Updates in the Management of Complex Chest Trauma

67

Aris Koryllos, Klaus-Marius Bastian, and Corinna Ludwig

Key Points

- Thoracic trauma is the third most common cause of death in trauma patients.
- Incidence rates of pulmonary contusion can vary between 17 and 75%, thus clinical investigation for pulmonary contusions after severe blunt chest trauma could be of great importance.
- Main symptom of pulmonary lacerations is air leakage and pneumothorax.
- Airway-related injuries include traumas of the trachea or the central bronchi. They are extremely rare (incidence 0.8–5%). Pre-hospital mortality rate can reach up to 81%.
- Rib fractures are one of the most frequent chest wall injuries, occurring in 10–40% after blunt chest trauma and approximately 10% of all trauma cases.
- Rib fracture osteosynthesis should be considered in all patients with flail chest and in patients with multiple fractures or in severe (bicortical) displaced fractures.

67.1 Introduction

Thoracic trauma is the third most common cause of death in trauma patients [1]. Thoracic trauma can lead to life-threatening injuries such as tension pneumothorax, massive parenchymal bleeding, or fail-chest with respiratory insufficiency. In most cases, conservative treatment with chest tube insertion is sufficient to stabilize the patient. Chest trauma in addition to brain injury is associated with a decreased chance of good neurologic recovery [2]. Identification of those patients with more complex lesions is mandatory.

In 2019, 36699 patients were documented in the German TraumaRegister DGU® (TR-DGU—Annual Report 2020). Of these 29,345, with a maximal AIS (Abbreviated Injury Scale) 2 or ≥3 scores (MAIS), were selected to analyze the severity of trauma and outcome in Germany. The ISS (Injury Severity Score) [3] was ≥16 in 53% of the patients. Severe thoracic trauma with an AIS >3 prevailed in 37%, underlining the frequency of severe chest trauma. The average age was 53 years, with a 70% male predominance. Pre-clinical chest-tube insertion was found in 3.9% and in-hospital in 10%. Surgery of any kind was necessary for 66.4%, whereas 86% required ICU care. In-hospital mortality was 11.9%. The data retrieved from TR-DGU underline that complex chest trauma is not rare in Germany.

Thoracic surgeons are only part of the core trauma team in German national trauma teams, unlike regional and local trauma teams where a thoracic surgeon may not even be available. We believe that the profound knowledge of thoracic surgeons is very important in trauma patient care and therefore plead for early involvement and interdisciplinary treatment of these high-risk surgical patients. Would we treat traumatic brain injury without consulting a specialist?

In this chapter, we will concentrate on identifying and treating parenchymal, airway and chest wall injuries in trauma patients.

67.2 Pulmonary Parenchyma and Airway-Related Injuries

67.2.1 Pulmonary Injuries

67.2.1.1 Pulmonary Contusions

Pulmonary contusions without lung lacerations occur usually after blunt chest trauma and are defined as the destruction of lung parenchyma with signs of alveolar hemorrhage [4, 5]. The pathophysiology of the injury can be described as an acute transmission of kinetic energy to the lung parenchyma. Cadaver studies have found that the speed of the impulse and the resulting compression are the most important factors for visceral organ damage [6]. Incidence rates can vary between 17 and 75%, thus clinical investigation for pulmonary contusions after severe blunt chest trauma could

A. Koryllos · K.-M. Bastian · C. Ludwig (✉)
Department of Thoracic Surgery, Florence Nightingale Hospital, Düsseldorf, Germany

P. Aseni et al. (eds.), *The High-risk Surgical Patient*, https://doi.org/10.1007/978-3-031-17273-1_67

be of great importance [7]. Parenchymal injuries can occur in the first 24 h after the initial trauma and can resolve radiologically and clinically after 3–14 days [3].

Clinical manifestation can consist of respiratory distress with or without hypercapnia or hypoxemia. This can be the result of reduced pulmonary perfusion, impaired respiratory movement of the chest wall and diaphragm (due to chest trauma) or increased intrapulmonary shunting [8]. Clinical examination shows symptoms of chest pain and dyspnea. Normally, a chest X-ray in combination with an arterial blood gas probe is used for emergency diagnosis [9]. A CT scan of the chest can help evaluate the size of the contusion and the number of affected lobes. Some authors suggest that this correlates with the clinical outcome [7]. Additionally, a CT scan can help differentiate between lung contusion and pulmonary hematoma. Radiological findings include consolidation areas combined with ground glass opacities.

Treatment of pulmonary contusions is mainly supportive and includes oxygen therapy, fluid management and sufficient analgesia. Although many centers additionally administer antibiotics, there are no sufficient data in the literature to justify such treatment, especially when no lung lacerations, pleural effusions or further risk factors for secondary empyema are present. Incidence of acute respiratory distress syndrome [10] in patients with pulmonary contusions can rise up to 50–60%, but in most cases, severe lacerations of the parenchyma and multiple rib fractures are also present [8]. In a big cohort study with n: 5042 chest trauma patients, Danilovic et al. described only an 8% ratio of mechanical ventilation for isolated pulmonary contusions without additional chest injuries [5]. In case of respiratory insufficiency, non-invasive respiratory support should be favored over invasive ventilation if possible [11]. There is no evidence for pharmacological treatment of pulmonary contusions. The use of steroids still remains controversial [3].

67.2.1.2 Pulmonary Lacerations

In contrast to contusions, pulmonary lacerations are defined by damage to the parenchymal tissue of the lung, usually caused by penetrating or non-penetrating injuries and rib fractures [7] (Fig. 67.1). Their incidence varies between 4.4 and 12% [12]. They can be divided into four different types [13]:

Type 1: lacerations caused by compression-induced lung rupture (most common type).

Type 2: lacerations caused by compression and occurring in the lower lobes and paraspinal region.

Type 3: lacerations are usually seen as a result of pleural puncture of rib fractures and are associated with pneumothorax.

Type 4: lacerations caused by rupture of pleural adhesions with no characteristic radiological findings.

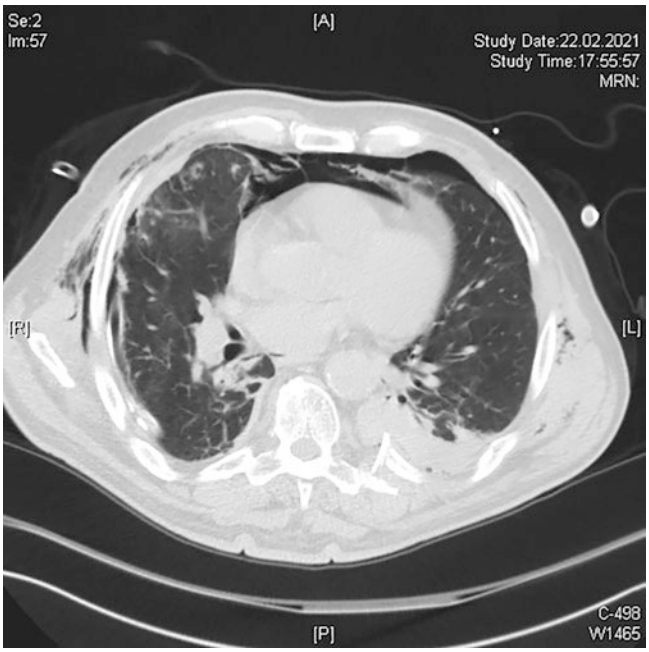

Fig. 67.1 Left basal laceration after rib fracture with rib fragment dislocation

The main symptom of pulmonary lacerations is air leakage and consequently pneumothorax [14]. Hemothorax can also develop if the pleural cavity is opened. Deep pulmonary lacerations are present in 50% of patients with intrathoracic hemorrhage in blunt chest trauma [15]. Pneumatocele has also been described as a possible consequence of lung lacerations. In cases of deep parenchymal lesions with active bleeding in traumatized pulmonary cavities blood and air, leakage can lead to hemato-pneumocele. This can lead to secondary infection after the bleeding has stopped [16].

Therapy of pulmonary lacerations varies according to severity. In most cases a chest tube is sufficient. Surgical intervention should be always considered if persistent bleeding and hemodynamic instability are present. Pulmonary resection (i.e., lobectomy) may even be indicated in cases of severe lacerations. Mortality is reportedly higher in cases of bilateral and/or major lacerations [12]. The healing process of pulmonary lacerations is longer than that of contusions and can last several months [12]. Some authors also suggest a surgical intervention in cases of severe air leakage without the presence of hemodynamic instability or active bleeding. There is no evidence in the literature for favouring surgery over supportive care for such cases. Our personal experience showed that patients with severe pulmonary lacerations usually have multiple traumatic lesions in different organs as a result of high-impact accidents and conservative management is usually initially adequate for these critical patients.

Fig. 67.2 Fracture of the cricoid cartilage after blunt chest and neck trauma, subcutaneous emphysema

67.2.2 Airway-Related Injuries

Airway-related injuries include traumas of the trachea or the central bronchi. They are extremely rare (incidence 0.8–5%) but when present are often accompanied by high mortality rates [17]. Non-iatrogenic tracheobronchial injuries usually occur after road accidents, crush injuries, stab injuries, gunshots, hyperextension of the neck, hanging or strangulation (Fig. 67.2). Pre-hospital mortality rate can reach up to 81% [18].

In cases of non-penetrating-injuries, the trauma mechanism consists of sudden force from anterior to posterior above the carinal level or rapid deceleration with the tear of the cricoid or severe compression of the thorax while the glottis is closed [19]. In non-iatrogenic tracheobronchial injuries, concomitant traumatic lesions very frequently involve osseous structures of the thorax (ribs, sternum, spine), lungs; diaphragm, spleen, liver; great vessels, heart; brain. However, airway injuries could also be the result of medical interventions in critical trauma patients, since 92% of all tracheobronchial injuries occur after oral intubation or emergency tracheotomy [20].

Diagnosis of airway-related injuries after blunt chest trauma is not trivial. In cases of penetrating injuries, the suspicion of tracheal or bronchial tear correlates to the location of the penetration but diagnosis can be difficult and delayed in cases of blunt force trauma [21]. Because of the severe concomitant injuries, tracheobronchial trauma can be challenging to differentiate. Symptoms include subcutaneous or mediastinal emphysema, dyspnea, hemoptysis, stridor, persistent atelectasis or pneumothorax, massive air leakage or alterations in phonation [22]. Imaging modalities such as chest X-ray or ultrasound can be insufficient due to mediastinal and subcutaneous emphysema, thus making CT-scan and mainly bronchoscopy inevitable for accurate diagnosis, localization of the tear and evaluation of its extent. Most non-iatrogenic tracheobronchial injuries after blunt chest trauma are located within 1cm from the main carina [21]. Cardillo et al. proposed an endoscopic classification of the tracheal tears based on the lacerated layers of the trachea, but validation data are still rare and the clinical importance has yet to be justified [23].

Management and approach of airway-related injuries should correlate with the current adult advanced life support guidelines, meaning: As long as a stable airway can be established and ventilation is adequate, the treatment of tracheobronchial injury can be postponed until other life-threatening injuries are repaired and the patient is stabilized [10]. But immediate intervention should be considered if the bronchial or tracheal tear does not allow sufficient ventilation or oxygenation [24]. A general recommendation for ideal management of airway-related injuries is difficult to generate, hence every case is individual and unique considering the patient's general status, concomitant injuries and anatomy. Nevertheless, it is important to mention that a substantial number of tracheobronchial injuries can be treated conservatively when the respiratory status allows [23]. In recent years, there has been an increase in publications supporting conservative treatment, but only patients with stable respiratory status were treated [25]. Endoscopic suturing by means of rigid bronchoscopy has also been reported, but it is technically feasible only if patients can tolerate jet ventilation, which makes it an attractive option for fairly respiratory-stable patients [26].

The main goal of emergency treatment is to maintain airway continuity and repair or temporarily "bridge" the damaged area. Adversely to the respiratory stress of the patient's positive pressure ventilation can lead to exacerbation of the critical situation [27]. If the tear is unusually located in the upper level of the trachea, an emergency tracheotomy caudal to the lesion could facilitate safe respiratory conditions after the placement of the tracheal cannula underneath the tear. Unfortunately, most of the tears are within a radius of 1cm from the main carina making the above treatment rather futile. Guided by bronchoscopy, placement of endotracheal tubes in the left or right main bronchus could allow temporary stability for further surgical management, but in cases of main bronchi involvement, it could result lead to negative results and enhancement of the tear. In severely-injured polytrauma patients with no respiratory stability even after con-

trolled placement of an endotracheal tube, case reports of extracorporeal oxygenation have been documented in recent years as a bridge to recovery or to allow surgical management [28, 29]. If surgical management is indicated, most surgeons prefer an antero- or posterolateral right thoracotomy or a median sternotomy for access. Surgical treatment includes primary sutures or resection with anastomosis or bronchoplasty [30]. Esophageal injury associated with tracheobronchial injuries should also be excluded because, if missed, complications such as mediastinitis and tracheoesophageal fistula may develop [4].

In conclusion, airway-related injuries in complex chest trauma patients are associated with high mortality rates and the prognosis is poor mostly because of the concomitant injuries. The main problem of their management is respiratory instability in combination with multiple organ damage/failure. Goal for the treating multidisciplinary team is to maintain airway continuity/stability and repair or temporarily "bridge" the damaged area.

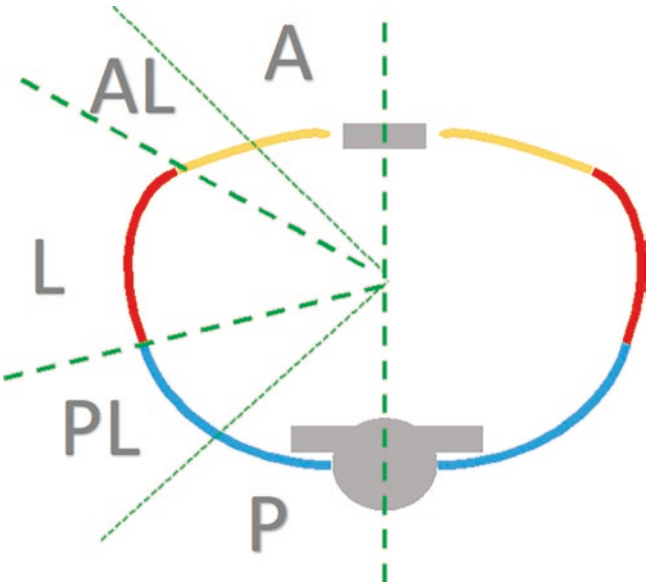

Fig. 67.3 Localization of rib fractures by the method of Ritchie et al. *A* anterior, *AL* antero-lateral, *L* lateral, *P* postero-lateral, *P* posterior

67.3 Chest Wall Injuries

Rib fractures are one of the most frequent chest wall injuries, occurring in 10–40% after blunt chest trauma and approximately 10% of all trauma cases [31].

In younger patients, rib fractures are caused by high-energy trauma, such as car accidents, whereas they result from low-energy trauma i.e. tripping in the elderly [32].

Rib fractures are associated with a significantly higher morbidity and mortality, with regards to older age, a total number of ribs fractured and the presence of a flail chest. A flail chest is defined as a fracture of three or more consecutive ribs in two or more places [33, 34].

The treatment of rib fractures is focused on pain reduction, quick mobilization and prevention of pneumonia. Long-term complications such as restrictive pulmonary disease, pseudoarthrosis and chronic chest pain syndrome are to be avoided by surgical therapy [31–33].

67.3.1 Classification

At this time, there is no accepted classification for rib fractures. The Müller AO (Arbeitsgemeinschaft für Osteosynthesefragen) classification system is a method of categorizing injuries according to their localization and severity, but rib fractures are not included in the Müller AO classification system. Bemelman et al. have developed a new classification system based on the Müller AO-classification [35]. An interesting method to illustrate the localization of rib fractures has been described by Ritchie et al. Using this method, the location of the fracture can be estimated based only on the impact at trauma (Figs. 67.3, 67.4, 67.5, and 67.6) [32]

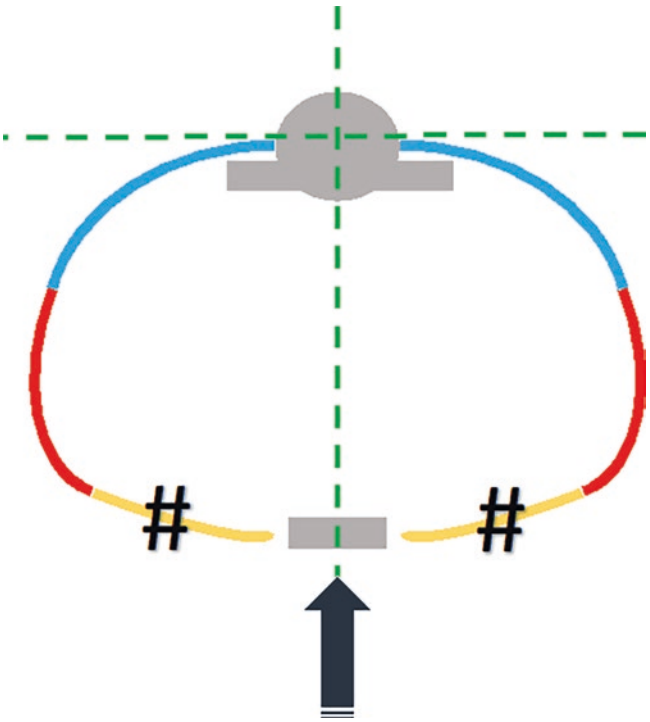

Fig. 67.4 If the power comes only from the sternum (i.e. CPR) most of the fractures are in A-AL (yellow)

67.3.2 Diagnostics

In the ATLS primary survey and in the emergency room, it is important to exclude life-threatening injuries such as pneumothorax, hemothorax and lacerations of the lung. For this, ultrasound is a good clinical tool (eFAST) but it is of no help in detecting rib fractures. The conventional chest X-ray may show some rib fractures. The CT scan is the "gold standard"

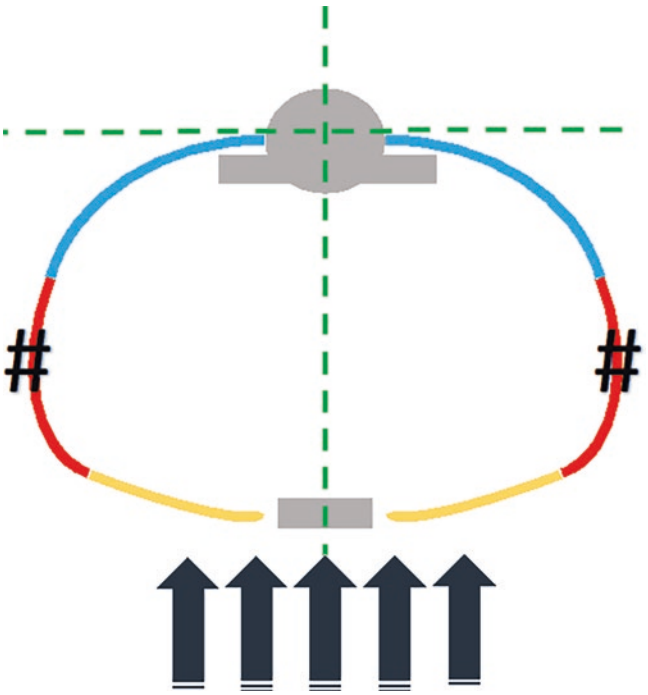

Fig. 67.5 If the power comes from the whole ventral body (i.e. car accident with the punch of the steering wheel) the rib fractures are often located in L [7]

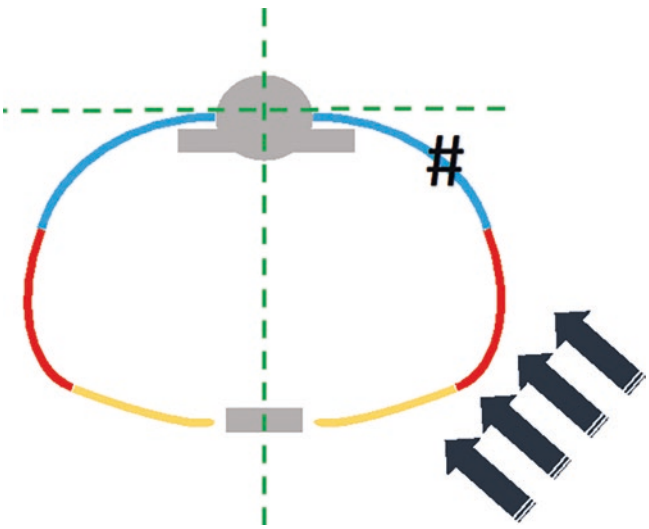

Fig. 67.6 If the power comes from the side (i.e. tripping, falls) the fractures are often located in PL to P (blue)

to detect every injury to the chest [30]. A 3D reconstruction of the CT scan can be helpful to plan the operation and visualize the fracture lines [31, 36].

Table 67.1 Indications and contraindications based on Pieracci et al. [31]

Indication	Contraindication
All patients with flail chest	Repair of ribs 1, 2, 11, and 12 do not confer additional benefit
Patients with multiple, severe (bicortical) displaced fractures	Fractures within 2.5 cm of the transverse process
Patients who fail early, optimal non-operative management	Bone loss and fracture gaps >10 mm should not be bridged using only a plate
Patients with chronic pain and/or instability due to pseudoarthrosis	Life-limiting injuries or illnesses

67.3.3 Indication and Contraindication for Osteosynthesis of the Ribs

Rib fracture osteosynthesis should be considered in all patients with flail chest and in patients with multiple fractures or in severe (bicortical) displaced fractures. In multiple-fracture series [11], both fracture lines should be stabilized wherever possible [31].

Stabilization of a fracture of the ribs 1, 2, 11, and 12 has no additional benefit in terms of either chest wall stability or pain control. If the fracture is within 2.5 cm of the transverse process, the osteosynthesis will be very critical because the distance to the transverse process of the spine is too short to drill for a minimum of three screws to fix the plate. Proximity within 2.5 cm of the costal cartilage is also a problem and the fracture should be repaired by fixation of the cartilage to the sternum [32, 37] (Table 67.1).

Conservative management is an alternative whenever surgery is not possible. Analgetics such as PDA and intensive respiratory physiotherapy may also lead to good results, especially if the morbidity and preoperative mortality do not allow an operation [18]. In cases in which optimal conservative management has failed, osteosynthesis can be performed later to treat chronic pain and instability due to pseudoarthrosis [18].

67.3.4 Surgical Approaches

There are several ways to stabilize the rib fracture (osteosynthesis plates, internal fixation system / intramedullary splint and rib brackets). We prefer a hybrid technique including video-assisted thoracoscopic (VATS) [30] inspection of the thorax, localization of the rib fracture and impaction of the chest wall. With VATS one can precisely determine the incision placement and define

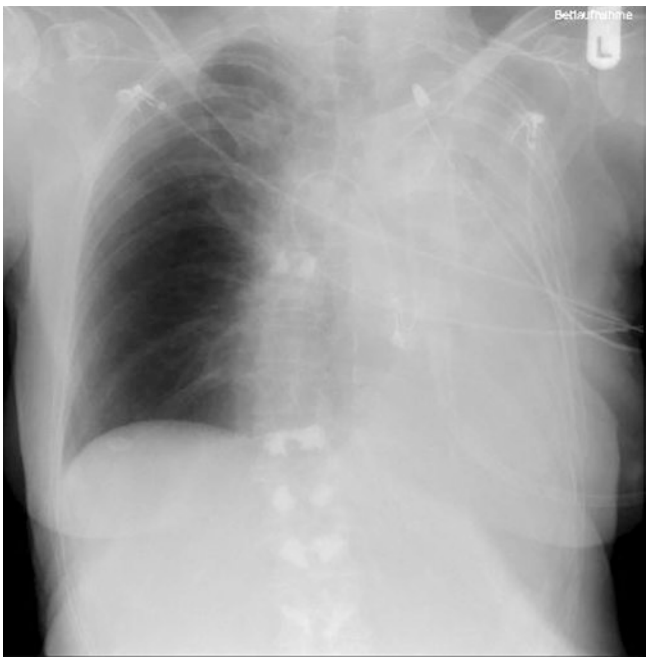

Fig. 67.7 Chest X-ray after chest tube insertion, with complete atelectasis of the left lung

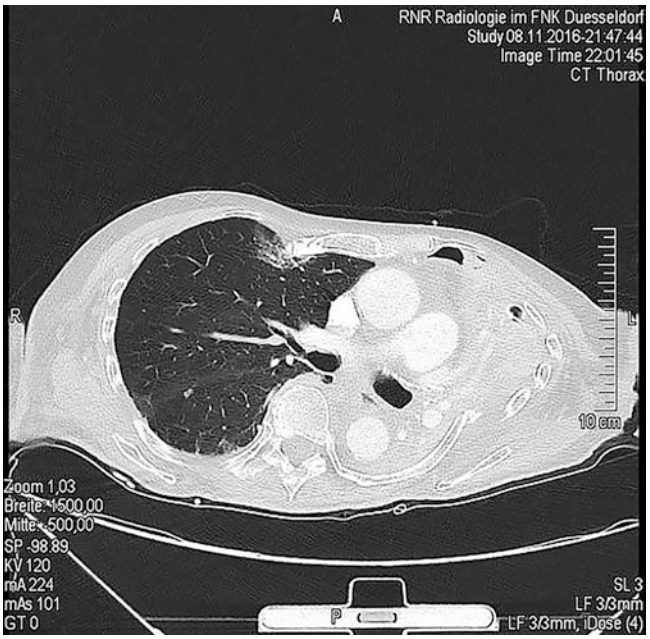

Fig. 67.8 CT trauma scan; flail chest and complete atelectasis of left the upper lobe

the perfect access for osteosynthesis. This method will help to minimize morbidity and damage to chest wall muscles from muscle division and obtain a good cosmetic result. Once the muscle has been carefully split, we use a small soft tissue retractor. With this soft retractor, it is possible to reach at least three ribs cranial and caudal to the fracture [38]. For stabilization, we prefer a plate system with self-drilling, stable angle, and bicortical screws. Once the fracture has been repositioned, additional video thoracoscopy [30] may help to evaluate the position of the screws, and the shape of the chest wall and exclude any further injury within the pleural space. Not every rib fracture must be stabilized to reshape the chest wall. As seen in Fig. 67.13, two plates were sufficient to bring the chest wall to an acceptable anatomical position. Chest tube placement is helpful to detect postoperative bleeding after osteosynthesis [36, 38].

Case 1

82-year-old woman with a flail chest and hemo-pneumothorax after falling from eight meters high. After emergency treatment of the hemothorax with a chest tube, she was stabilized in ICU. Despite intensive physiotherapy and pain control during her intensive care stay, she developed complete atelectasis of the left lung (Figs. 67.7 and 67.8 X-ray and CT Thorax before bronchoscopy). This led to the indication of rib osteosynthesis.

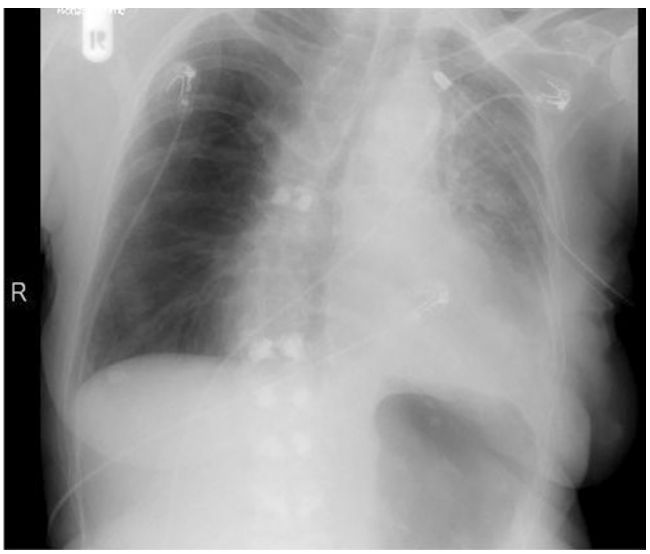

Fig. 67.9 Chest X-ray after bronchoscopy

Preoperative bronchoscopic inspection revealed MRSA pneumonia with signs of infection in her blood values. Under these circumstances, the operation was postponed.

Conservative therapy was intensified (Fig. 67.9: After routine bronchoscopy). Outpatient visit 4 weeks later (Fig. 67.10: X-ray after conservative treatment).

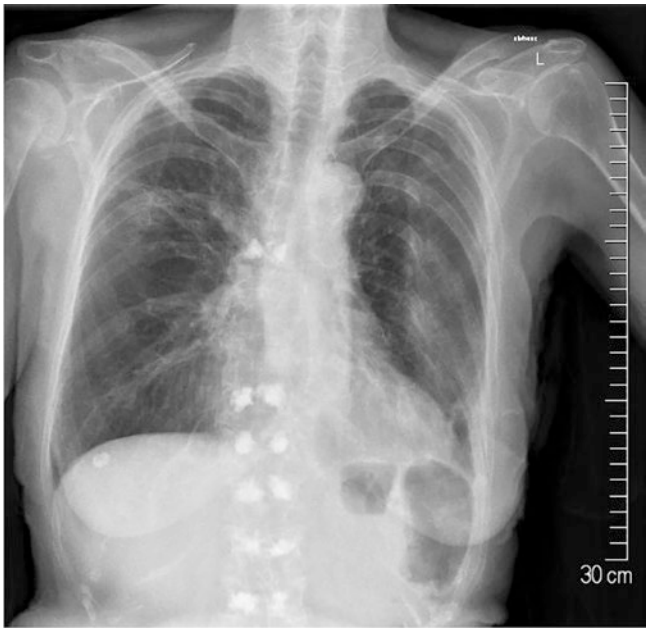

Fig. 67.10 Final chest X-ray after conservative treatment

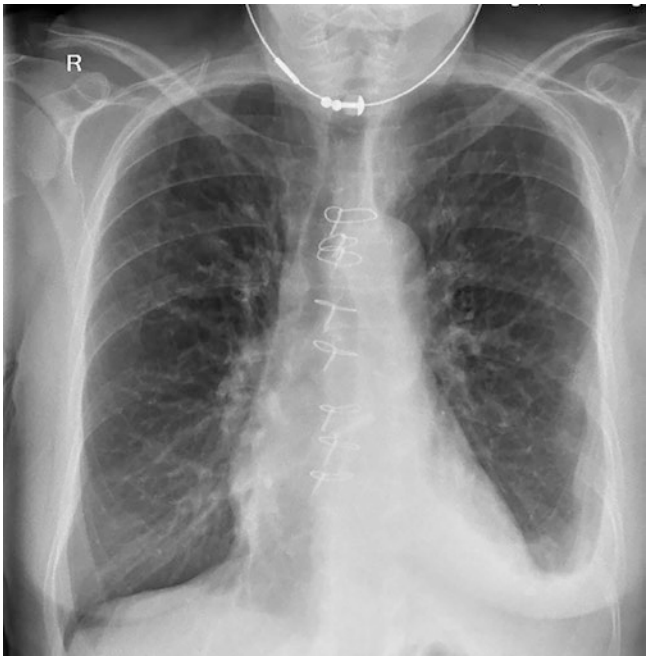

Fig. 67.12 X-Ray 4 days later with left side pleural effusion and secondary dislocation of the rib fractures on the left side

Case 2

A 61-year-old woman fell on her left side against the bathtub. Initial treatment was conservative with respiratory physiotherapy, oral analgetics, and epidural analgesia. Four days later, she suddenly had more pain and required oxygen. Figures 67.11 and 67.12 shows that the fractured ribs number 4–7 were now dislocated and there was a new pleural effusion. With surgical treatment of rib fracture by osteosynthesis as described above, the patient was able to leave the hospital without pain and required only mild oral analgesia (Fig. 67.13).

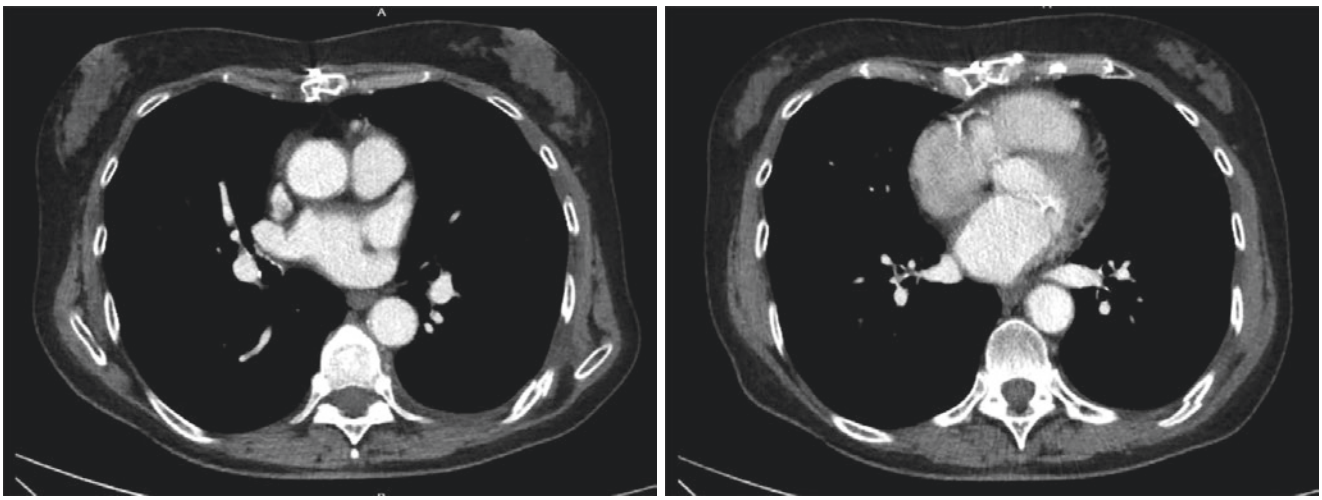

Fig. 67.11 Trauma CT-scan with rib fracture 5 and 7, initially without dislocation

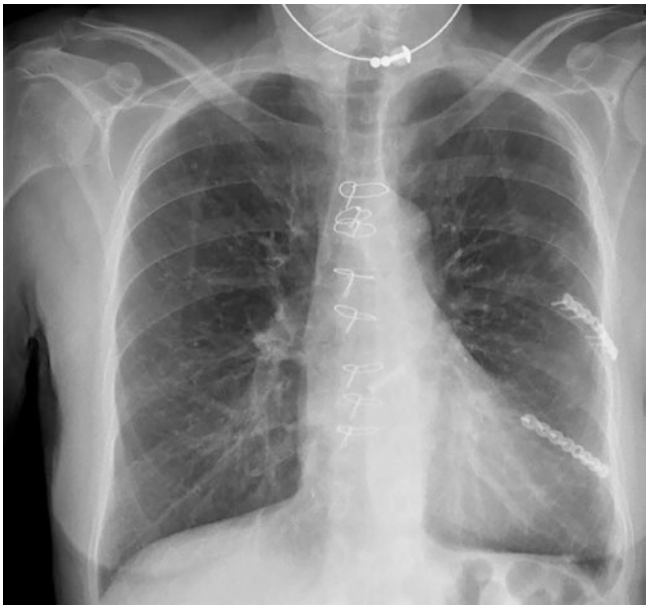

Fig. 67.13 X-ray after osteosynthesis of the ribs 5 and 7

References

1. Krug EG, Sharma GK, Lozano R. The global burden of injuries. Am J Public Health. 2000;90:523–6. https://doi.org/10.2105/ajph.90.4.523.
2. Schieren M, Wappler F, Wafaisade A, et al. Impact of blunt chest trauma on outcome after traumatic brain injury—a matched-pair analysis of the TraumaRegister DGU(R). Scand J Trauma Resusc Emerg Med. 2020;28:21. https://doi.org/10.1186/s13049-020-0708-1.
3. Cohn SM, Dubose JJ. Pulmonary contusion: an update on recent advances in clinical management. World J Surg. 2010;34:1959–70. https://doi.org/10.1007/s00268-010-0599-9.
4. Farzanegan R, Alijanipour P, Akbarshahi H, et al. Major airways trauma, management and long term results. Ann Thorac Cardiovasc Surg. 2011;17:544–51. https://doi.org/10.5761/atcs.oa.11.01679.
5. Pozgain Z, Kristek D, Lovric I, et al. Pulmonary contusions after blunt chest trauma: clinical significance and evaluation of patient management. Eur J Trauma Emerg Surg. 2018;44:773–7. https://doi.org/10.1007/s00068-017-0876-5.
6. Viano DC, Lau IV. A viscous tolerance criterion for soft tissue injury assessment. J Biomech. 1988;21:387–99. https://doi.org/10.1016/0021-9290(88)90145-5.
7. Elmali M, Baydin A, Nural MS, et al. Lung parenchymal injury and its frequency in blunt thoracic trauma: the diagnostic value of chest radiography and thoracic CT. Diagn Interv Radiol. 2007;13:179–82.
8. Ganie FA, Lone H, Lone GN, et al. Lung contusion: a clinicopathological entity with unpredictable clinical course. Bull Emerg Trauma. 2013;1:7–16.
9. Klein Y, Cohn SM, Proctor KG. Lung contusion: pathophysiology and management. Curr Opin Anaesthesiol. 2002;15:65–8. https://doi.org/10.1097/00001503-200202000-00010.
10. Soar J, Nolan JP, Bottiger BW, et al. European Resuscitation Council Guidelines for Resuscitation 2015: section 3. Adult advanced life support. Resuscitation. 2015;95:100–47. https://doi.org/10.1016/j.resuscitation.2015.07.016.
11. Marasco S, Lee G, Summerhayes R, et al. Quality of life after major trauma with multiple rib fractures. Injury. 2015;46:61–5. https://doi.org/10.1016/j.injury.2014.06.014.
12. Huber S, Biberthaler P, Delhey P, et al. Predictors of poor outcomes after significant chest trauma in multiply injured patients: a retrospective analysis from the German Trauma Registry (Trauma Register DGU(R)). Scand J Trauma Resusc Emerg Med. 2014;22:52. https://doi.org/10.1186/s13049-014-0052-4.
13. Hollister M, Stern EJ, Steinberg KP. Type 2 pulmonary laceration: a marker of blunt high-energy injury to the lung. AJR Am J Roentgenol. 1995;165:1126. https://doi.org/10.2214/ajr.165.5.7572488.
14. ATLS Subcommittee; American College of Surgeons' Committee on Trauma; International ATLS Working Group. Advanced trauma life support (ATLS(R)): the ninth edition. J Trauma Acute Care Surg. 2013;74:1363–6. https://doi.org/10.1097/TA.0b013e31828b82f5.
15. Nishiumi N, Inokuchi S, Oiwa K, et al. Diagnosis and treatment of deep pulmonary laceration with intrathoracic hemorrhage from blunt trauma. Ann Thorac Surg. 2010;89:232–8. https://doi.org/10.1016/j.athoracsur.2009.09.041.
16. Karmy-Jones R, Jurkovich GJ. Blunt chest trauma. Curr Probl Surg. 2004;41:211–380. https://doi.org/10.1016/j.cpsurg.2003.12.004.
17. Schneider T, Volz K, Dienemann H, et al. Incidence and treatment modalities of tracheobronchial injuries in Germany. Interact Cardiovasc Thorac Surg. 2009;8:571–6. https://doi.org/10.1510/icvts.2008.196790.
18. Cheaito A, Tillou A, Lewis C, et al. Traumatic bronchial injury. Int J Surg Case Rep. 2016;27:172–5. https://doi.org/10.1016/j.ijscr.2016.08.014.
19. Shemmeri E, Vallieres E. Blunt tracheobronchial trauma. Thorac Surg Clin. 2018;28:429–34. https://doi.org/10.1016/j.thorsurg.2018.04.008.
20. Evagelopoulos N, Tossios P, Wanke W, et al. Tracheobronchial rupture after emergency intubation. Thorac Cardiovasc Surg. 1999;47:395–7. https://doi.org/10.1055/s-2007-1013183.
21. Kiser AC, O'Brien SM, Detterbeck FC. Blunt tracheobronchial injuries: treatment and outcomes. Ann Thorac Surg. 2001;71:2059–65. https://doi.org/10.1016/s0003-4975(00)02453-x.
22. Mohammadzadeh AR, Kayalha H. Delayed diagnosis of bronchial transection following blunt chest trauma. Asian Cardiovasc Thorac Ann. 2017;25:540–3. https://doi.org/10.1177/0218492317728665.
23. Cardillo G, Carbone L, Carleo F, et al. Tracheal lacerations after endotracheal intubation: a proposed morphological classification to guide non-surgical treatment. Eur J Cardiothorac Surg. 2010;37:581–7. https://doi.org/10.1016/j.ejcts.2009.07.034.
24. van Roozendaal LM, van Gool MH, Sprooten RTM, et al. Surgical treatment of bronchial rupture in blunt chest trauma: a review of literature. J Thorac Dis. 2018;10:5576–83. https://doi.org/10.21037/jtd.2018.08.22.
25. Tazi-Mezalek R, Musani AI, Laroumagne S, et al. Airway stenting in the management of iatrogenic tracheal injuries: 10-year experience. Respirology. 2016;21:1452–8. https://doi.org/10.1111/resp.12853.
26. Welter S, Krbek T, Halder R, et al. A new technique for complete intraluminal repair of iatrogenic posterior tracheal lacerations. Interact Cardiovasc Thorac Surg. 2011;12:6–9. https://doi.org/10.1510/icvts.2010.248641.
27. Self ML, Mangram A, Berne JD, et al. Nonoperative management of severe tracheobronchial injuries with positive end-expiratory pressure and low tidal volume ventilation. J Trauma. 2005;59:1072–5. https://doi.org/10.1097/01.ta.0000188643.67949.82.
28. Chung J, Berguson M, Mendelson A, et al. Cross-field ventilation for treatment of harlequin syndrome in traumatic tracheobronchial injury repair using intraoperative venoarterial extracorporeal mem-

brane oxygenation. J Cardiothorac Vasc Anesth. 2019;33:3090–4. https://doi.org/10.1053/j.jvca.2019.03.033.
29. Moon SH, Kim KN, Jung JJ, et al. Heparin-free veno-venous ECMO applied to a patient with severe lung contusion and hypovolemic shock due to trauma. Ulus Travma Acil Cerrahi Derg. 2018;24:497–500. https://doi.org/10.5505/tjtes.2018.33802.
30. Ludwig C, Koryllos A. Management of chest trauma. J Thorac Dis. 2017;9:S172–7. https://doi.org/10.21037/jtd.2017.03.52.
31. Pieracci FM, Majercik S, Ali-Osman F, et al. Consensus statement: surgical stabilization of rib fractures rib fracture colloquium clinical practice guidelines. Injury. 2017;48:307–21. https://doi.org/10.1016/j.injury.2016.11.026.
32. Liebsch C, Seiffert T, Vlcek M, et al. Patterns of serial rib fractures after blunt chest trauma: an analysis of 380 cases. PLoS One. 2019;14:e0224105. https://doi.org/10.1371/journal.pone.0224105.
33. Cannon RM, Smith JW, Franklin GA, et al. Flail chest injury: are we making any progress? Am Surg. 2012;78:398–402.
34. Dehghan N, de Mestral C, McKee MD, et al. Flail chest injuries: a review of outcomes and treatment practices from the National Trauma Data Bank. J Trauma Acute Care Surg. 2014;76:462–8. https://doi.org/10.1097/TA.0000000000000086.
35. Bemelman M, Baal MV, Raaijmakers C, et al. An interobserver agreement study with a new classification for rib fractures. Chirurgia (Bucur). 2019;114:352–8. https://doi.org/10.21614/chirurgia.114.3.352.
36. Cooper A, Edwards M, Brandling J, et al. Taxonomy of the form and function of primary care services in or alongside emergency departments: concepts paper. Emerg Med J. 2019;36:625–30. https://doi.org/10.1136/emermed-2018-208305.
37. Hennon M, Yendamuri S. Video assisted thoracoscopic surgery vs. thoracotomy for lobectomy: why are we still talking about this? J Thorac Dis. 2019;11:S1284–5. https://doi.org/10.21037/jtd.2019.04.106.
38. Schulz-Drost S, Grupp S, Pachowsky M, et al. Stabilization of flail chest injuries: minimized approach techniques to treat the core of instability. Eur J Trauma Emerg Surg. 2017;43:169–78. https://doi.org/10.1007/s00068-016-0664-7.