Chapter 21

THORACIC TRAUMA

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Thoracic trauma represents one of the most frequent and harmful injuries in polytrauma. Besides the direct effects of mechanical injury caused by the impact itself, pulmonary integrity and function are also compromised by the systemic release of inflammatory mediators due to additional injuries in other body regions (Horst and Hildebrand, 2020). More than two-thirds of

blunt thoracic traumas in developed countries are caused by motor vehicle collisions, while the remainder results from falls from height or direct impact to the chest. Penetrating chest injuries include gunshot wounds, stabbings, explosions, and penetration by other objects (including workplace and sports injuries, such as archery). Ballistic injuries are one of the main causes of morbidity and mortality in the United States and often involve the chest (Lewis *et al*., 2021).

Recent studies, such as those by Huang *et al.* (2019), have evaluated the relevance of post-trauma complications and observed that, over eight years, chest injuries were a significant risk factor for the development of acute respiratory distress syndrome (ARDS). The mechanism of injury is crucial to predict the need for intervention, as penetrating injuries are more likely to require surgical exploration (Stretch). The Advanced Trauma Life Support (ATLS) Guidelines (ACS, 2018) recommend emergency surgical intervention for patients with blunt and penetrating trauma if initial hemorrhagic loss is less than 1,500 mL of fluid, but with ongoing bleeding that may require thoracotomy, based on the continuous blood loss rate (200 mL/h for 2 to 4 hours), considering the patient's physiological state.

According to Lewis *et al.* (2021), thoracic trauma occurs in about 60% of polytrauma patients and presents a wide range of mortality, globally estimated at 10%. In more severe cases, such as closed polytrauma with bilateral pulmonary contusions and hemopneumothorax, mortality can exceed 50%. Severe rib fractures lead to immobilization, inadequate breathing, and suppression of coughing, contributing to approximately a 30% increase in the risk of developing pneumonia in these patients (Beloy *et al*., 2022).

Imaging plays a fundamental role in the diagnosis and treatment of pulmonary trauma; however, chest X-rays may not diagnose most fractures, with computed tomography (CT) being more sensitive to help assess injury severity and identify additional findings that may alter the therapeutic approach. CT, however, can fail to diagnose, especially in non-displaced, chondral, or anterior fractures (Caragounis; Xiao and Granhed, 2019). It is crucial to identify and appropriately treat patients at higher risk of complications. The use of analgesics may be indicated to avoid respiratory complications, pneumonia, and atelectasis, while in some patients, surgical fixation is more appropriate (Simon; Wickham, 2019).

Trends in techniques and diagnostic methods have evolved significantly, as discussed by Marro *et al.* (2019) and Horst; Hildebrand (2020). These studies highlight the growing adoption of advanced technologies, such as artificial intelligence and machine learning, to enhance the accuracy and efficiency of medical diagnoses. Additionally, there is a renewed focus on personalized medicine, using genomic data and biomarkers to develop targeted therapies. These approaches promise not only to revolutionize clinical practice but also to transform traditional healthcare standards, making them more tailored to individual patient needs.

EPIDEMIOLOGY

Understanding the epidemiology of thoracic trauma is crucial for guiding prevention strategies and improving patient care. According to Lundin *et al.* (2022), the prevalence of chest injuries among trauma patients was 32%. These patients exhibited distinct injury patterns according to age. Older individuals (≥60 years) tend to have a higher proportion of rib fractures, while younger individuals (<60 years) suffer more from internal thoracic organ injuries, such as pneumothorax, pulmonary contusion, and vascular injury.

In terms of demographic data, the typical chest injury patient was a middle-aged man (Elgar; Smiley and Latifi, 2022). Blunt trauma, such as falls and car accidents, was the predominant injury mechanism. This population showed greater injury severity, with higher median scores on severity scales (ISS and NISS), compared to trauma patients without chest injuries. The differences in injury patterns across age groups indicate the need for specific therapeutic approaches for each group (Lundin *et al.*, 2022).

Thoracic trauma is responsible for a significant portion of trauma admissions, ranging between 10% and 15%, and for 25% to 35% of trauma deaths, given that the chest houses vital organs such as the heart, lungs, major vessels, and esophagus (Orlas *et al.*, 2020; Lundin et al., 2022; Birse et al., 2020). Besides contributing substantially to morbidity, thoracic trauma imposes a significant financial burden on the healthcare system (Elgar; Smiley and Latifi, 2022).

A study conducted by Caragounis, Xiao, and Granhed revealed that traffic accidents are the main cause of chest trauma among young people (62%), especially motorcycle accidents (29%), while falls predominate among older patients (59%). According to Elgar, Smiley, and Latifi, high-speed traffic accidents result in blunt thoracic trauma in approximately 60% of polytraumatized patients, with a mortality rate of 20% to 25%. The higher the frequency of invasive diagnostic and therapeutic procedures, the higher the mortality rates.

Previous studies indicate that elderly patients have worse outcomes after blunt thoracic trauma, possibly due to the presence of comorbidities. Additionally, the higher prevalence in men may be related to more common activity patterns and risk behaviors in this group. Regarding environmental factors, the severity of thoracic trauma, such as the number of rib fractures and the presence of pulmonary contusion, plays a crucial role in prognosis. As for lifestyle factors, the presence of comorbidities such as respiratory diseases, liver diseases, and coagulopathies significantly increases the risk of mortality in this population (Elgar; Smiley and Latifi, 2022).

Thoracic trauma represents a significant cause of global mortality and morbidity, especially among young adults. In Cali, Colombia, these injuries rank third in causes of death due to homicides, behind TBI and polytrauma, and fourth in traffic accidents (Orlas et al., 2020).

Complications such as pneumonia or respiratory failure occur in 16.2% of patients over 65 years old and in 28.6% of patients over 85 years old who suffered isolated closed

thoracic trauma. In the elderly, minor pulmonary contusions are associated with double the risk of mortality and longer hospital stays, despite having few consequences in healthy young people (Simon and Wickham, 2019).

Severe rib fractures, such as hemothorax or pneumothorax, are more common in people over 65 years old, significantly increasing mortality compared to younger individuals. Data from the US National Trauma Data Bank show that the number of fractured ribs correlates with an increased risk of pneumonia and/or death, especially with multiple fractures (Simon and Wickham, 2019).

Studies indicate that 35% of trauma-related deaths in the US are due to blunt thoracic trauma, with one in four trauma patients dying from chest injuries (Dogrul et al., 2022). High-speed accidents result in blunt thoracic trauma in about 60% of polytrauma patients, with a mortality rate between 20% and 25% (Elgar; Smiley and Latifi, 2022).

Rib fractures are common in approximately 40% of patients with closed thoracic trauma, contributing to higher morbidity, injury severity, and mortality. Elderly patients with rib fractures generally have less severe injuries and lower Injury Severity Scores (ISS) compared to younger patients, although they have higher mortality rates (Caragounis; Xiao and Granhed, 2021).

Advanced age is a significant factor for rib fractures, with a higher proportion among occupants aged 65 years or older compared to younger individuals. With aging, the chest's ability to absorb impacts decreases due to bone demineralization and rib deterioration, increasing their susceptibility to fractures (O'Donovan *et al.*, 2022).

DIAGNOSIS

Thoracic injuries are common in trauma cases and can be categorized as blunt or penetrating. After initial evaluation, these injuries are classified according to the associated life risk: immediate, fatal, or potentially fatal (Okoye *et al.*, 2023). In severe chest traumas, early mortality is significant, highlighting the need for rapid physical assessments and imaging tests for accurate injury identification (Wong *et al.*, 2023). Early detection is crucial to guide treatment and appropriate patient referral, avoiding acute complications (Chan *et al.*, 2020).

A systematic approach in the initial evaluation facilitates the identification of injuries requiring immediate intervention. Physical examination and chest X-ray are generally sufficient to diagnose many injuries, while bedside ultrasound, such as extended FAST, is effective in detecting life-threatening injuries (Chan et al., 2020). Although radiography is the main diagnostic resource, computed tomography (CT) is more sensitive in specific cases and should be used cautiously in unstable patients (Okoye *et al.*, 2023).

The "ABC-Please" approach is used to interpret thoracic findings in trauma, with "A" (abnormal air) referring to the predominance of pneumothorax and pneumomediastinum,

often benign and associated with interstitial pulmonary lacerations. These cases generally present symptoms such as dyspnea and chest pain, potentially leading to severe complications if not properly treated (Chan *et al.*, 2020; Wong *et al.*, 2023). “B” (abnormal bones) indicates that thoracic spine fractures are often associated with rib fractures, with an incidence ranging from 10% to 70% in patients undergoing CT scans. “C” (abnormal cardiovascular system) highlights the importance of contrast-enhanced chest CT in detecting direct and indirect aortic injuries, such as contrast extravasation and periaortic hematoma, as well as identifying massive hemothorax (Wong *et al.*, 2023). Finally, “Please” (abnormal parenchyma and pulmonary vessels) covers lung parenchymal injuries, such as contusions and lacerations, which are common in 75% of blunt thoracic trauma cases. These injuries can progress to complications, including pneumonia, lung abscess, bronchopleural fistula, and acute respiratory distress syndrome (ARDS). Rupture of pulmonary arterial pseudoaneurysms can result in massive hemoptysis and impairment of alveolar gas exchange (Wong*et al.*, 2023).

Volumetric chest CT is ideal for diagnosis in stable patients and can be performed with contrast for detailed evaluation, ensuring safety and good communication between teams (Wong *et al.*, 2023). However, there are debates about its use due to potential iatrogenic side effects, especially in cases of stab wounds with normal chest X-ray outside the thoracoabdominal zone (Augustin *et al.*, 2020). The initial clinical examination, according to Reichardt *et al.*(2020), should not be replaced by diagnostic tests, being crucial for the prognosis of trauma victims.

Trauma patients are primarily clinically evaluated to identify life-threatening conditions, requiring resuscitation with intravenous fluids, blood products, intubation, or thoracostomy, according to ATLS protocols (Chan *et al.*, 2020). Chest X-ray is recommended as an initial diagnostic complement, essential to identify critical thoracic conditions such as hemothorax, pneumomediastinum, pulmonary contusion, or rib fractures (Chan *et al.*, 2020; Wong et al., 2023).

According to Wong (2022), rapid physical and radiographic assessments play crucial roles in identifying severe thoracic traumas. Chest X-ray is frequently used in trauma patients to identify life-threatening conditions. Current ATLS guidelines recommend chest X-ray as a complement to the primary assessment in initial trauma care (ATLS, 2012). This diagnostic tool is commonly employed to identify thoracic injuries such as hemothorax, pneumomediastinum, pulmonary contusion, or rib fracture. During acute resuscitation, the trauma patient is generally kept supine until a complete assessment is performed. Performing a chest X-ray in this position requires time, resources, and equipment, potentially delaying the diagnosis and treatment of pneumothorax (Chan *et al.*, 2020).

While chest X-rays, even when repeated, may not detect some injuries, such as small pneumothorax, chest CT avoids repeated X-rays and offers greater sensitivity, especially for anterior and small pneumothorax. However, despite greater sensitivity, CT may only reveal

minor new findings without significantly impacting the management of penetrating thoracic trauma (Augustin *et al.*, 2019). Additionally, CT exposes the patient to an estimated ionizing radiation dose of 7 mSv, equivalent to two years of natural background radiation exposure, and may cause allergic reactions to contrast. Depending on the patient's condition, emergency thoracotomy may be performed at any time during trauma resuscitation (Chan *et al.*, 2020).

TREATMENT

Due to its severity, identifying thoracic injuries should be a priority in caring for polytrauma patients (Marro *et al.*, 2019). It is essential to predict an adequate prognosis and conduct an effective assessment of thoracic trauma severity for proper management (Mukerji et al., 2021). Effective treatment requires a multidisciplinary approach, including analgesia, stabilization of flail chest, hemodynamic resuscitation, and ventilatory support. Additionally, chest drains may be necessary for managing hemothorax and pneumothorax (Cheruvu *et al.*, 2023).

Cases of flail chest, defined as a fracture of three or more sequential ribs resulting in paradoxical chest wall movement, can be treated conservatively or surgically. Conservative treatment involves adequate pain control using oxygenation, opioid analgesia, intercostal nerve block, neuraxial block, and epidural catheter. Surgical treatment includes stabilization with plates and intramedullary stabilization. Immobilizing the flail chest segments aims to minimize movement during breathing to avoid ineffective ventilation and secondary respiratory failure (Cheruvu *et al.*, 2023; Marro *et al.*, 2019; Hisamune *et al.*, 2024).

In cases of acute respiratory distress syndrome (ARDS) caused by thoracic trauma, management includes mechanical ventilation with lung protective techniques and alveolar recruitment maneuvers (Dagod *et al.*, 2021). However, prolonged mechanical ventilation is associated with high rates of pneumonia, tracheostomy, and barotrauma, among other complications (Hisamune *et al.* 2024).

When thoracic trauma is penetrating, treatment and consequences are directly related to the severity of damage to internal organs, especially respiratory failure caused by airway obstruction and bleeding. The primary goal in ensuring an adequate airway is to improve ventilation and prevent air leaks into adjacent areas using an endotracheal tube with a balloon positioned below the injury site. Penetrating airway injuries can quickly progress to airway obstruction and respiratory failure. When endotracheal intubation is not feasible, emergency tracheostomy becomes the only appropriate option. In cases of tracheal injuries, it is preferable to position the tracheostomy in the affected area to preserve the normal portion of the trachea, facilitating subsequent surgical repair (Cakmak *et al.*, 2022).

Traumas resulting in pneumothorax and hemothorax can be treated with chest drains. In cases of hemothorax with significant hemorrhage and active bleeding due to

costal artery injury, exploratory thoracotomy, assisted video thoracoscopy, or embolization by interventional radiology may be necessary (Marro *et al.*, 2019). Massive hemothorax can result in the absence of breath sounds on the affected side. Blood pressure should be stabilized with rapid fluid administration, and a chest drain should be inserted. Patients with worsening subcutaneous emphysema, progressive pneumomediastinum, pneumothorax with continuous leakage, persistent pneumothorax despite the chest drain, or esophageal wall prolapse towards the trachea should undergo emergency surgery (Cakmak *et al.*, 2022).

The approach to treating rib fractures can be classified into two main categories: conservative treatment and surgical treatment. Although conservative treatment was the main choice in the past, surgical stabilization of rib fractures (SSRF) has increased substantially in the past ten years (Hisamune *et al.*, 2024). Isolated rib fractures are treated conservatively with effective pain control, essential to avoid blood gas disturbances, atelectasis, and pneumonia caused by hypoventilation due to pain. However, rib fractures can be accompanied by pulmonary contusions, pneumothorax, and hemothorax, which can arise late. Therefore, in patients with known rib fractures who present worsening, it is highly recommended to perform new imaging to assess the progression of the thoracic injury (Marro *et al.*, 2019). Surgical treatment, based on SSRF (Surgical Stabilization of Rib Fractures), uses fundamental orthopedic principles of realignment and fixation to treat rib fractures, restoring chest wall stability, reducing pain, and improving compromised respiratory function (Hisamune *et al.*, 2024).

DOUBLE-LUMEN MECHANICAL VENTILATION

Various clinical manifestations can occur after thoracic trauma, with airway maintenance being the primary initial conduct. In a case of severe thoracic trauma, a patient underwent thoracotomy and mechanical ventilation with a double-lumen tube. Despite the endotracheal tube, oxygen saturation remained low due to severe left lung contusion. A rupture of the tracheal membrane up to the carina, with a 0.5x0.5 cm cavity in the carina membrane, was identified. Due to the patient's lateral position, the use of ECMO (extracorporeal membrane oxygenation) was not possible. To improve breathing, an innovative method called "double-lumen mechanical ventilation" was proposed and applied. This method involved inserting a single-lumen tube into the right intermediate bronchus for ventilation of the right middle and lower lobes. This procedure significantly improved the patient's oxygen saturation, which remained around 98%. During the operation, a myocutaneous flap was used to cover the carina defect, and the tracheal membrane was repaired. The patient was discharged without complications after seven days (Shen and Ma, 2020).

VENO-VENOUS ECMO (VV-ECMO) THERAPY AND INDEPENDENT LUNG VENTILATION (ILV)

Studies demonstrate one of the first cases of massive air leakage after heterogeneous thoracic trauma associated with refractory hypoxemia, successfully treated with a combination of veno-venous ECMO (vv-ECMO) and independent lung ventilation (ILV). Vv-ECMO has proven to be a reliable rescue strategy for acute respiratory distress syndrome (ARDS) in traumatized patients, even with bleeding risk, improving outcomes and reducing the need for extensive surgeries. In cases where one side of the lung presents significant collapse, causing severe hypoxemia, ILV allows adequate ventilation for each lung, aiding in the healing of the leaking lung and keeping the healthy lung open. Although ILV is challenging, it can reduce complications and the time to wean from ECMO. In summary, vv-ECMO is a valuable rescue strategy for traumatic airway leaks, allowing consideration of non-operative management or minimized pulmonary resection (Cheruvu*et al.*, 2023).

CHALLENGES IN TREATING THORACIC TRAUMA

Treating thoracic trauma faces unique challenges that go beyond conventional and innovative approaches, requiring deep understanding and specific strategies to overcome them and promote adequate patient care. One of the biggest challenges is the complexity and variety of injuries that can occur, such as pneumothorax, hemothorax, pulmonary contusions, rib fractures, and major vessel injuries (Cheruvu *et al.*, 2023). Maintaining a patent airway and controlling bleeding are critical and challenging, often requiring invasive procedures that must be performed carefully not to aggravate injuries (Cakmak *et al.*, 2022). Controlling bleeding, especially from major vessels, requires a quick and effective response to avoid hemorrhagic shock and ensure patient survival (Schmitt *et al.*, 2021).

Intense pain is a constant in thoracic trauma, and its proper management becomes a challenge. It not only affects the patient's quality of life but can also compromise breathing and mobility, increasing the risk of complications (Mukerji *et al.*, 2021; Schmitt *et al.*, 2021). Pulmonary complications, such as pneumonia and acute respiratory distress syndrome (ARDS), also represent significant challenges in managing thoracic trauma, as they can develop rapidly and require constant vigilance and intensive care (Dagod *et al.*, 2021).

The rapid evolution of medical technologies presents both opportunities and challenges. Adapting to new diagnostic and treatment technologies, such as advanced imaging techniques and minimally invasive procedures, requires continuous training and updating of professionals involved in patient care with thoracic trauma. The need for a multidisciplinary approach is another important aspect, requiring the collaboration of a diverse team of highly skilled professionals (Cheruvu *et al.*, 2023).

To overcome the challenges in treating thoracic trauma, specific strategies are necessary. Investing in the continuous training and updating of professionals is fundamental

to deal with the complexities of thoracic trauma and new treatment technologies (Cheruvu *et al.*, 2023). Developing and implementing care protocols is essential to ensure a cohesive and efficient approach to treating these patients (Cheruvu *et al.*, 2023). Research and innovation also play a crucial role, as developing new diagnostic and treatment techniques is fundamental to improving patient outcomes (Dagod *et al.*, 2021). Finally, adopting a patient-centered approach, considering their specific treatment and recovery needs, is indispensable for providing quality and personalized care (Schmitt *et al.*, 2021).

Moreover, the team must be trained to quickly identify and control internal bleeding, particularly from major vessels or thoracic organs. This often requires a combination of advanced diagnostic techniques and immediate surgical interventions. CT plays a crucial role in this context, allowing for a more accurate assessment of rib fractures and pulmonary complications, although it requires the patient's clinical stability to be performed (Mukerji *et al.*, 2021).

Recovery for patients with thoracic trauma often involves long-term challenges, including pulmonary rehabilitation and managing sequelae such as pulmonary dysfunction and chronic pain. Pulmonary rehabilitation, an integral part of recovery, aims to improve lung function, exercise capacity, and quality of life (Cheruvu *et al.*, 2023).

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