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REVIEW ARTICLE

Urban thoracic trauma: diagnosis and initial treatment of non-cardiac injuries in adults

Vasileios Leivaditis[1], Athanasios Papatriantafyllou[1], Ioanna Akrida[2], Michail Galanis[3], Emmanouil Dimopoulos[4], Anastasia Papaporfyriou[5], Benjamin Ehle[6], Efstratios Koletsis[7], Nikolaos Charokopos[7], George Pappas-Gogos[8], Francesk Mulita[2*], Georgios-Ioannis Verras[2], Konstantinos Tasios[2], Vasiliki Garantzioti[2], Levan Tchabashvili[2], Manfred Dahm[1], Konstantinos Grapatsas[9]

[1]Department of Cardiothoracic and Vascular Surgery, Westpfalz Klinikum, Kaiserslautern, Germany, [2]Department of Surgery, University General Hospital of Alexandroupolis, Alexandroupolis, Greece, [3]Department of Thoracic Surgery, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland, [4]Department of General and Visceral Surgery, Marienhospital Stuttgart, Stuttgart, Germany, [5]Department of Pulmonology, Internal Medicine II, Vienna University Hospital, Vienna, Austria, [6]Department of Thoracic Surgery, Asklepios Lung Clinic Munich-Gauting, Gauting, Germany, [7]Department of Cardiothoracic Surgery, Patras University Hospital, Patras, Greece, [8]Department of Surgery, Patras University Hospital, Patras, Greece, [9]Department of Thoracic Surgery and Thoracic Endoscopy, Ruhrlandklinik, West German Lung Center, University Hospital Essen, University Duisburg-Essen Essen, Germany

ABSTRACT

This comprehensive review aims to delineate the prevailing non-cardiac thoracic injuries occurring in urban environments following initial on-site treatment and subsequent admission to hospital emergency departments. Our study involved a rigorous search within the PubMed database, employing key phrases and their combinations, including "thoracic injury," "thoracic trauma," "haemothorax," "lung contusion," "traumatic pneumothorax," "rib fractures," and "flail chest." We focused on original research articles and reviews. Non-cardiac thoracic injuries exhibit a high prevalence, often affecting polytrauma patients, and contributing to up to 35% of polytrauma-related fatalities. Furthermore, severe thoracic injuries can result in a substantial 5% mortality rate. This review provides insights into clinical entities such as lung contusion, traumatic haemothorax, pneumothorax, rib fractures, and sternal fractures. Thoracic injuries represent a frequent and significant clinical concern for emergency department physicians and thoracic surgeons, warranting thorough understanding and timely intervention.

Keywords: hematothorax, pneumthorax, thoracic trauma, urban trauma

INTRODUCTION

Non-cardiac thoracic injuries are a frequent occurrence, particularly in polytrauma patients, with the potential to account for as much as 35% of fatalities in this patient group. Moreover, severe thoracic injuries independently contribute to a substantial 5% mortality rate (1,2). The historical significance of thoracic trauma is deeply ingrained in the annals of human existence, dating back to the earliest conflicts and struggles of mankind. The description of thoracic trauma can be traced to 3000 BC in the Edwin Smith Surgical Papyrus (1), providing a testament to its enduring relevance. Notably, the ancient Greeks, in one of the earliest meticulously organized military campaigns, the siege of Troy, catalogued a significant number of thoracic injuries. Homer's epic, the Iliad, meticulously records 54 thoracic injuries, accounting for 35.7% of the injuries described within the text (2).

In the modern urban environment, where a substantial portion of thoracic injuries occurs, the prevalence of thoracic trauma among patients admitted to the emergency department varies, at times reaching as high as 70% (3). The clinical presentation of these patients and the mortality associated with their injuries are contingent upon a myriad of factors, including the patient's overall condition and the specific mechanisms of injury (3,4).

* **Corresponding author:** Francesk Mulita
Department of Surgery, General University Hospital of Patras
Rio, 26504 Patras, Greece
Phone: +30 26 13603300;
E-mail: oknarfmulita@hotmail.com
ORCID: https://orcid.org/0000-0001-8692-0059

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This review endeavours to provide a comprehensive exploration of the diagnosis and treatment of the most common non-cardiac thoracic injuries.

GENERAL MECHANISMS OF THORACIC INJURIES

Thoracic injuries occurring within urban settings can be categorized based on their trauma mechanism, typically classified as blunt or penetrating, though cases combining both mechanisms are not uncommon (5).

Blunt thoracic trauma predominantly results from motor vehicle accidents and involves the abrupt deceleration of the human body (5,6). Common causes include motor vehicle collisions, motorcycle accidents, and incidents involving pedestrians (5). To illustrate, a trauma centre in Nigeria reported motorcycle accidents in 15% of blunt thoracic injuries, while larger vehicles such as cars, buses, vans, and trucks were implicated in 37% of cases (Figure 1) (6).

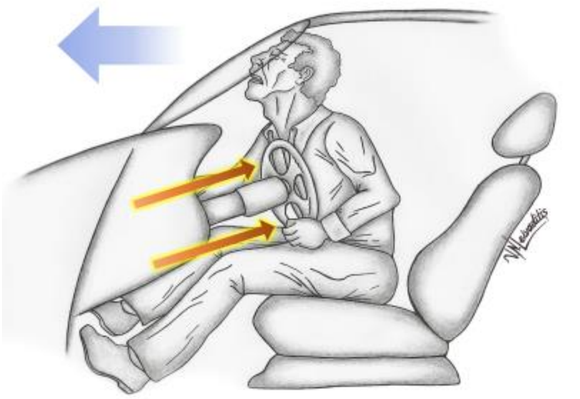

Figure 1. Anterior chest wall injury in a car accident caused by deceleration of the human body and direct blunt trauma to the anterior chest wall (Leivaditis V, Westpfalz Klinikum, Kaiserslautern, Germany, 2023)

Penetrating thoracic injuries, on the other hand, predominantly result from stabbings (Figure 2), other sharp penetrating objects, or firearms (5).

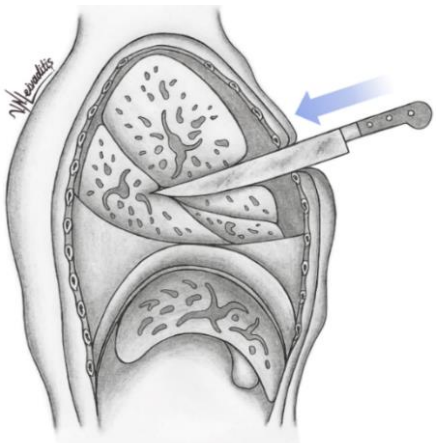

Figure 2. Schematic representation of a penetrating thoracic injury caused by a knife (Leivaditis V, Westpfalz Klinikum, Kaiserslautern, Germany, 2023)

Stabbings account for the majority of penetrating trauma, followed by gunshot wounds (7) (Figure 3). Aghaei Afshar et al. reported that stabbing constituted 93.7% of penetrating chest trauma cases, with gunshot wounds making up only 5.94% (7). The clinical presentation of these thoracic injuries depends on the injury's mechanism, the patient's general condition, and the specific anatomical region affected (7,8).

In instances of immediate fatality at the injury site, injuries to critical structures like cardiac cavities, the thoracic aorta, or the tracheobronchial tree are typically involved (8,9) (Figure 4).

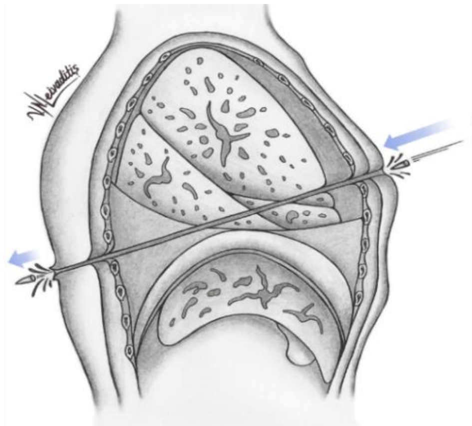

Figure 3. Schematic representation of a gunshot penetrating the thoracic cavity (Leivaditis V, Westpfalz Klinikum, Kaiserslautern, Germany, 2023)

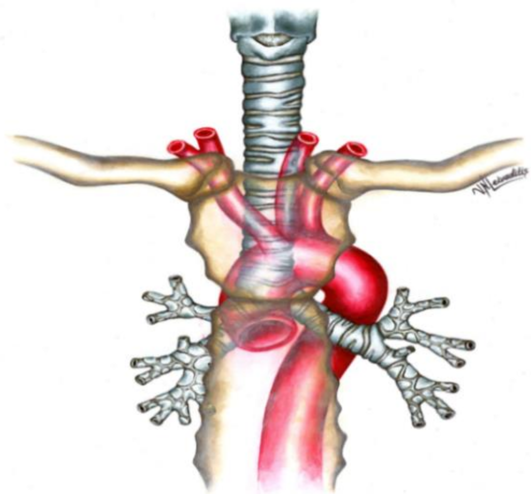

Figure 4. Anatomical relations of the aorta, tracheobronchial tree, and sternum. Thoracic injuries involving vital anatomical structures can result in high mortality. Considering the anatomical relations in this region can aid in clinical diagnosis (Leivaditis V, Westpfalz Klinikum, Kaiserslautern, Germany, 2012)

Early deaths stemming from thoracic injuries are often attributed to airway obstruction or significant respiratory distress, such as tension pneumothorax or cardiac tamponade (5,8). Hypoxia can arise from airway obstruction or imbalances between intrathoracic and extrathoracic pressures, as seen in conditions like flail chest or tension pneumothorax (5,8,9).

MANAGEMENT OF EMERGENCY DEPARTMENT PATIENTS WITH THORACIC INJURIES

In thoracic injury cases, adherence to the Advanced Trauma Life Support (ATLS) principles (10), specifically the ABCDE approach (Airway, Breathing, Circulation, Disability/Neurologic assessment, Exposure, and environmental control) (10), is recommended, aligning with the standard practice for trauma patients (10). This systematic approach aims to assess the patient's clinical condition and stabilize their overall health. The injury's clinical history provides insights into the trauma mechanism and chest trauma severity (11).

Upon arrival at the emergency department, chest X-rays (CXR) are the most commonly conducted initial examinations (12). Hemodynamically unstable patients should prioritize CXRs as the primary radiological assessment (13). CXRs can reveal injuries to major thoracic vessels, rib fractures, mediastinal widening, pneumothorax, or haemothorax (11). In cases where the thoracic trauma's severity or extent is uncertain, a chest computed tomography (CT) scan is recommended (11). CT scans offer a comprehensive evaluation of the entire thoracic cavity, as CXRs often miss significant injuries. Aukema et al. found that relying solely on CXRs led to significant misses in identifying haemothoraces, pneumothoraces, and rib fractures (12). For hemodynamically stable patients, a standard practice in many hospitals is to perform a whole-body CT scan (brain, thorax, abdomen/pelvis) to uncover additional thoracic injuries (14).

In the 21st century, ultrasonography has emerged as a prominent bedside examination. Many trauma centres incorporate ultrasonography into the Focused Assessment with Sonography in Trauma (FAST) (15). Regarding non-cardiac thoracic ultrasonography, it can assess pleural effusion quantity and quality in the thoracic cavity and detect intrathoracic air in cases of pneumothorax. This examination can also be administered by non-radiologist clinicians upon the patient's emergency department arrival, facilitating swift exclusion of life-threatening cardiac tamponade (10,11,15). Notably, Wilkerson et al. have proposed that thoracic ultrasonography is more sensitive than supine anteroposterior CXRs in detecting pneumothorax following blunt chest trauma (16).

When intervention is required for non-cardiac thoracic injuries, the standard initial approach involves placing a chest drain tube (CDT). In many non-cardiac thoracic trauma cases, CDT placement, appropriate pain management, and respiratory care constitute the primary treatment (10,11). As for CDT size, Inaba et al. suggest that small CDTs (28-32 Ch) yield similar clinical outcomes as larger ones (36-40 Ch) for chest trauma patients, with no discernible difference in pain at the insertion site (17).

Monitoring blood loss through the CDT is crucial. Initial blood loss exceeding 1,500 mL or a rate surpassing 200 mL per hour over 2–4 hours necessitates immediate thoracic surgical intervention (10,11). Other indications for prompt surgical intervention include endobronchial bleeding, extensive contusion causing significant mechanical ventilation impairment, tracheobronchial tree injury, or damage to the heart or a major thoracic vessel (11).

THE MOST COMMON NON-CARDIAC THORACIC INJURIES

Lung contusion

Lung contusion (LC), primarily a result of blunt thoracic trauma, occurs in approximately 25-35% of such cases (Figure 5C) (18). LC can also emerge from blast-related lung injury during explosions or penetrating trauma due to shock wave effects (19,20). In urban settings, crashes involving fixed objects or thoracic intrusion represent the most common causes of LC (21). LC is not exclusive to civilian scenarios; it is prevalent in military conflicts, with Keneally et al. noting LC as the most frequent thoracic trauma in Iraq and Afghanistan wars (20,21).

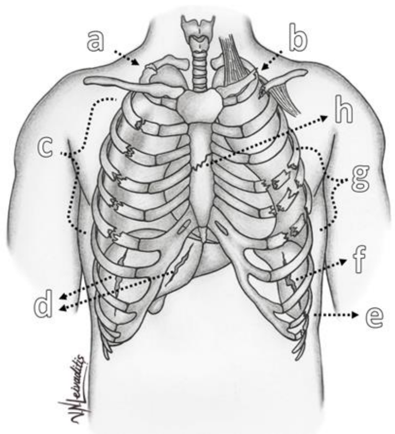

Figure 5. Schematic reconstruction of possible thoracic injuries. A) first rib fracture; B) clavicle fracture; C) multiple rib fractures and underlying lung contusion; D) liver injuries; E) lower rib fractures; F) spleen injury; G) flail chest; H) sternal fracture (Leivaditis V, Westpfalz Klinikum, Kaiserslautern, Germany, 2023)

Pathologically, LC manifests as alveolar capillary damage, leading to blood and fluid accumulation in lung parenchyma. This impairs gas exchange, results in ventilation/perfusion mismatch, reduces compliance, and induces hypoxia (18). LC may exhibit an unpredictable clinical course, possibly culminating in acute respiratory acidosis necessitating mechanical ventilation and raising concerns about acute respiratory distress syndrome (ARDS). Around 50-60% of LC patients may develop bilateral ARDS due to an inflammatory response to blood in the lungs (18,22,23). Older patients with restricted respiratory function face an elevated risk of complications (18).

Clinical presentation includes tachypnoea, tachycardia, or arterial hypotension (18). Lung auscultation may reveal reduced breath sounds, and patients may experience cough and haemoptysis (4). While chest X-rays (CXR) can aid in LC diagnosis, it may not be evident initially, requiring a follow-up CXR after 6 hours. Detection might even take up to 48 hours, with concomitant pneumothorax or haemothorax complicating the diagnosis (18,24). In contrast, a CT scan can promptly diagnose LC as lung consolidation following thoracic injury. Radiologically, LC may resolve within 3-10 days (18), and skilled sonographers can raise suspicion of LC (25).

Pharmacological interventions lack efficacy in LC treatment, making support to the primary approach. Noninvasive positive airway pressure (CPAP) and bilevel positive airway pressure (BiPAP) aid in oxygenation (8,9). Fluid management requires careful consideration to restore lost volumes without overloading the patient. Diuretics may be used to reduce pulmonary capillary pressure. Bronchoscopy, pulmonary toilet, and chest physiotherapy help remove mucus and blood, reducing the 20% incidence of pneumonia as an LC complication (18,19).

LC's mortality ranges from 14 to 40%, contingent on associated injuries and LC severity (18,19). Typically, LC heals with medical supportive care, although intensive care unit hospitalization may be necessary. In cases progressing to ARDS, extracorporeal membrane oxygenation (ECMO) can be a life-saving option, despite the potential clinical dilemma regarding heparin use and bleeding risk in polytrauma patients with LC and ARDS (26,27). To prevent complications from blunt chest trauma and ARDS, various thoracic trauma scoring systems have been employed (28,29). Daurat et al. found that an extreme Thoracic Trauma Score upon admission predicts delayed ARDS development in LC following blunt thoracic trauma (28).

Traumatic pneumothorax

Traumatic pneumothorax may result from either penetrating or blunt chest trauma. Penetrating trauma introduces air directly into the thoracic cavity, either through the injury site or from the tracheobronchial tree following injury to lung parenchyma. When a penetrating injury leads to pneumothorax, it is often referred to as open pneumothorax, and it may frequently coincide with hematothorax (30–33). In contrast, blunt trauma-induced pneumothorax may arise from visceral pleural injury due to rib fractures or alveolar rupture, often a consequence of increased alveolar pressure during chest compression. In cases of chest injury, tension pneumothorax, a life-threatening condition, can develop (30,31).

Upon the patient's arrival at the emergency department following chest trauma, clinical manifestations may include chest pain, dyspnoea, anxiety, tachypnoea, and tachycardia. Clinically, hyper resonance and diminished breath sounds may be observed on the affected side. Tension pneumothorax is marked by respiratory distress, lung collapse, tracheal deviation, mediastinal shift, hypotension, decreased consciousness level, neck vein distension, and cyanosis. In all cases of thoracic injury, clinical suspicion of pneumothorax is essential (30,31).

However, interpreting a supine anteroposterior chest X-ray (CXR) in the emergency department can be misleading. In such instances, the "deep sulcus sign" can provide guidance as air accumulates anteriorly and basally in the injured chest cavity (30–33). Computed tomography (CT) is a more sensitive diagnostic tool for pneumothorax, and sonography can also aid in diagnosis (30).The standard treatment for traumatic pneumothorax involves chest tube insertion into the thoracic cavity. Notably, the use of whole-body CT in many trauma centres has led to the diagnosis of numerous occult pneumothoraxes that require no further intervention (30,31).

Traumatic hematothorax

Traumatic hematothorax, frequently presents a challenge for both emergency department personnel and thoracic surgery clinicians. Estimating the precise prevalence of hematothorax in hospital emergency departments remains challenging. In the United States, approximately 300,000 hematothorax cases are treated annually (34). Traumatic hematothorax in urban settings typically results from penetrating or blunt trauma affecting the lung parenchyma, intercostal vessels, or major intrathoracic vessels. Uncommonly, hematothorax may also result from injuries to cardiac cavities (35).

Clinical suspicion of hematothorax is aroused in the emergency department through the patient's medical history and injury mechanism. Common patient complaints include chest pain and haemoptysis, often accompanied by cardiovascular symptoms or the development of hypovolemic shock. Diagnosis relies on standard emergency department examinations, including chest X-ray (CXR), computed tomography (CT), and sonography, much like in cases of traumatic pneumothorax. Notably, sonography is valuable for early hematothorax detection upon the patient's arrival in the emergency department (36).

Initial treatment in the emergency department involves the insertion of a wide-lumen chest tube (28 to 32 Charrière). In cases of chest tube drainage exceeding 1500 mL within 24 hours, 200 mL/h, or continuous bleeding despite successive blood transfusions, surgical intervention is warranted (34). Specifically, when the patient remains hemodynamically stable, video-assisted thoracoscopic surgery (VATS) can be performed for intrathoracic bleeding (34,37,38). VATS offers a dual benefit: it enables hematothorax removal, hemithorax assessment, and lung parenchyma injury correction, making it a valuable diagnostic and therapeutic tool in thoracic trauma (38,39). Residual hematothorax, which sometimes persists despite chest tube drainage due to diaphragm and lung movement interference with complete defibrillation and coagulation, can be effectively managed with VATS. This approach reduces the risk of fibrothorax, intrathoracic infections, and pleural empyema formation, ultimately leading to better patient outcomes and shorter hospitalization times (38,39). The optimal timing for VATS remains debatable, with some suggesting a 24-72-hour window for maximized effectiveness (40). VATS confers several advantages, including safe operative procedures for hemodynamically stable patients, reduced pain, and faster discharge from the hospital. Indications for VATS in non-cardiac thoracic injuries include stable patients with penetrating injuries, persistent haemothorax, post-traumatic empyema, persistent air leakage, and suspected diaphragmatic rupture (11).

An alternative to VATS for treating hematothorax is intrapleural fibrinolytic (IPF) therapy administered via the chest tube. IPF therapy aims to dissolve residual blood clots within the pleural cavity that remain after chest tube drainage. This approach is generally safe and often leads to clot resolution (34,41). IPF has demonstrated a success rate of 91.3% among treated patients (41). Some experts advocate for IPF as the initial treatment for residual hematothorax instead of VATS (42). However, there is a disagreement on the ideal timing of VATS for thoracic injuries, and early VATS performed within the first three days after the injury can minimize infection risks (43). To determine the optimal approach, VATS or IPF, it is important to consider the patient's individual characteristics and the risks associated with each method.

In cases of active bleeding and hemodynamically unstable patients, exploratory thoracotomy is indicated. This procedure primarily aims to locate the bleeding source, explore the thoracic cavity, and remove the hematoma (34,37,38). The recommended incision for this procedure is the anterolateral thoracotomy in the 4–6th intercostal space, providing access for a comprehensive examination of the hemithorax. In some cases, when all lesions cannot be assessed adequately, a modified incision, such as the Clamshell incision, may be utilized for improved thoracic organ exposure (44,45). Resuscitative thoracotomy cases may benefit from the Clamshell incision, as it offers comparable performance time to the classic left anterolateral thoracotomy while providing superior thoracic organ exposure (45).

Prophylactic antibiotic administration is recommended for patients with hematothorax, and the duration of antibiotic therapy remains a subject of debate. Boersma et al. have suggested prophylactic antibiotics for 24 hours in patients with uncomplicated hematothorax to reduce the risk of pleural empyema formation (34). Additionally, Eren et al. recommend prophylactic antibiotics for patients with prolonged chest tube drainage, extended intensive care unit stays, lung contusion, laparotomy, or retained haemothorax, as these factors independently contribute to posttraumatic empyema risk (46).

Rib and sternal fractures

Rib injuries rank as the most prevalent injuries to the thoracic cavity. The precise incidence of rib fractures diagnosed in the emergency department remains challenging to ascertain. Nevertheless, it is estimated that rib fractures represent 10% of all fractures treated in hospital emergency departments. Despite their frequent occurrence in trauma patients, rib injuries carry a significant burden of mortality and morbidity, which tends to be more pronounced in the elderly population (47). Upon arrival in the emergency department, patients commonly present with chest pain, chest deformities, and a diminished quality of life (48). Lower rib fractures, and potential traumatic dislocations, may pose a risk to adjacent organs, such as the liver and spleen (Figure 5F). Therefore, abdominal sonography is recommended by the Advanced Trauma Life Support (ATLS) guidelines upon the patient's arrival to exclude free abdominal fluid (10).

The most reliable method for diagnosing rib fractures is through computed tomography (CT), as approximately 50-75% of rib fractures go undetected by plain chest X-rays (48,49). Rib fracture management typically follows a conservative approach, often effectively treated with appropriate analgesic therapy and intensive respiratory physiotherapy (49). The administration of analgesics to these patients should consider potential concomitant injuries, such as spinal cord injuries, in polytrauma cases. Additionally, in elderly patients, comorbidities and anticoagulation therapy should be carefully considered due to their potential to complicate the treatment (47).

Surgical correction may be indicated for patients experiencing respiratory failure or acute pain attributed to rib fractures (49,50). Bemelman et al. have proposed an algorithm for rib fracture treatment, recommending surgical rib fixation for patients aged over 45 with a pain score exceeding 6 on the visual analogue scale and a dislocated rib fracture (49). Chest deformity and thoracic instability are also indications for rib correction (49–51). Patients with flail chest (Figure 5G), characterized by three or more contiguous ribs with two fractures, and who experience hypoxemic respiratory failure, are recommended to undergo rib fracture fixation as standard care (48,52). Additionally, more than three severely displaced bicortical fractures may indicate the need for surgical intervention, as well as chronic pain resulting from rib fractures (48).

Sternal injuries and fractures (Figure 5H) represent another facet of thoracic skeletal injuries. Sternal fractures result from deceleration injuries, which are often seen in car accidents, or direct blunt anterior chest wall injuries. These fractures may be present in up to 8% of motor vehicle accidents, with higher risk factors associated with elderly patients and post-menopausal women. Sternal injuries can be accompanied by various other thoracic injuries, including flail chest, pneumothorax, hematothorax, cardiac tamponade, lung contusion (LC), and myocardial injuries. Additionally, abdominal injuries, thoracic spine compression, head, and neck injuries could coexist (53). Hemodynamically unstable patients or those exhibiting abnormal ECG findings should raise suspicion of myocardial contusion, necessitating further investigation with cardiac enzymes and echocardiography. These patients may require posttraumatic monitoring or admission to the intermediate care unit or intensive care unit (53,54). Computed tomography serves as a pivotal diagnostic tool and aids in determining the need for possible surgical intervention (53). Patients with isolated sternal fractures and normal electrocardiogram, cardiac enzyme levels, chest X-rays, and absence of complications typically require no further investigation (53,54). However, these patients are often admitted to hospitals as a routine but unnecessary precaution (53,55). For instance, Guska et al. reported that 34.7% of their patients with isolated sternal fractures were discharged with analgesic therapy in less than 24 hours, while 73.5% were discharged in under 48 hours (55). Operative sternal fixation may be indicated in cases of displaced or unstable sternum, with options including sternal wires or formal osteosynthesis using plates and screws (53,56).

Uncommon non-cardiac thoracic injuries

Tracheobronchial injuries, esophageal injuries, and diaphragm ruptures are relatively rare injuries but can occur following a thoracic trauma, warranting vigilance from emergency department clinicians. Tracheobronchial injuries, while sparingly observed in patients surviving accidents, require clinical suspicion and knowledge of the injury mechanism. Patients may manifest cutaneous emphysema, persistent pneumothorax despite chest drain tube (CDT) placement, pneumomediastinum, or haemoptysis. Diagnosis is typically achieved through computed tomography (CT) and bronchoscopy (57).

Diaphragm injuries, which may result from both blunt or penetrating traumas, can manifest with variable symptoms or be entirely asymptomatic. Patient complaints may include shoulder or epigastric pain, dyspnoea, or symptoms indicative of partial or complete intestinal obstruction. Initial suspicion can arise from chest X-rays, with confirmation facilitated through CT imaging (58).

Esophageal injuries, although uncommon due to the protective anatomical positioning within the thoracic cavity, carry a substantial burden of morbidity and mortality, primarily stemming from penetrating traumas. Makhani et al. reported that gunshot wounds represent the predominant cause of esophageal injuries (47.7%). Clinical presentation upon arrival in the emergency department can be diverse, encompassing complaints of dysphagia, odynophagia, chest pain, and potential septic signs. Diagnosis often relies on both CT scans and esophagogastroduodenoscopy (59).

FUTURE PERSPECTIVES

As we advance in the realm of thoracic trauma management, continuous progress is anticipated. Innovative diagnostic modalities, such as advanced imaging techniques and point-of-care ultrasound, will likely enhance early injury detection. Additionally, personalized treatment strategies and minimally invasive interventions may become increasingly prevalent, contributing to improved outcomes for patients with thoracic trauma. Research into novel pain management protocols and further exploration of the benefits of early surgical interventions may shape the future landscape of thoracic trauma care. In this evolving field, multidisciplinary collaboration and a holistic patient-centred approach will continue to be of paramount importance, offering the promise of better patient outcomes and reduced morbidity and mortality.

In conclusion, thoracic trauma constitutes a common challenge for emergency department healthcare providers, bearing the potential for substantial morbidity and mortality. Many thoracic injuries can effectively be managed through chest tube insertion, meticulous analgesic therapy, and diligent physiotherapy. Nevertheless, it is imperative that these injuries be addressed with precision by a multidisciplinary team, which includes both emergency clinicians and thoracic surgeons. Such an approach should always consider the injury mechanism, the patient's underlying comorbidities, and the potential clinical complications that may arise post-injury.

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