as the primary trauma mechanism in numerous studies ranked third in this cohort.**[27]**

Cardiac involvement in polytrauma patients is multifactorial and is frequently underdiagnosed or incompletely evaluated. This condition contributes to the development of acute cardiac dysfunction and long-term cardiovascular complications. Therefore, it is imperative to analyze the role of systemic inflammation, oxidative stress, neurohormonal activation, and immune dysregulation in trauma-induced myocardial injury. **[28]**

Furthermore, vascular injuries presenting with hemodynamic instability or those affecting high-risk critical vessels are associated with high mortality rates. The interventions of choice include emergency department thoracotomy and definitive surgical repair. In a series of 1,441 vascular injuries analyzed over 10 years, a mortality rate of 34% (329 deaths) was recorded, with penetrating trauma being the most common mechanism (n=854, 88%) compared to blunt trauma (n=111, 12%). In the context of thoracic trauma, it was documented that thoracic aortic injury *(p=0.0206*), cardiac injury (*p<0,001*); 14.4 (IC del 95%: 1.6-134); OR: 14.4; 95% CI: 1.6–134), or the necessity for emergency thoracotomy (p=0,0032) serve as critical prognostic indicators. **[29]**

Regarding the diagnosis of thoracic trauma, management strategies are based on the etiology and mechanism of injury. Trauma center activation criteria are implemented to classify patients and ensure appropriate resource allocation. Using a triage system based on prehospital physiological variables, series of up to 14,232 patients have been reported, with an Intensive Care Unit admission rate of 12.1%, a transfusion rate of 1%, and a mortality rate of 1%. Within these cases, interventions included 170 abdominal surgeries, 18 angio-interventions, 265 neurosurgical procedures, and 227 thoracic procedures. **[30]**

The initial clinical presentation is fundamental for diagnostic orientation; for instance, the development of dysphagia and airway compromise may result from retropharyngeal chyle accumulation. Diagnostic imaging beginning with chest X-rays (posteroanterior and rib series), followed by ultrasound, echocardiography, and computed tomography (CT) is decisive in revealing specific findings, such as prevertebral fluid collection. **[31]**

It is imperative to note that cardiac and thoracic vascular injuries are among the most severe and potentially lethal conditions in trauma care. Frequently, these injuries are not documented via imaging because many patients either succumb before hospital arrival or require immediate emergency surgery. However, obtaining precise and timely imaging, when the patient's stability permits, is essential for guiding urgent treatment and optimizing outcomes in both blunt and penetrating trauma of the heart and great vessels. **[32]**

The presence of intact costal cartilage is essential for chest wall elasticity; however, injuries to these structures are frequently underdiagnosed in trauma computed tomography scans, even in patients with confirmed rib fractures. A high index of clinical suspicion for costal cartilage involvement must be maintained in patients with a high injury burden, radiographically detected flail segments, or concomitant sternal fractures. **[33]** Digital health technologies, particularly Artificial Intelligence, are increasingly employed to mitigate diagnostic delays in high-acuity clinical settings. Conventional radiological interpretation remains limited by heavy workloads and the inherent complexity of subtle findings, which make rib fractures difficult to detect on standard chest X-rays. **[34]**

The reported sensitivity for detection by radiologists can be as low as 15%, meaning up to half of all fractures may go unnoticed. Although CT and ultrasound can improve diagnostic accuracy, they are resource-intensive and not always feasible for first-line triage. **[35]** In contrast, the application of Artificial Intelligence achieves a sensitivity of 74.5% and a specificity of 93.3%, delivering diagnostic results in seconds—over 1,000 times faster than formal radiological reports. **[36]**

Rib fractures are the most common traumatic injuries and can lead to significant morbidity and mortality; nonetheless, surgical stabilization of rib fractures is not yet uniformly implemented across trauma centers. The heterogeneity of inclusion criteria and the varied taxonomy of rib fractures—especially regarding the degree of displacement—hinder diagnostic consensus and subsequent therapeutic management. **[37]** Furthermore, for patients with three or more traumatic rib fractures, or any number of fractures associated with hemothorax, pneumothorax, or the requirement for chest tube thoracostomy during admission, an outpatient follow-up chest X-ray is recommended. This practice aims to identify persistent abnormal radiographic findings and determine the need for post-discharge interventions while limiting unnecessary imaging. **[37]**

To optimize prognostic accuracy in patients with both blunt and penetrating thoracic trauma, the substantial disease burden underscores the imperative need for early diagnosis, expedited risk stratification, and specialized management to improve survival rates and clinical outcomes. **[38]** While computed tomography-based evaluations remain the diagnostic cornerstone, significant gaps persist. In this regard, the implementation of independent Artificial Intelligence algorithms has demonstrated remarkable efficacy, achieving a mean Jaccard index of 0.963 and a data similarity coefficient of 99% in diagnostic certainty. **[39]**

Regarding intrathoracic organ injuries, specifically traumatic cardiac valvular lesions following blunt chest trauma, these present a low incidence and are routinely overlooked during the initial trauma assessment. It has been documented that echocardiography can reveal severe aortic and mitral insufficiency as late as one week after hospital discharge, emphasizing the critical role of postoperative follow-up. **[40]** Currently, CT diagnostic resources in thoracic trauma are being integrated into multimodal dynamic fusion models that combine baseline clinical parameters, radiological features, and deep learning analysis of CT scans obtained from both emergency departments and inpatient settings. **[41]** This approach enables dynamic prognosis through the precise quantification of pulmonary contusions, hemothorax, and pneumothorax, allowing for the early identification of patients at risk of poor outcomes. This facilitates the real-time optimization of therapeutic strategies and ensures timely intervention, thereby significantly improving the overall prognosis. **[42]**

Anterior mediastinal hematomas following blunt thoracic trauma are typically not lethal; however, in exceptional cases, they can cause extra pericardial tamponade, requiring urgent surgical intervention. These are confirmed via chest computed tomography by ruling out intracardiac or great vessel injuries. In these scenarios, despite initial hemodynamic stability, subsequent clinical deterioration necessitates a transthoracic echocardiogram, which may reveal right ventricular compression consistent with said tamponade. **[43]**

Furthermore, diagnostic tools based on biomarkers have been implemented to identify myocardial contusions and differentiate between types of myocardial infarction following blunt trauma. The use of cardiac troponin is noteworthy, **[44]** given that cardiac involvement in polytrauma is multifactorial and frequently underdiagnosed. Current protocols include transthoracic echocardiography and electrocardiography, complemented by the measurement of serum concentrations of troponin T and NT-proBNP using high-sensitivity electrochemiluminescence immunoassays. **[45]** The ability of high-sensitivity troponin I to predict major cardiac events has been evaluated, demonstrating a sensitivity of 74% and a specificity of 72% in predicting 30-day mortality. **[46]** Sudden Arrhythmic Death Syndrome (SADS) represents a significant cause of sudden cardiac death in young individuals with structurally normal hearts and negative toxicology. In cases associated with trauma or suicide, endocardial and pericardial adipocyte density has been identified as a key discriminating factor in diagnostic models. Genetic analysis has detected pathogenic variants in several cases, while histology has revealed significant differences in hearts previously considered normal. **[47]** Regarding the surgical management of thoracic trauma, the surgical stabilization of rib fractures (SSRF) has gained significant importance; most studies demonstrate its efficacy in patients with severe isolated chest wall injuries. In polytraumatized patients, this intervention significantly reduces mortality and is associated with a lower incidence of acute respiratory distress syndrome (ARDS), especially when stabilization is performed within the first 72 hours of admission. **[48]** For posterior rib fractures, the objective is to preserve the musculature; it has been shown that muscle-sparing posterolateral, axillary, and anterior approaches allow for the recovery of up to 95% of periscapular strength at six months. In fractures near the spinal column, a distance of at least 2 cm between the rib head and the tubercle is recommended to allow for the placement of two plate holes in the rib neck. **[49]**

Furthermore, pain management is critical in thoracic trauma. Although thoracic epidural anesthesia and paravertebral blocks have been the gold standard techniques, they

present technical difficulties and considerable failure rates. In this context, the costotransverse foramen block emerges as a novel and safe option; by depositing local anesthetic adjacent to the foramen, it provides effective analgesia in both acute and long-term phases, reducing opioid consumption. **[50]** Similarly, ultrasound-guided regional anesthesia techniques are progressively replacing deep sedation, allowing for procedures such as shoulder reduction by combining brachial and cervical plexus analgesia with greater safety and muscle relaxation. **[51]**

Regarding tracheal injuries in the context of penetrating trauma, these represent critical clinical events requiring prompt surgical assessment and specialized airway management. Primary end-to-end tracheoplasty is often the indicated surgical approach; in scenarios involving concomitant esophageal involvement, the utilization of an intercostal muscle flap alongside specialized surgical access—such as sternotomy or thoracotomy—has been documented as a viable strategy in high-acuity cases. **[52]** Finally, the clinical management of traumatic aortic injuries has seen a paradigm shift. Current clinical consensus leans toward conservative medical management for Grade I and II injuries, while thoracic endovascular aortic repair is preferred for Grades III and IV. Open surgical repair remains an alternative depending on the complexity of the case and the institutional capabilities. **[53]**

Regarding the safety and efficacy of endovascular repair, a technical and clinical success rate of 100% has been reported, with a safety profile of 95% and no procedure-related mortality. In patients undergoing Thoracic Endovascular Aortic Repair, evaluation via Computed Tomography Angiography is essential to ensure short-, medium-, and long-term success. **[54]** Given that blunt traumatic aortic injury is potentially lethal with a spectrum ranging from minor intimal tears to complete aortic rupture, the latter often being fatal before hospital arrival the failure of conservative medical management justifies the use of both endovascular and open surgical repair techniques, the latter being the historical gold standard. **[55, 56]**

On the other hand, Thoracic Outlet Syndrome refers to a complex of vascular and/or neurological symptoms related to the compression of the neurovascular bundle beneath the clavicle and the branches of the brachial plexus. This compression generally occurs in one of three spaces: the interscalene triangle, the costoclavicular space, and the sub-pectoralis minor tunnel. **[57]** In addition to the clinical presentation, the diagnostic protocol may include chest X-rays, arterial and venous Doppler ultrasound, or electromiography when neurological symptoms are present.**[58]** Surgical treatment is indicated if symptoms persist after conservative management or as a first-line therapy if a deficit is identified or an anatomical obstruction is evident. Decompression through first rib resection is the most common surgical procedure in this context.**[59]** While the traditional approach is open surgery via cervical/supraclavicular or axillary access, robot-assisted minimally invasive surgery using a posterior approach has also been described.**[60]**

In the context of cardiac trauma, cardiac tamponade is a critical scenario where the diagnosis can be established through clinical findings, echocardiography, or computed tomography. The physiological volume of fluid in the pericardial space typically does not exceed 50 ml; however, in chronic pathologies, it can accumulate up to 1,000 ml. **[61, 62]** In selected cases of cardiac trauma where studies demonstrate the presence of rib fractures without pneumothorax or active bleeding, management may be conservative and actively

monitored for 72 hours, provided the patient remains hemodynamically stable until discharge. **[63]**

Anterior mediastinal hematomas following blunt thoracic trauma are typically not life-threatening; however, in rare instances, they can cause extrapericardial tamponade requiring urgent surgical intervention. Compression of the cardiac chambers is uncommon following blunt thoracic trauma. **[64]** The selection of the surgical approach must consider both the operative modality (open versus minimally invasive) and the anatomical route (subxiphoid versus transthoracic). Although median sternotomy remains the standard approach for anterior mediastinal hematomas with hemodynamic compromise. **[65]** Stabbing injuries are infrequent but potentially lethal emergencies; although the clinical relevance of cardiac involvement in penetrating thoracic trauma remains uncertain, these traumatic lesions are rare but severe and require structured, multidisciplinary hospital management. Minimally invasive approaches are feasible in hemodynamically stable patients. The low rate of prehospital chest tube placement warrants a more exhaustive evaluation, given an overall mortality rate of 3.6%. **[66]**

Cardiac arrest resulting from severe thoracic trauma combined with aortic injury presents a complex scenario in emergency medicine. Extracorporeal cardiopulmonary resuscitation serves as a specialized intervention in such contexts; nevertheless, its application depends on institutional infrastructure and specific clinical expertise, as it represents a highly specialized surgical resource.**[67]** Conversely, while various injuries are managed through conservative protocols, surgical stabilization of rib fractures for flail segments has been studied for its role in clinical recovery and respiratory management. Minimally invasive and thoracoscopic techniques are continuing to advance, though their implementation is influenced by resource requirements and technical complexity. **[68, 69]**

In efforts to address mortality in cases requiring immediate surgical intervention, research has explored surgical strategies such as resuscitation median sternotomy combined with aortic occlusion techniques for hemodynamically unstable patients with penetrating thoracic trauma. This approach is characterized by its versatility, allowing access to mediastinal structures and both hemi thoraces through a single incision in specific emergency scenarios. **[70]** As previously mentioned, cardiac tamponade is a critical condition resulting from the accumulation of fluid typically blood within the pericardial sac. This leads to impaired ventricular filling, a reduction in stroke volume, and ultimately, obstructive shock. Diagnostic ultrasound can reveal pericardial effusion suggestive of tamponade; when hemopericardium is confirmed (frequently involving at least 200 ml of blood), emergency thoracotomy is required as a definitive life-saving measure.**[71]** Alternatively, pericardiocentesis is a rapid, minimally invasive technique primarily used for medical tamponade or as a temporary stabilization measure. Its utility in traumatic tamponade is limited due to the frequent presence of clotted hemopericardium. **[72]**

The thoracic region encompasses the spinal cord, where spinal cord injuries resulting from gunshot wounds represent a frequent and severe clinical condition. These injuries carry significant associated morbidity and mortality, accounting for 13% to 17% of all cases. Such traumatic events are particularly costly due to high medical expenses and the substantial decline in quality of life; they predominantly affect young men (87.5%, with a mean age of 29.5 years), which is consistent with the literature. Among the operated levels, the thoracic

spine was the most frequently treated, representing 58% of cases. **[73]** These patterns are usually stable, except in the case of a vertebral body burst fracture. Vertebral body fractures present a higher frequency of associated injuries, regardless of the spinal segment, due to their anatomical location. The primary indications for surgery were instability, mainly secondary to vertebral body burst fractures, and the removal of the projectile when lodged within the spinal canal. Associated injuries influenced clinical management decisions, as they often required more urgent treatment than the spinal cord injury itself. **[74]** Percutaneous vertebroplasty reduced the rates of intervertebral bridge ossification in patients with thoracolumbar osteoporotic vertebral fractures, potentially related to the improvement of local mechanical stability. Conservatively managed patients who developed intervertebral bridge ossification had significantly better functional scores than those who did not. **[75]**

CONCLUSIONS

In Mexico, thoracic trauma surgery is predominantly driven by interpersonal violence, primarily affecting the male population. While the diagnosis is frequently evident upon initial clinical evaluation, successful definitive management relies directly on the surgical proficiency and clinical judgment of the medical team.

Despite significant institutional limitations including deficiencies in infrastructure, specialized personnel, logistics, medical supplies, and high-level administrative management surgeons demonstrate high levels of efficiency and efficacy in resolving these complex cases. Practicing trauma surgery within the current public health system presents a continuous challenge; nevertheless, professional competence and technical commitment allow for the overcoming of systemic shortcomings, achieving favorable clinical outcomes in high-acuity scenarios and resource-limited settings.

Conflict of Interest

The authors stated that they had no potential conflicts of interest regarding the research, authorship, and/or publication of this article.

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