Thoracic Trauma: Interventional Radiology

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Gianpaolo Carrafiello, Chiara Floridi, Francesca Patella, Francesco Morelli, Filippo Pesapane, and Matteo Crippa

13.1 Introduction

Polytrauma is a leading cause of death and disability worldwide; the major cause is road traffic collisions but other causes exist such as workplace and battlefield injuries [1, 2].

Thoracic injuries both blunt and penetrating mechanisms account for approximately one quarter of deaths due to trauma and contribute to 25–50% of the remaining deaths [3, 4]. Trauma to the thorax is responsible for 20–25% of all motor collision-related deaths, and the thorax is the third most common site of traumatic injury after the head and extremities [5]. Trauma patients are at risk for shock, coagulopathy, acidosis, and multi-organ system failure: their treatment is a race against time and most patients with thoracic trauma die at the crash scene [6]. Among those who survive the traumatic event, aortic injury is usually lethal if left untreated although 70% of patients survive with intervention [7]. In the absence of aortic injury, thoracic trauma may usually be managed with appropriate life support and monitoring [8].

The increased prevalence of penetrating chest injury and improved prehospital and perioperative care have resulted in an increasing number of critically injured but potentially salvageable patients presenting to trauma centers [9]. Moreover, a rapid recovery and mobility will allow patients to resume work and other activities thus resulting in a reduced overall cost to the social and healthcare systems.

In the last decades, there has been an acknowledged improvement in trauma care, and there are constant ongoing developments, especially there has been a growing role for both diagnostic and interventional radiology (IR) in all types of trauma affecting different areas of the body, thorax included, with imaging becoming an integral part of the multidisciplinary approach to modern trauma care [10].

Computed tomography (CT) has sensitivity as high as 98% for depiction of aortic injury [11]. Injuries range from subtle intimal damage to active extravasation, with the latter rarely seen

G. Carrafiello (✉)
Diagnostic and Interventional Radiology Department, San Paolo Hospital, Università degli Studi di Milano, Milan, Italy
e-mail: gcarraf@gmail.com

C. Floridi
Diagnostic and Interventional Radiology Department, Fatebenefratelli Hospital, Milan, Italy

F. Patella • F. Morelli • F. Pesapane
Postgraduation School in Radiodiagnostics, Diagnostic and Interventional Radiology Department, San Paolo Hospital, Università degli Studi di Milano, Milan, Italy

M. Crippa
Vascular Surgery Department, San Paolo Hospital, Università degli Studi di Milano, Milan, Italy

V. Miele, M. Trinci (eds.), *Diagnostic Imaging in Polytrauma Patients*,
https://doi.org/10.1007/978-3-319-62054-1_13

because of its high lethality [6]. Dissection, seen as intimal flaps, is often present in conjunction with pseudoaneurysm, whose appearance varies from an eccentric irregular outpouching of contrast material to a sudden change in caliber that is sometimes referred to as pseudocoarctation [12]. Endovascular intervention (EVI) has emerged as the preferred treatment in patients with such injuries. The multisciplinar team (MT) decision to perform EVI rather than conventional surgical repair is typically made on the basis of CT angiographic findings [12].

Among the MT, interventional radiologists are ideally qualified to play an important role in the management of thoracic trauma patients [13]. Aside from their specialized training in the delivery of transcatheter therapies, IRs receive broad-based multimodality imaging training, which renders them highly capable of correlating findings from preprocedural imaging studies to speed diagnosis and treatment of trauma patients in the emergency setting [14].

Aortic injury may be safely excluded if no luminal or mural abnormality is seen, irrespective of the presence of mediastinal hematoma [15]. When it abuts the aorta, hematoma may result from injury to the vasa vasorum, and when it is isolated to the anterior or posterior mediastinum, it likely is related to sternal or spinal injuries [16]. No treatment or further imaging is needed in either case; however, attention should be paid to the great vessels because periarterial hematoma in the superior mediastinum may be a sign of a great vessel injury [16].

Rupture of the hilar pulmonary arteries may result in brisk extravasation with massive hemothorax, respiratory compromise, and exsanguination [17]. The pulmonary trunk and the anterior aspect of the intrathoracic IVC are intrapericardial structures, and injury to these regions will likely lead to hemopericardium. The ensuing rapid increases in intrapericardial pressure that result from bleeding into an intact pericardium cause cardiac tamponade and hemodynamic compromise.

Although the primary role of whole-body CT angiography in patients with chest trauma is to identify or exclude the presence of aortic or other types of major vascular injury, important nonvascular injuries may also be identified. In elderly patients, even a solitary rib fracture may lead to pulmonary insufficiency requiring prolonged periods of mechanical ventilation [18]. CT is able to depict large pneumothoraces that require immediate chest tube insertion [18]. However, detection of small pneumothoraces is also important because their size may increase in patients who are intubated [19]. Although parenchymal lung injuries such as contusion and laceration are typically treated conservatively, early diagnosis is important because these injuries may contribute to respiratory failure [18]. Diaphragmatic injuries are uncommon in patients with chest trauma but also in this case an early diagnosis is essential to prevent herniation and strangulation of abdominal contents [18, 19].

In conclusion, thoracic trauma patients need to be rapidly and accurately assessed to determine the nature of their injuries with treatments prioritized by injury severity [11].

13.2 Blunt Traumatic Aortic Injuries

13.2.1 Introduction

Blunt traumatic aortic injury (BTAI) is the second most common cause of death after blunt trauma among patients with major traumatic injuries although it accounts for 1% of adult admissions to level I trauma centers [20].

Indeed, an estimated 80–90% of all victims die at the scene of the accident [20]. The prognosis for patients who survive the initial injury remains poor: nearly 30% will die within the first 6 h, and 50% of these patients will not live beyond the first 24 h after the injury [20].

The affected population is generally young with an average age of 40 years [21].

The classic injury mechanism of blunt thoracic aorta is related to the combination of sudden deceleration and traction on the inner curvature of the arch at the ligamentum arteriosum, which represents the junction between the relatively mobile aortic arch and the fixed descending aorta. Thus, the isthmus is the most common location for rupture (50–70%), followed by the ascending aorta or aortic arch (18%) and the distal thoracic aorta (14%) [22].

Given the location of injury, conventional surgical repair typically involves a high posterolateral thoracotomy with or without cardiopulmonary bypass, aortic cross clamping, and significant blood loss, which can negatively impact the status of the patient. Historically, open repair of traumatic aortic injuries has been associated with a 28% mortality rate [23] and a 16% paraplegia rate [24]. There has been a risk of delayed rupture in the unrepaired thoracic transection that has been estimated to be 2–5% [25].

Thoracic endovascular aortic repair (TEVAR) is a rapidly evolving alternative therapy in the treatment of a variety of thoracic aortic pathologies, consisting in placing an endovascular stent graft into the thoracic aorta from a remote peripheral location under imaging guidance.

To date, no randomized controlled trials have sought to determine whether use of TEVAR for treatment of BTAI is associated with reduced mortality and morbidity when compared with conventional open surgery [26]. However, clinicians are moving forward with EI of BTAI on the basis of a number of meta-analyses and large clinical series, which assessed that TEVAR is a safe and effective procedure for patients with traumatic aortic injuries and involves lower mortality and spinal ischemia rates, as well as reduced risk of graft infection and systemic infection when it is compared with open repair [26].

13.2.2 Technique

TEVAR procedures can be performed under local or general anesthesia in an IR operating room. The abdomen and bilateral groins are prepared in standard way. Single femoral access may be achieved using an open or percutaneous technique. Then, the location of the injury is identified during an arch aortography. The cerebrovascular anatomy should also be evaluated based, especially if left subclavian artery coverage is planned. If angiography is equivocal, IVUS can be used. The patient is then anticoagulated with heparin with a smaller dose than the standard weight-based protocol especially in patients with intracranial hemorrhage. The thoracic device(s) is selected on the basis on contrast enhanced CT images according to the manufacturer's sizing recommendations. The device(s) is delivered over a stiff wire and then deployed using the standard technique without any pharmacological adjunct. The subclavian artery can be covered in order to obtain a proximal landing zone or gain better apposition with the lesser curvature of the aortic arch, and if necessary the vessel can be selectively revascularized. Post-deployment balloon angioplasty is generally not performed given the high risk of rupture [27, 28]. The procedure is supposed to end with a diagnostic angiography to check the position of the graft and the resolution of the injury (Fig. 13.1).

13.2.3 Indications and Guidelines

According to the most recent consensus of the Society for Vascular Surgery (SVS) the use of TEVAR is supposed to follow some guidelines that the committee suggested on the basis of a systematic review and meta-analysis of the literature including 7768 patients from 139 studies [29]. As it was said before, only observational studies, case series and unsystematic observations or expert opinion are available to date; thus, using the GRADE system, all of the following indications should be regarded as Grade 2, Level C statements:

1. *Timing of TEVAR in a stable patient*

   The committee suggests urgent (24 h) repair in the absence of other serious concomitant non-aortic injuries, or repair immediately

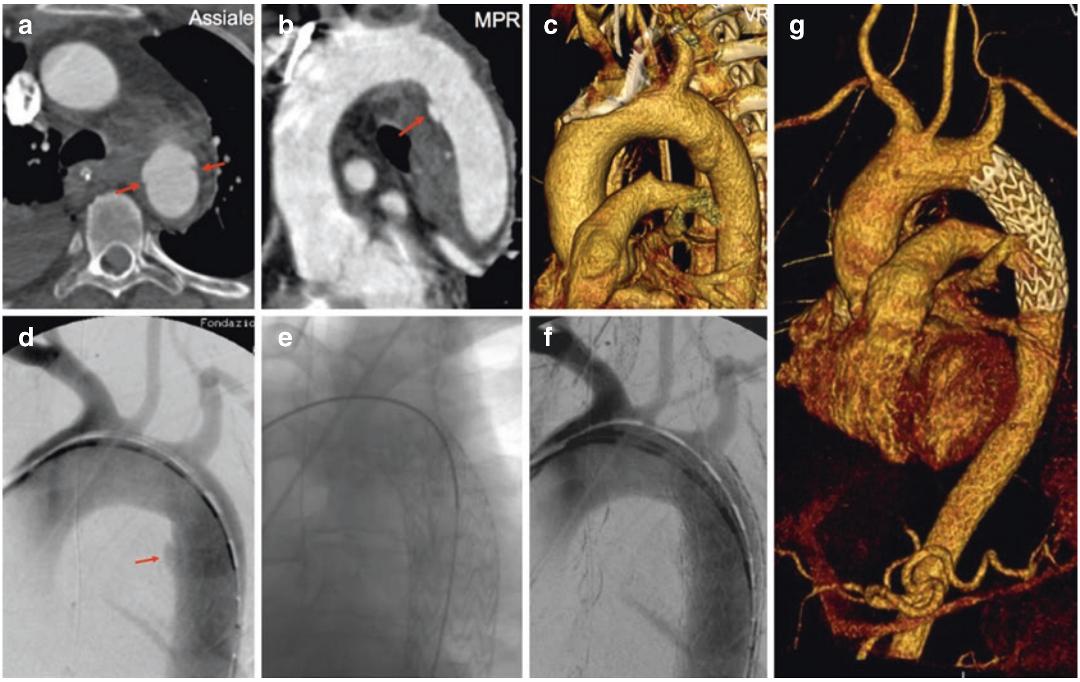

Fig. 13.1 (**a**–**c**) CT-angiography showing intimal tear at the aortic istmus (*arrows*); (**d**) DSA confirms the presence of an intimal tear (*arrow*); (**e**, **f**) placement of the stent graft; (**g**) follow-up CTA showing the correct placement of the stent graft with disappearance of intimal tear

after other injuries have been treated, but at the latest prior to hospital discharge [30, 31]. This is consistent with the available evidence in which mortality was 46% in those managed nonoperatively [32].

2. *Management of "minimal aortic injury"*

   Based on imaging, BTAI can be classified in four grades of severity:

   - type I: intimal tear
   - type II: intramural hematoma
   - type III: pseudoaneurysm (presence of a thin layer of adventitia that covers a transverse tear in the intima and media preventing complete rupture)
   - type IV: rupture

     The committee suggests expectant management with serial imaging for type I injuries, while types II to IV should be repaired. This is consistent with the evidence that most type I injuries can be managed with medical therapy (anti-impulse control). Decision to intervene and its timing should be guided by progression of the initial radiographic abnormality and/or symptoms [33].

3. *Choice of repair in the young: TEVAR vs. open*

   Age should not be a factor influencing the choice of the type of repair. The risks of death and spinal cord ischemia are significantly lower in all age groups after endovascular repair compared with open surgery, and these advantages overcome the concerns of potential late complications [34].

4. *Management of left subclavian artery*

   LSA is generally covered in 30% [32]. The committee suggests selective revascularization (either before or after TEVAR) depending on the status of the vertebral anatomy, especially whether the right vertebral artery is atretic or hypoplastic with or without an intact Circle of Willis.

5. *Systemic heparinization*

   The committee suggested routine heparinization, but at a lower dose than in elective TEVAR.
6. *Spinal drainage*

   Given the low risk of spinal cord ischemia during TEVAR for BTAI treatment (3%) [32], the proximal location of the injury involving limited coverage of the thoracic aorta, and the risk of epidural hematoma in a coagulopathic patient, the committee suggests that spinal drainage is not routinely indicated, and it should only be placed for symptoms of spinal cord ischemia.
7. *Choice of anesthesia: general vs. regional vs. local*

   The committee endorses general anesthesia because of unreliable cooperation of an agitated trauma patient and the presence of concomitant injuries that may require additional surgery.
8. *Femoral access technique*

   The committee suggests open femoral exposure
9. *Optimal follow-up strategy*

   In the absence of any abnormalities on imaging (i.e., stable endograft position, no endoleak) in the first 12–36 months, some have suggested decreasing the frequency to 2–5 years, while others have expressed that, lacking any evidence to the contrary, follow-up for traumatic thoracic aortic injuries should be no different than those treated with TEVAR for other pathologies. There was, however, some consensus suggesting that a combination of a multi-view chest X-ray and a magnetic resonance angiography (MRA) may be preferable over conventional contrast computed tomographic angiography (CTA) for long-term imaging, with due consideration of the metallic composition of the endograft.

13.2.4 Challenges and Limits

Despite TEVAR is associated with a lower risk of complications compared to open repair, there remains a number of controversial issues:

1. *Young age of affected population*:

   As mentioned before, BTAI tends to affect younger populations, in contrast to the aneurysm population. It is not uncommon that adolescent or pediatric patients may present with this injury [29].

   This carries some challenges:

   - Poor conformability of grafts to the aortic arch:
   - Young patients present not only a smaller aortic diameter, but also a shorter radius of aortic curvature compared to elderly patients. As individuals age, not only does the aorta enlarge, but the radius of curvature also increases [29]. This is potentially problematic for devices that are designed to mimic the stiffness of older patients with thoracic aneurysms. As such, their conformability is not ideal along the lesser curvature of the arch, potentially resulting in proximal endoleaks.

     Furthermore, when coupled with the increased aortic impulse in young patients, a lack of proximal conformability can also cause an aortic pseudocoarctation from compression of the device.

     Both device collapse and endoleaks are not always predictable and avoidable occurrences. They can, however, be treated when they occur.
   - Uncertain natural history of the repair:

     Given the morphologic changes of the aorta that come with age, the possibility of stent-graft migration as the aorta enlarges must be considered [29].
2. *Stent sizing*:

   Severe hypovolemia can lead to aortic contraction with underestimation of the aortic diameter ranging from 5 to 40% [35]. This can result in potential problems because undersized devices are associated with type I endoleak, persistent lesion perfusion, and bleeding. Oversizing the device would help minimize this risk but excessive oversizing can also lead to major complications as the aforementioned device compression [20].

3. *Manipulation of an endograft in the vicinity of the ascending aorta*:

   It is not only technically difficult but also carries a risk of stroke complications [29].

13.3 Interventional Radiology of Thoracic Wall Arteries

13.3.1 Introduction

Chest wall trauma shows a significant morbidity and mortality rate, with reported mortality ranging from 5 to 25% [3, 4].

Pape et al. [36] developed a scoring system for guiding initial clinical decision-making in the blunt chest trauma patient with multiple associated injuries. However, there are no evidence-based guidelines for management in the blunt chest wall trauma patients without associated injuries.

13.3.2 Clinical Considerations

The chest wall is a typical site of injury in patients with thoracic trauma. Rib fractures, sternum fractures, and flail chest are quite common findings, especially in case of blunt chest trauma. Dislocated fractures can induce damages to the pleuro-pulmonary structures and vessels, with formation of hemothorax, pneumothorax, pulmonary hematoma, pulmonary contusion, and hemomediastinum.

Penetrating injuries of the chest wall are lesser associated with bone fractures, but have similar risk to damage the pleuro-pulmonary structures and vessels.

Bone fractures generally undergo to nonoperative management. An exception is flail chest, for which recent studies suggest major benefits from surgical stabilization [37].

Vascular injury is a quite rare finding in chest wall trauma but its prompt recognition and management is fundamental for patient's life. Both blunt and penetrating traumas are recognized to be causes of vascular damages of the chest wall arteries.

Thoracotomy was the only useful treatment in these patients until 1977, when Barbaric et al. first reported the effectiveness of TAE for post-traumatic intercostal arterial hemorrhage [38].

13.3.3 Anatomy

The chest wall is the boundary of the thoracic cavity. Arterial supply originates from the intercostal arteries and the internal thoracic arteries [39]. Knowledge of the anatomy is fundamental in case of EVTs because of the high number of collateral vessels that may cause reperfusion and delayed failure of TAE.

The intercostal arteries (11 for each side) are divided into two branches, anterior and posterior. They lie in the intercostal space near the lower margin of the rib, between the intercostal vein (above) and the intercostal nerve (below).

Posterior branches originate directly from thoracic aorta (except for the first and second branch, which arises from the supreme intercostal artery-collateral of the costo-cervical trunk). They give a dorsal branch which feeds the spinal cord (radicular and spinal arteries).

From the first to the sixth, the anterior branches originate from the two internal thoracic arteries, which give rise to the subclavian arteries; from the sixth space the internal thoracic artery divides into the superior epigastric artery and musculophrenic artery. The latter goes downward and laterally and gives out the remaining anterior intercostal branches.

13.3.4 Management

Arterial injuries of the thoracic wall should be suspected in every case of trauma patient with:

- Abundant hemothorax/hemomediastinum
- Markedly displaced rib fractures

Even if a wide consensus is missing, many authors [40, 41] suggest the following management for these patients.

Patients with chest trauma and evidence of a pneumothorax or hemothorax have to undergo tube thoracostomy. Hemodynamically unstable patients and patients with >200 mL/h of blood loss from the thoracostomy tube should require emergent thoracotomy. When emergent thoracotomy is not indicated, CECT need to be performed. CECT may help to distinguish blood loss from an arterial source versus blood loss from a pulmonary lesion (bleeding from low-pressure pulmonary circulation), which is usually self-limited and in any case cannot be resolved with EVI. If CECT reveals arterial extravasation of contrast medium, angiography with TAE is indicated.

Prompt recognition is important because of the high blood flow in these arteries (150 mL/min for thoracic internal artery), which can be potentially life-threatening in few minutes [42]. Although a lesion of these arteries can achieve temporary hemostasis due to arterial spasm and hypotension, rebleeding may occur after the patient is resuscitated [43].

Active extravasation of contrast medium can be easily detected with CECT, which accurately shows the anatomic location of the bleeding and indicates the probable vascular origin. CECT, therefore, can be used as a guide for angiographic or surgical procedures [44].

CECT can show two types of alterations:

1. Active bleeding: extravasation of contrast medium increasing in the time
2. Pseudoaneurysm: disruption of one or more layers of the arterial wall forming a perfused sac with contrast medium that washes away with bloodstream

Both these lesions require an invasive treatment because pseudoaneurysms are by definition instable lesions and may develop in a real arterial rupture in the time.

In these cases, the patient should be carried in an angiographic suite to have an arterial angiography with TAE. The advent of superselective microcatheters has made the detection of bleeding sources easier and TAE safer [45].

The most common embolic materials used are pushable microcoils and polyvinyl alcohol (PVA) particles. Different embolization strategies can be used depending on the location of the bleeding source:

- If the bleeding source is in the main artery, microcoils can be first placed distal to the bleeding source (to prevent retrograde bleeding and to protect the thoracic wall from embolization). This is followed by placement of further microcoils proximal to the bleeding source. Eventually, final injection of PVA particles can accelerate thrombosis.
- If the source is in a distal part of the artery and could not be reached by the microcatheter, embolization need to be performed by first injecting PVA particles of a medium size (250–500 μm) which can occlude distally to the bleeding source; then, by placing coils proximal to the bleeding afterwards.

These approaches reduce the risk of delayed failure of TAE due to perfusion from other feeding vessels that may be too small to detect during the first angiography [46].

Spinal cord ischemia is the only serious potential complication related to TAE and has been reported by several authors [47].

Nowadays, this adverse event is very rare because microcatheters can go beyond, with their tip, to the origin of medullary branches (Fig. 13.2).

13.3.5 Conclusions

Lesions of thoracic wall arteries are rare but potentially life threatening. Their management includes TEA or thoracotomy, but actually there aren't standardized inclusion and exclusion criteria.

Some authors suggest that the endovascular treatment could be the most effective strategy to control hemorrhage, minimizing potential complications, so that TAE should always be considered before surgery in stable patients [48].

Whigham et al. [43] demonstrated a higher success of TAE with respect to surgery (91.6%

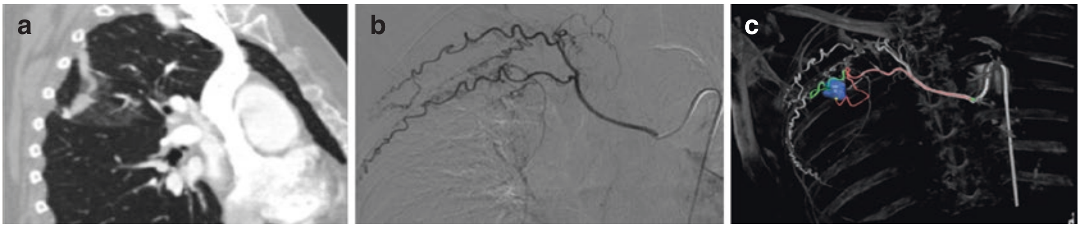

Fig. 13.2 (**a**) CTA shows a small bleeding from a right intercostal artery. (**b**) DSA confirms the presence of a little contrast medium extravasation from the same vessel. (**c**) Embolization planning by the C-arm Cone Beam CT embolization software

vs. 66.0%) to stop the bleeding. Nonetheless, in most centers these traumas are still treated more frequently via thoracotomy.

According to the literature and the state of the art [49–52], stable patient with isolated or not isolated chest wall trauma should always be submitted to CECT. In case of active arterial bleeding, TAE should always be considered before surgery and performed as soon as possible.

13.4 Pleural and Airways Injuries in Trauma Patient

Airways trauma is a life-threatening condition which may be a result of blunt and penetrating injuries to the neck and chest [53]. Therefore, prompt diagnosis is mandatory for the survival of these patients, also because the presence of concomitant severe injuries and unspecific symptoms may delay the diagnosis and lead to early fatal outcome or late sequela such as airway stenosis and recurrent pulmonary infections [54]. The treatment of these patients provides an adequate ventilation and then the repair of the airways injury with a smaller impact on the respiratory function and the quality of life of the patients [55].

Blunt chest trauma causes an abrupt increase in intrathoracic airways pressure. If this happens against a closed glottis, the trachea and major bronchi can be injured secondary to the increased pressure.

The incidence of tracheobronchial injuries (TBI) among trauma patients with thoracic injuries, including those that died immediately, is estimated at 0.5–2% [56, 57]. The mortality from traumatic TBIs has decreased from 36% before 1950 to 9% in 2001 [53]. Laceration of the mediastinal pleura and/or bronchial injuries may allow air to enter in the pleural cavity; pneumothorax occurs in 17–70% of the patients with TBIs [58] and in 30–40% of all patients with a blunt chest trauma [59]. The most common cause is a rib fracture that lacerates the lung, but it also may be caused by rupture of a preexisting bleb at the time of impact [59]. Finally, hemothorax is seen in approximately 50% of patients who sustain blunt chest trauma [60]. Bleeding into the pleural space can originate from injury to the pleura, chest wall, lung, diaphragm, or mediastinum.

Concerning the approach to the patient with thoracic trauma, the airway in a neurologically intact patient is easily assessable: the injured patient who is alert and able to speak normally is maintaining a patent airway. However, especially in polytrauma patient, this must be carefully monitored as facial fractures with associated bleeding or edema, emesis, or foreign bodies can eventually compromise airway patency. The symptoms and signs of TBI depend on the site and the severity of the injury and most of them are not specific for this kind of injury.

Subcutaneous emphysema is the most common finding in TBI occurring in up to 87% of the patients [61]. Dyspnea, tachypnea, and respiratory distress are found in 59–100% of the patients [62], while hemoptysis can be seen in up to 74% of the cases [63].

Clinical signs of pneumothorax can be subtle and difficult to elicit in a patient who has multisystem trauma [60]. Detection of even a small, asymptomatic pneumothorax is important because up to one third can develop into a tension pneumothorax with potential cardiopulmonary decompensation [64].

The most common findings in chest X-rays are subcutaneous emphysema, pneumomediastinum, and pneumothorax.

Subcutaneous emphysema signs include: tracheal deformity, a defect in the tracheal contour, an endotracheal tube out of place, and the tube's cuff over-inflated and protruding beyond the edge of the tracheal wall [65].

Radiographic signs of a pneumothorax can be subtle, and the appearance differs based on the patient position at the time that the radiograph was performed. In the supine position, air collects within the anterior costophrenic sulcus, which extends from the seventh costal cartilage to the 11th rib at the midaxillary line [64]. This appears radiographically as abnormal lucency in the lower chest or upper abdomen, an abnormally wide and deep costophrenic sulcus (the "deep sulcus" sign), a sharply outlined cardiac or diaphragmatic border, depression of the hemidiaphragm, or as a "double diaphragm" sign that is seen when air outlines the dome and anterior insertion of the diaphragm [66].

The appearance of hemothorax on a chest radiograph depends on the amount of blood that has collected in the pleural space and patient position. Plain radiography of the upright chest may be adequate to establish diagnosis by showing blunting at the costophrenic angle or an air–fluid interface if a hemopneumothorax is present. If the patient cannot be positioned upright, a supine chest radiograph may reveal apical capping of fluid surrounding the superior pole of the lung. In the acute trauma setting, the portable supine chest radiograph may be the first and only view available from which to make definitive decisions regarding therapy [60, 67]. When the size of a hemothorax reaches approximately 200 mL, an upright chest radiograph demonstrates blunting of the costophrenic angle. With progressive increase in size, a meniscus-sign will be seen: a concave upward sloping of fluid in the costophrenic angle. In contrast, a straight air–fluid level on the upright chest radiograph indicates a hemopneumothorax. A large hemothorax can opacify the hemithorax completely and cause contralateral shift of the mediastinum as the result of mass effect [68].

It is believed that up to 10–20% of the patients with TBI may have no signs of TBI on chest X-rays [57]; therefore, CT imaging helps the detection of the airways and pleural injury [15], especially the multi-slice detector CT (MDCT) with MPR/3D reconstruction of the images that can significantly increase the diagnostic accuracy of the procedure up to 94–100% [1, 69]. Discontinuity of the tracheal or bronchial wall can be seen, with air leaking around the airway. Among the indirect, more specific signs of tracheobronchial tear, there are the collapsed lung resting on the most dependent area away from the hilum (fallen lung sign), persistent pneumothorax after tube thoracostomy and herniation or overdistention of an endotracheal cuff in an intubated patient [57, 70]. All of these findings can be readily detected with MPR and 3D reconstructions using MDCT, particularly when looking for discontinuity of the airway wall. The MDCT improved significantly the spatial resolution, bringing us isotropic multiplanar and volume-rendering reconstructions and the MDCT's increasingly faster acquisition times have made it more appealing as a screening tool in the trauma setting [18]. Moreover, CT is highly sensitivity in detecting a small hemothorax and the Hounsfield unit (HU) measurement of fluid in the pleural space can be used to identify the origin of the fluid. Hemothorax measures 35–70 HU, depending on the amount of clot present [60]. In contrast, a sympathetic serous pleural effusion, which can be seen in patients who have splenic, hepatic, or pancreatic injuries, typically measures less than 15 HU. Other less common causes of pleural effusion in the patient who has experienced trauma include chylothorax from injury to the thoracic duct [71] and bilious effusion, which is caused by formation of a biliopleural fistula in the patient who has injury to the liver and the right hemidiaphragm [72]. Clues to the source of the bleeding into the pleural space can be gleaned from the appearance on imaging studies. A hemothorax that is due to bleeding from venous origin typically is self-limiting because of the tamponade effect from the lung parenchyma and usually does not increase in size. Arterial bleeding, such as from an intercostal artery, can be inferred by progression of size on radiography or CT [60]. CT also may demonstrate active bleeding within the hemothorax showing a focus of high density of the nearest large artery and multiplanar CT reformatted images can be especially useful to demonstrate the site of active bleeding [60].

It should be recalled that up to 80% of the TBI can be missed during the first 24–48 h after the trauma because of the nonspecific nature of the presenting symptoms and the fact that an airway injury may sometimes allow near normal ventilation [62, 73, 74]. With time the bronchus will be filled with fibro-granulation tissue and organizing hematoma. In the former, recurrent pulmonary infections may lead to bronchiectasis and destruction of the lung parenchyma, while in the later the lung distally to a completely obstructed bronchus is filled with mucus and protected from infections [73].

As a general rule, for patients with severe neck and thoracic trauma, tracheal intubation is required in the presence of the following conditions: severe brain injury, documented or highly suspected thermal inhalation injury, severe pulmonary contusion with hypoxemia or ventilatory insufficiency, high cervical spine injuries, or any injury resulting in pulmonary failure. However, the tracheal intubation in this patients with airway injury may result disastrous [53] because the pressure over a fractured cricoid may dislocate it enough to completely distort the upper airway or even lead to complete airway transection and obstruction [75]. Attempts to blindly overpass an upper airway injury may worsen the laceration and/or create false passage of the tube [76]. Therefore, spontaneous breathing of the patient should be preferred until safe airway has been achieved [53].

The final goals of airways injuries treatment are the following:

1. closing of the airway defect to improve ventilation
2. preventing mediastinal spillage and infection
3. avoiding spontaneous healing complications which can lead to airway stenosis and recurrent pulmonary infections.

The definitive management is essentially with surgery although in the 2001 was published a large revision of patients with blunt tracheobronchial injuries published in the literature [73] showing that conservative management is associated with higher rates of death; since then, several studies have commented on the possibility for nonoperative management in patients with airways injuries [56, 77] and the recent data shows a rating of conservative treatment in patients with TBI that ranges from 33.3 to 94.4% [53, 61].

Concerning the treatment of pneumothorax, patients who are symptomatic or who demonstrate a greater than 20% pneumothorax are generally considered for chest tube [78]. Prophylactic insertion of a chest tube also may be considered in a patient who has a small, asymptomatic pneumothorax who will be placed on a mechanical ventilator or who will be undergoing a lengthy operative procedure.

A tension pneumothorax is a life-threatening condition in which air progressively accumulates in the pleural space as the result of a one-way valve mechanism and causes high ipsilateral intrathoracic pressures. This can cause compression of the vena cava, which impairs venous return and decreases cardiac output. Radiographic signs of a tension pneumothorax include shift of the mediastinum to the contralateral side, abnormal lucency of the hemithorax with a collapsed lung in the hilar region, depression of the ipsilateral hemidiaphragm, and widening of the intercostal spaces. Prompt evacuation with needle aspiration or placement of a chest tube can be life saving.

TBI, bronchopleural fistula, or malpositioning of the chest tube should be considered if a pneumothorax does not respond completely to treatment [60].

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