Chapter 11

Thoracic Trauma

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Additional information is available at the end of the chapter

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1. Introduction

Thoracic trauma is a significant cause of morbidity and mortality in both adults and children. It is a leading cause of death in approximately 25% of multiple trauma patients and, when associated with other injuries, it causes death in additional 50% of multiple trauma patients, usually as a result of hypoxia and hypovolemia. When cardiac trauma is not involved, mortality from isolated penetrating chest injury is low (<1%), but if cardiac trauma is present, mortality rises to about 20%. The most important issue with thoracic trauma is to prevent lethal outcomes, because many of these wounds are fatal shortly after the injury or a few hours afterwards. Thoracic injury may occur in isolation (isolated thoracic trauma), or in the presence of polytrauma. According to etiology, thoracic injuries are divided into: blunt traumas and penetrating chest wounds. Specific injuries are: pulmonary barotraumas, burns of the tracheobronchial tree resulted from aspiration, blast lung injury, parenchymal lung damage from aspiration, and iatrogenic injury. Fractures associated with the chest wall may be caused by a direct force, and the tissues and organs of the chest may be damaged including contusions, lacerations or rupture. In addition, traumatic forces can act indirectly; in such cases the effect of a traumatic force is manifested after the disintegration of the tissue (air embolism resulting from the entrance of air into the pulmonary veins after lung laceration).[1]

The most common mechanisms of blunt trauma are road traffic accidents (70%), while drivers and front seat passengers in motor vehicles are most exposed to risk, and motorcycle drivers are much less frequently injured (10%), but with the highest percentage of death at the site of accidents (30%).[2,3] There are five types of motor vehicle-related injuries: head-on collision, side impact crashes, rear impact crashes, rotational impact and rollover, and injuries resulted from deceleration (deceleration injury) and crushing (crush injuries). At deceleration, a rapidly moving body is brought to a sudden halt, and injuries occur at the time of the abrupt impact of the body, damaging the chest wall, while internal organ injuries result from reflex glottic closure and therefore rapidly increasing intra-thoracic pressure. The transverse thoracic diameter increased rapidly, and when the traumatic force overcomes the elastic limit of the lungs the tracheobronchial tree injuries occur along with the injuries of the lung parenchyma, diaphragm, and mediastinal structures. The mechanism of deceleration injury is identical to the falls. [3]

Penetrating thoracic wounds occur as a consequence of side arms or firearms and are classified into three groups:

1. " Sleeper " wounds (no exit wound)
2. Perforating wounds (entrance wound and exit wound)
3. Wounds in which the projectile penetrates through the whole intra-thoracic cavity and remains in the subcutaneous tissue.

A common feature of all penetrating wounds is in direct communication between the external environment and the pleural space. If a defect in the chest wall is large, an open pneumothorax occurs. In small defects, wounds close spontaneously due to the contraction of muscle or blood clotting. However, it should be always borne in mind that establishing communication between the external environment and the pleural space leads to suction of air and devitalised tissue in the pleural space, favouring the infection development and further complicating the clinical management of the injuries.[4-6]

2. Pathophyslogy of thoracic trauma

Traumatic force with thoracic trauma impairs lung function by causing:

1. Disorder in the mechanics of breathing
2. Disruption in ventilation-perfusion relationship
3. Gas exchange abnormalities of alveolocapillary membrane

3. Disorder in the mechanics of breathing

Disorders in the mechanics of breathing with thoracic trauma are caused by blunt trauma related to rib fractures and flail chest and are accompanied with hypoventilation, atelectasis, difficult expectoration of sputum from the tracheobronchial tree, the development of bronchopneumonic complications, acute respiratory failure and even death, especially with elderly patients with penetrating injuries with direct communication between the external environment and the pleural space, leading to the occurrence of pneumothorax, haemothorax, traumatic diaphragmatic rupture and ruptured large airway. The presence of air or blood in the pleural space leads to the collapse of the lungs, the development of arteriovenous shunt and hypoxia. Disorder of breathing mechanics may threaten the life of the injured because it leads to respiratory disturbance, hypoxia and cyanosis, as in the case of tension pneumothorax.[1-6]

4. Disruption in ventilation - perfusion relationship

Normal blood oxygenation and elimination of CO_2 depends on the ventilation-perfusion relationship in the lungs. In thoracic trauma the disorder in ventilation-perfusion relationship appears with the lung collapse or mechanical obstruction of the large airway. Lobar collapse or the whole lung collapse is accompanied by perfusion through collapsed parenchyma, but since oxygenation is not maintained, it leads to systemic hypoxia. Impaired lung perfusion may appear following vascular thrombosis in damaged lung parenchyma and/or massive fat microembolism, disseminated intravascular coagulation (DIC) and acute respiratory distress syndrome (ARDS).[1-6]

5. Gas exchange abnormalities of alveolocapillary membrane

The alveolocapillary membrane is composed of the surfactant layer, the surface of macrophages, alveolar epithelium, the interstitial space and the capillary endothelium. In thoracic trauma direct damage to the alveolocapillary membrane may occur, as in the case of lung contusion, smoke inhalation, aspiration of gastric contents, heart failure and pulmonary interstitial oedema due to the excessive use of infusion solutions and blood transfusion. The most important factors that later damage the alveolar membrane are: ARDS, the development of hyaline membrane and alveolar oedema, terminal airway collapse and occlusion of blood capillaries, acid-base disturbance due to hypoxemia and hypercapnia, pulmonary hypertension, increased interstitial fluid pressure which increases the capillary resistance and disseminated intravascular coagulation.[2-6]

6. General surgical assessment of thoracic trauma

6.1. Introduction

A comprehensive and thorough examination of the injured and the assessing the injury severity must be done shortly, sometimes during the immediate treatment of potentially lethal injuries. Upon the arrival to the surgery, initial examination and assessment are important. It is of decisive importance for the injured, regardless of difficulties that may arise from the very beginning. The main task of a surgeon is to assess the state of the injured in order to detect or prevent life-threatening conditions. Conditions in case of thoracic trauma require medical emergency care, often immediately upon the patient's admission to hospital. These are:[7]

- airway obstruction
- massive haemothorax
- tension pneumothorax
- open pneumothorax
- flail chest
- cardiac tamponade

These states should be distinguished from other possible severe lesions that need to be treated by surgery. The surgeon must perform a physical examination and must ensure quick resolution, when the situation is complex and laboratory tests and a chest X-ray are time-consuming. Physical examination and clinical judgment are needed to decide upon the necessity for tracheostomy, chest drainage, emergency pericardiocentesis or thoracotomy. In certain cases, the information gained from arterial blood gas analysis directs towards the diagnosis of acidosis, hypoxemia, or alkalosis. Physical examination is important regarding the patient health history. Such information may result in the proper assessing the injury-related condition, and also may be a guideline for additional therapeutic procedures which are not directly due to trauma. Data on hypertension, cardiac arrhythmias, cardiomegaly, diabetes, renal failure, peripheral arterial occlusive disease, phlebothrombosis, hepatomegaly and splenomegaly, pulmonary emphysema and chronic obstructive pulmonary disease, possible alcoholism or alcoholism findings, and taking drugs or sedatives may be very significant.

6.2. Attitudes in thoracic trauma surgery

The first priority in the evaluation and treatment of thoracic injury is restoring of the airway passages, safety of lung ventilation and cardiovascular stability. Blood gas analysis can provide useful information when the circulatory system is preserved. The decision regarding the widening of airway passages can be made only on the basis of clinical observation. Tachypnoea (respiratory rate >30 breaths per minute) or clinical signs of increased respiratory muscle fatigue are common symptoms of respiratory insufficiency which requires urgent consideration. Endotracheal intubation and mechanical ventilation are indicated in patients with clinical signs of respiratory fatigue and tachypnea of over 35 breaths per minute, in patients in a state of shock, and in patients with associated craniocerebral injuries. Circulatory status is evaluated and adjusted simultaneously with the widening of the airway passages. In patients with hypotension it is necessary to evaluate the state of intra-thoracic organs in order to identify the cause of shock [8-10] induced by:

- tension pneumothorax
- haemothorax
- cardiac tamponade
- cardiac dysfunction after myocardial contusion
- air embolism
- large intra-thoracic vessel injuries
- massive contusion of lung parenchyma
- rupture of the diaphragm

Data on the mechanism of injury may be valuable for surgeons while assessing the types and characteristics of thoracic injuries. For example, patients who were run over in road traffic accidents or those crushed in motor vehicle accidents are expected to have severe intra-thoracic injuries. Deceleration injuries indicate potential injuries to large blood vessels (aortic arch and thoracic aorta) or large airway (trachea and main bronchi). In patients admitted with symptoms of hypotension diagnostic procedure begins with the examination of the neck veins. Distended (swollen) neck veins may point to possible cardiac compression shock, caused by tension pneumothorax or cardiac tamponade, while hypovolaemic shock is mainly associated with the neck vein collapse. Examining the chest wall during spontaneous respiration may indicate paradoxical breathing due to flail chest. Palpation may reveal the unstable chest wall integrity due to fractures or subcutaneous emphysema crepitation, which may be associated with the development of pneumothorax. Pain and tenderness may occur over the rib, sternum and clavicle fractures. Isolated chest trauma resulting from blunt trauma is very rare. Blunt thoracic trauma in polytraumatized patients is mainly associated with extra-thoracic injuries. The most common injuries among the associated extra-thoracic injuries and chest injuries are:

- Cranial injuries
- Abdominal injuries
- Extremity fractures
- Pelvic fractures
- Vertebral fractures

Associated extra-thoracic injuries occur in approximately two thirds of multiple trauma patients (Shor et al, 1987; Besson and Saegesser 1983; Glinz 1991) [3,11,12]. Main cause of haemodynamic instability in half of the injured patients with systolic pressure less than 100 mm Hg on admission to hospital is in severe intra-abdominal injury. Localization of penetrating thoracic injuries is important; entrance and/or exit wounds should be observed, but such wounds should not be probed. If the entrance penetrating injury is below the fifth rib, it is necessary to investigate the possibility of diaphragmatic rupture and intra-abdominal organ injury. The integrity of the diaphragm may be checked by using different techniques: video-assisted thoracoscopy, thoracoscopy, laparoscopy, laparotomy, and thoracotomy. Exploration of the abdomen in haemodynamically unstable patients with multiple chest and abdominal injuries is recommended first. Then abdominal bleeding is controlled, providing the intra-thoracic organs are stable. Finding the cause of intra-abdominal bleeding, the chest organ injuries may be explored and treated. Chest radiography is necessary if there is no need for emergency thoracotomy or if developing tension pneumothorax is excluded. Besides the investigation of the usual effects of thoracic trauma, particular attention is paid to possible injury-related complications or injuries that may be easily overlooked in the initial evaluation. The most common injuries that may be overlooked on the initial chest radiography in multiple trauma patients are:

- soft tissue injury
- bone injury
- ruptured diaphragm
- mediastinal expansion
- foreign body
- pneumomediastinum

Up to 35% of the patients with thoracic trauma along with a ruptured diaphragm appear to have normal or nearly normal results on initial radiographic findings. In patients with penetrating injuries it is useful to mark the entrance wound with an X-ray sensitive marker. It is useful to mark the initial localization of the foreign body inside the chest because it may move later, or cause embolism. Low-speed projectile wounds cause minimal injury to the chest wall, except when associated with intercostal vascular injury or internal mammary artery. Penetrating chest wall injuries are treated conservatively for possible massive bleeding. In the case of bleeding vessels, the therapy should include thoracotomy and ligation of the injured vessels. High-speed projectiles and firearms at close range have high penetrating power causing the considerable destruction in the projectile trajectory and surrounding tissue. Surgical treatment and debridement of the devitalised tissue is indicated in most cases. Chest wall trauma often indicates possible associated intra-abdominal injuries. According to some authors, diaphragmatic rupture and abdominal organ injuries are possible in such cases.[13] In such haemodynamically stable patients the integrity of the diaphragm may be assessed using laparoscopy. Similarly, in cases where diaphragmatic rupture is initially recognized, laparotomy is performed to inspect the abdomen and treat the diaphragmatic rupture. Laparotomy is also indicated in haemodynamically unstable patients with penetrating trauma to the chest wall and in patients with blunt trauma in the same area, since in such cases intra-abdominal injury may be expected. Chest wall injuries and intra-thoracic injuries are common in road accidents. In such cases common extra-thoracic injuries significantly complicate the patient's condition. It is not rare that other injuries are even more severe than the thoracic injury itself.[14] Complex polytrauma requires multiple specialist input, but output is often uncertain, especially in patients with severe intra-thoracic and craniocerebral injuries. After the initial treatment of life-threatening conditions, thoracic trauma is further managed with pain control and chest physiotherapy. Poor thoracic pain management and insufficient chest physiotherapy, i.e. poor respiratory hygiene, necessarily lead to various pulmonary complications.

Thoracotomy or thoracoscopy are indicated in the cases of: [15-18]

- open pneumothorax
- penetrating injuries due to foreign bodies or suspected foreign bodies
- bleeding complications of chest drain
- massive haemoptysis
- continuous air leak from the chest drain and permanent collapse of the lung
- tracheobronchial injury
- cardiac tamponade
- damage to large blood vessels and heart injuries
- diaphragm injuries and oesophagus injuries
- Thoracoabdominal injuries associated with intra-thoracic organ injuries
- complication of the injury - evacuation of coagulum or decortication (empyema)

7. Diagnostic procedures with thoracic trauma

7.1. Chest radiography and other techniques in the diagnosis of chest trauma

Chest radiography is the first-line diagnostic tool providing additional information in the diagnosis and evaluation of thoracic injuries.[19] The initial radiograph includes assessment of the injury and disorders directly or potentially threatening to a patient's life. Notwithstanding the objective limitations of the methods on the basis of clinical and radiographic findings, in many cases the surgeon may decide about the appropriate surgical treatment. In unconscious patients with multiple traumas chest radiography is useful immediately after the admission, after the establishment of airway passages (usually endotracheal intubation) and the insertion of nasogastric or orogastric tubes (used to determine the position of the mediastinum). In patients with penetrating injuries entrance and exit wounds should be marked with radiosensitive markers. Radiographs are normally taken in the AP or PA views. It is desirable to take a radiograph in inspiring, but if taken during expirium it may be useful in detecting small pneumothorax. Native radiographs may be used for evaluation of chest wall integrity, primarily to detect rib fractures and to examine the spine and mediastinum. Lateral decubitus radiographs are useful for the detection of air and liquid collection. Patient's position during exposure may be important in evaluation findings. A surgeon carefully and systematically interprets chest radiographs in order not to overlook some possible injuries. Then, the surgeon must check: [20]

1. **The correct placement of the endotracheal tube**: A surgeon must be sure that the tube is not positioned too high in the trachea, just below the vocal cords, as there is a risk of pulling it out while dealing with the patient; or the tube may be placed too deep – commonly in the right main bronchus to prevent the ventilation of the left lung.
2. **Pneumothorax**: The finding can easily be overlooked in the rush or when the radiograph is not carefully analyzed. Special attention must be paid to the lateral side of the chest and the possible costophrenic angles with increased lucency.
3. **Tension pneumothorax**: a typical radiograph shows increased lucency in the ipsylateral hemithorax, along with the diaphragm depression and shift of the trachea and mediastinum to the opposite side (easily noticeable if nasogastric tube is placed).
4. **Haemothorax**: Shaded area of hemithorax can be seen in X-ray findings. An X-ray reveals a shadow in the hemithorax due to persistent bleeding. However, in minor bleeding there is no characteristic radiographic finding and the interpretation is more difficult. In such cases, it is useful to compare the findings of both hemithoraces and spot X-ray shadowed areas, particularly in the costophrenic angles. When the radiograph is taken in the supine position, the blood may spread in the posterior part of hemithorax, which appears as the slight shadow of hemithorax on the X-ray through which the normal lung pattern is shown.
5. **Mediastinal emphysema**: There is no air in the mediastinum under usual conditions. When the X-ray shows the presence of air in the mediastinum and neck, especially when it is associated with pneumothorax (chest drain does not encourage lung re-expansion), tracheobronchial rupture should be considered.
6. **Lung contusion**: It cannot be seen on initial radiographs, but it is indicated by lung parenchyma diffuse shadows.
7. **The protrusion of intra-abdominal organs into the thorax**: Diaphragm injury is followed by herniation of intra-abdominal organs into the chest. On the left side the finding of hydroaeric collection may be mistaken for hydropneumothorax. Therefore, it is useful to place a nasogastric tube indicating the character of the injury. Radiographic diagnosis of diaphragmatic rupture on the right side is sometimes very difficult. The liver is most commonly herniated organ, and then the only possible finding is the elevation of the right hemi-diaphragm.

8. **Fractures**: Rib fractures are sometimes difficult to recognize in the native radiographs. Therefore, a detailed physical examination is necessary. However, multiple fractures such as flail chest are easily detectable. Attention should be paid to possible fractures or vertebral dislocation, fractures of clavicle and humeral condylar fractures.
9. **Projectiles in the thorax**: Any penetrating wound of the chest should be examined radiographically, especially in order to understand the direction of projectile penetration, the scope of organ damage and the position of the projectile in the chest. When a projectile enters from one side of the body to the other, or when it passes through the mediastinum, additional examination of the oesophagus, aorta and trachea should be performed for potential harm. Laparotomy is indicated when the projectile is located under the diaphragm and the entrance wound is above it.
10. **Mediastinal expansion**: Extended mediastinal shadow is a major finding indicating aortic rupture. When the initial radiograph shows extended mediastinal shadow, especially in the supine position, it is necessary and useful to take a posterolateral radiograph in the standing position. Mediastinal shadow wider than 8 cm most likely indicates the transection of the aorta and aortography should follow. Other radiographic findings indicating the aortic rupture are shadowing in the aortopulmonary window, depression of the left main bronchus, nasogastric tube deviation to the right, fractured ribs on the left side and left haemothorax.

In some cases, when the patient's condition is relatively stable, it is recommended to use thoracic computed tomography (chest CT) in additional diagnostic procedure. Using CT scan with contrast pleural space, lung parenchyma and mediastinum can be evaluated more precisely.

Another useful method is ultrasound scan of the abdomen and chest, especially for evaluation of the subdiaphragmatic space findings and when small collections of fluid in the pleural space are detected, and also for cardiac evaluation, especially when blood is present in the pericardial space. Ultrasound scan is simple, fast, non-invasive and reliable technique applicable to different body parts, such as the abdomen and thorax (evaluation of the subdiaphragmatic space including the liver, spleen, pancreas, retroperitoneal space, kidney, diaphragm; detection of the subphrenic collection; detection of small collections of fluid in the pleural space that cannot be seen in standard chest radiographs). Echocardiography, transesophageal echocardiography (used to assess the functional state of the heart and collection of blood in the pericardial space), and Color Doppler (used for the evaluation and detection of injuries to the brachiocephalic vessels) are also in current use. Ultrasound of the abdomen and thorax is becoming a routine diagnostic method that is used along with chest radiography. Fast and careful radiographic evaluation is indicated in patients with thoracic trauma. Native thoracic radiography is still the primary diagnostic tool. However, in modern and well equipped facilities chest CT and MSCT and ultrasound scan of the abdomen and chest have an important role in the diagnosis of thoracic trauma. Quick and qualitative diagnostics and therapeutics are possible only in direct cooperation between surgeons and radiologists, not only in taking and interpretation of radiographic or ultrasonographic findings, but also in monitoring the effects of the therapy applied or dealing with possible complications. VATS (Video-Assisted Thoracoscopy) has become widely used surgical procedure in the evaluation of thoracic trauma. Indications of VATS in thoracic trauma patients are signs of mild or moderate prolonged bleeding in haemodynamically stable and conscious patients, haemothorax, early treatment of fibrothorax, treatment of empyema in the initial stage of fibrin barrier formation, diaphragm injury (the advantage of VATS over laparoscopy is in fact that in laparoscopic procedure air may enter the pleural cavity and cause tension pneumothorax), traumatic chylotorax, removal of foreign bodies from the pleural cavity or the peripheral lung, evaluation of pericardium conditions, the heart and large vessels.

8. Monitoring of thoracic trauma

The surgeon must always have sufficient useful information about the patient's condition in order to be able to act in a timely way, monitoring the use of diagnostic and therapeutic procedures. Most reports deal with ideal conditions and well-equipped institutions providing optimal medical treatment and care. Of course, it is not always possible and therefore it is necessary to list the parameters applicable in most institutions. Minimal necessary parameters that are regularly monitored in all patients with thoracic trauma, immediately upon their admission in surgical unit and later, are the following: [23-27]

- Arterial pressure
- Arterial pulse and heart rate (obtained by electrocardiogram - ECG)
- Central venous pressure (in patients with shock and mechanical ventilation)
- Volume of urine (measured by urinary catheter in patients with shock)
- Cardiac index
- Arterial PO2, PCO2 and pH
- Haematocrit value

Monitoring of arterial pressure, pulse, haematocrit, and the volume of urine can be used as general parameters in the assessment of fluid replacement. Analysis of arterial blood gases is a very useful test of pulmonary function and in calculating the degree of metabolic acidosis, if occurs. In cases with permanent loss of circulating fluid (mostly due to bleeding), which is constantly replaced, it is necessary to insert a central venous catheter for pressure monitoring in order to calculate fluid volume replacement. Initial haematocrit values may be unreliable, especially in patients with excessive blood loss who receive crystalloid solutions. It is known that the restoration of circulating volume and haemodilution after a large amount of crystalloid solution is a slow process. Therefore, haematocrit value cannot be considered a parameter indicating the volume of blood loss or replacement in cases when acellular solutions are used in restoration of circulating volume. Haematocrit value can be accepted as a useful tool for determining the type of fluid rather than the fluid volume replacement. Thus, it cannot be accepted as a tool for estimating blood loss or for calculating fluid replacement and correction of fluids. Specific issues are control and blood pressure in patients who had greater blood loss and adequate compensation within a relatively short period of time (up to 2 hours). It is believed that the value of blood pressure in such patients after replacement should be lower if compared to the value before the injury. In other words, restoring blood pressure to normal values before the injury may result in hypervolaemia. It is satisfying to stabilize the systolic pressure at 90 mmHg or slightly above in order to correct hypovolemia and to prevent hypervolemia. Care must be taken in patients who had hypertension before the injury, because the pressure for lower values of 80 to 100 mmHg still may be a sign of hypovolemia and incomplete and inadequate volume replacement, regardless of the normal pressure that may be satisfying for the surgeon (90 mmHg or slightly above). Monitoring of patients cannot be exclusively based on physiological parameters, although it is desirable to conduct such monitoring for each of the injured patients. The benefits of such patient monitoring are particularly in careful interpretation of the obtained values in correlation with therapeutic procedures and the patient's recovery.

9. Shock in thoracic trauma

In a large number of casualties, shock is a consequence of hypovolemia, loss of circulating volume (haemorrhage) or loss of tissue fluids (burns). In the early stages of shock, venous flow to the heart (preload) is reduced due to the loss of circulating fluid, which decreases stretching of the cardiac muscle of the right and left ventricles resulting in decreased cardiac output and the development of hypotension and tissue hypoperfusion. The body strives to maintain a normal circulating volume by moving fluid from tissues into blood vessels, by increasing heart rate due to activation of the sympathetic nervous system and reduction the inhibitory effects of the parasympathetic nervous system, by vasoconstriction in the splanchnic bed and limb peripheries, and by fluid retention in the body due to the reduction of diuresis. In later stages of shock, at the cellular level hypoxia is compensated by anaerobic metabolism and lactic acid production, leading to the development of metabolic acidosis. If the shock is left untreated, tissues swell, oedema occurs and the cells lose functions. In order to prevent further cell damage, circulating fluid should be immediately compensated and adequate tissue oxygenation should be provided. It is believed that the average blood loss per fractured rib is approximately 150ml, and in haemothorax it can be 2-2.5L and above. In suspected case of shock, the condition of the injured should be quickly evaluated including: mental status (conscious people breathe spontaneously, they are able to communicate normally and adequate oxygenation and perfusion of the cortex are provided). Hypovolemia accompanied by subsequent hypoxia leads to changes in the level of consciousness, (from anxiety, through confusion and aggressiveness, to the development of coma and death), the colour of the skin and visible mucous membranes (hypovolemic patients are pale, their skin is cold and occasionally bedewed with sweat, with possible signs of cyanosis), the heart rate (the presence of a radial pulse implies that the systolic blood pressure is less than 90 mmHg, while the absence of radial pulse and the presence of femoral pulse imply systolic pressure of 80-90 mmHg; the pulse of carotis communis implies systolic pressure of 70 mmHg), and capillary charge and blood pressure control. Symptoms of shock can be easily identified, but they are not perceived before blood loss exceeds 30% of circulating volume. The first signs of hypovolemic shock are the symptoms of peripheral vasoconstriction and tachycardia and decreased pulse pressure. The goal of initial resuscitation is to achieve blood pressure, which ensures adequate tissue perfusion, i.e. blood pressure of 90 mmHg. In a state of shock, the priorities are ensuring the patient's airway, provision of supplemental oxygen (10-15 L/min) in case of respiratory distress using mask-balloon ventilation, and measures to stop both external and internal bleeding. A large-bore cannula should be inserted in the antecubital fossa in order to compensate the lost volume. If it is not possible, the cannula should be placed into the femoral vein or the central vein. Crystalloid solutions, colloids and blood transfusions are used to restore the volume. Crystalloids are saline-based fluids that remain only temporarily in the circulation (30 minutes) before passing into the intracellular space. They are useful for the immediate replacement of the circulating volume. Initially, two liters of crystalloid (Hartmann's solution or Ringer's lactate) should be infused. The advantages of crystalloids over other solutions are in their low cost, simple production, and long shelf life. Besides, they do not have allergenicity, do not cause coagulation problems and do not transmit transmissible diseases. Colloidal solutions are blood-derived, gelatin-derived or dextran-derived products. The advantages of these solutions are in their low cost, simple production, and long shelf life, as well as in lost volume replacement on a one-to-one basis, in their remaining in the circulation for long periods and avoiding disease transmission, while the disadvantages are in their occasional causing allergic reactions and coagulation disorders. The shock causes pain, so the injured should be given painkillers, fractures should be stabilized and immobilized. Distention of the stomach may be complicated by regurgitation and aspiration of gastric contents in the airway, and may be prevented by nasogastric suction. Endotracheal intubation and mechanical ventilation with high concentrations of inspired oxygen protect the airway from aspiration and ensure adequate ventilation and oxygenation. In patients with shock the following parameters should be monitored: heart rate and blood pressure, capillary refill time, respiration rate (frequency and symmetry of the chest) and neurological status. In addition to these basic parameters, it is desirable to monitor the following: pulse oximetry, diuresis (adults over 50 m/h, children 1-2 ml/kg/h), central venous pressure and blood gas analysis.

10. Acute respiratory distress syndrome (ARDS)

Acute respiratory distress syndrome (ARDS) is a life-threatening respiratory failure manifested by non-cardiogenic pulmonary oedema, hypoxemia, decreased lung compliance, high intrapulmonary shunt and progressive pulmonary fibrosis in the late stage of development. The American-European Consensus Conference of 1994 proposed new definitions:

1. Acute lung injury (acute lung injury – ALI)
2. Acute respiratory distress syndrome (ARDS)

In the first group are injured with mild hypoxemia (relation between the partial pressure of oxygen in arterial blood and fractional inspired oxygen concentration at the level of 300) (Pa02/Fi02). In the second group are injured with severe hypoxemia (relation between the partial pressure of oxygen in arterial blood and fractional inspired oxygen concentration at the level of 200) (Pa02/Fi02). The other three characteristics – their acuteness, bilateral infiltrates on chest radiography and pulmonary artery occlusion pressure of 18 mmHg – are common to both illnesses.

Predisposing risk factors for ARDS are classified into two groups. In the first group are pulmonary contusion, aspiration of gastric contents, pneumonia, inhalation injury and drowning. In the second group are: severe traumatic shock and need for repeated infusion/transfusion, head trauma, abdominal sepsis, burns, fat embolism, excessive volume replacement and disseminated intravascular coagulation. From a pathophysiological point of view, ARDS occurs as the consequence of the systemic inflammatory response of the injured. Neutrophil activation, aggregation and degranulation lead to the release of oxygen free radicals and proteases; monocytes/macrophages activation leads to the formation of arachidonic acid metabolites (prostaglandin, leukotrienes, prostacyclin); T-cells release cytokines (interleukins) inducing the damage of the capillary endothelium. Platelet activation and aggregation and fibrinolysis lead to microthrombosis causing further damage to microcirculation. Severe injury to type I pneumocytes and capillary endothelial cells leads to increased permeability of the alveolar membrane, so that the alveoli become progressively filled with exudate which is rich in plasma proteins, erythrocytes, platelets and leukocytes, which eventually leads to the development of interstitial and alveolar pulmonary oedema. Alveolar obliteration and surfactant dysfunction lead to numerous microatelectasis and increasing intrapulmonary shunt. Pulmonary circulation responds to hypoxemia with vasoconstriction, reducing blood flow to the unventilated alveoli, which is a strong risk factor for pulmonary hypertension and the load on the right heart, causing severe hypoxemia. The first exudative phase is followed by the second proliferative phase when type 2 pneumocytes proliferate and transform into pneumocite type 1, resulting in the regeneration of the alveolar membrane. In the third fibrotic phase large amounts of collagen accumulate in the lungs and pulmonary fibrosis is developed.

Clinical manifestation of ARDS depends on its causes. Very soon after the injury, during the first 12-24 hours, tachypnea and tachycardia occur. The patients use auxiliary respiratory muscles, and on auscultation they have high-pitched expiratory crackles. Arterial blood gas analysis indicates progressive hypoxia, hypercapnia, and acidosis. Chest X-ray shows diffuse spotty infiltrations becoming confluent with progressive clinical deterioration of ARDS. Prognosis of ARDS is uncertain and depends on the severity of the injury. Prevention of ARDS includes correction of disturbed ventilation and haemodynamics. The treatment of ARDS requires mechanical ventilation in order to achieve adequate oxygenation. The primary function of mechanical ventilation is to keep the alveoli open as long as possible, which is achieved by intermittent positive pressure ventilation with or without positive end-expiratory pressure. In the treatment of ARDS, fluid should be reduced in order to prevent pulmonary oedema. The intravascular volume should be maintained at the lowest level. Vasopressors and inotropes are used when the system is unable to maintain the perfusion by replacing of intravascular volume. Use of aerosolized surfactant was first appreciated while the nitric oxide, when inhaled, is a powerful pulmonary vasodilator. Glucocorticoids and other anti-inflammatory agents do not have significant effects on ARDS. Glucocorticoids are more efficient in preventing fibrosing alveolitis.

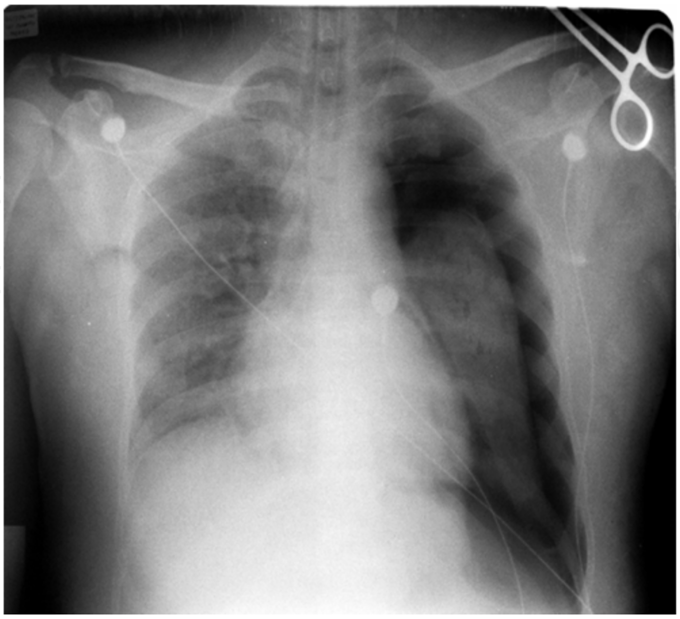

Figure 1. ARDS caused by left-sided pneumothorax

11. Blunt chest injuries

Blunt chest injuries are: contusions and haematoma in the chest wall, rib fractures, flail chest, broken sternum, blunt injury to the lung parenchyma, traumatic injuries to the trachea and major bronchi, traumatic pneumothorax, and traumatic haemothorax.

11.1. Contusions and haematomas of the chest wall

Chest wall contusion and haematoma are the most common thoracic injuries. As a result of blunt trauma to the chest wall massive bleeding may occur due to injured blood vessels in the skin, sub-cutaneous tissue, muscles, and intercostal blood vessels. Bleeding or extrapleural haematoma, manifested on X-ray as a semicircular model growing from the pleura, may appear in the chest wall, muscles of the chest wall, around the ribs and in the sub-pleural space. Most extrapleural haematomas do not require surgery because of the small amount of spilled blood. Only large haematomas or haematoma infection require surgical intervention

11.2. Rib fractures

Rib fractures are among the most common chest injuries, as a result of direct or indirect blunt force. Rib fractures occur in about 35% - 40% of thoracic injuries. Characteristics of rib injuries depend on the type of impact against the chest wall. Spontaneous rib fractures may be caused by a terrible cough (from rib VI to IX). Pathological rib fractures due to metastatic tumour or some other bone disease is very rare. In elderly patients, rib fractures may result from the chest injuries – after relatively low impact trauma. Even isolated rib fractures in elderly people can be a cause of death, with the range 10-20%. Rib fractures in children are rare, but when they occur they are clinical signs of thoracic injury, since the chest wall in children is very flexible, as opposed to adults. The mortality rate for rib fractures in children is about 5%. Lower chest wall injuries in children, but without rib fracture, is often associated with injuries to the diaphragm, spleen and liver. Discontinuity in the ribs without dislocation of sternal rib ends may be not revealed in the initial radiograph, but can be diagnosed as soon as callus begins forming. Rib cartilage fractures and fractures of the costochondral junctions cannot be seen on chest X-ray. They can be detected by careful physical examination, detection of crapitation and tenderness on palpation. Most common rib fractures are from rib IV - IX. In patients with serial rib fractures from IV-IX rib particular patience should be paid for possible intra-abdominal injuries. First, second and third ribs are relatively protected in blunt force trauma, supported by the strong back muscles and front pectoral muscles. The first and second ribs are further protected with the clavicle, scapula and shoulder harness. Only a severe traumatic force may break the first and second ribs. These fractures indicate possible associated injuries of large blood vessels in the aortic arch or injury to the tracheobronchial tree. In such cases, the mortality rate of up to 36% has been recorded. Anteroposterior compression of the chest causes the fractures of the lateral rib ends, which are then directed outwards. Injuries of the pleura or lungs rarely occur in such cases. Traumatic force may direct broken ribs to collapse inwards, leading to the subsequent lacerations of the intercostal vessels, pleura and lungs and may cause haemothorax, pneumothorax or haemopneumothorax. Specific symptom of rib fracture is pain. It increases with coughing, deep breathing or movement. The patient prevents the injured area from moving which consequently leads to hypoventilation. Decreased chest-wall movement and bad respiratory hygiene can cause atelectasis and pneumonia or the development of an infection. Oral/parenteral analgesics, intercostal nerve block, and intrapleural catheter analgesia or transcutaneous electrical nerve stimulation are used as methods of pain relief in chest trauma. Immobilization of the chest wall in order to achieve analgesia, especially thoracic cingulum, is not justified. However, in clinical practice, there is a relatively good

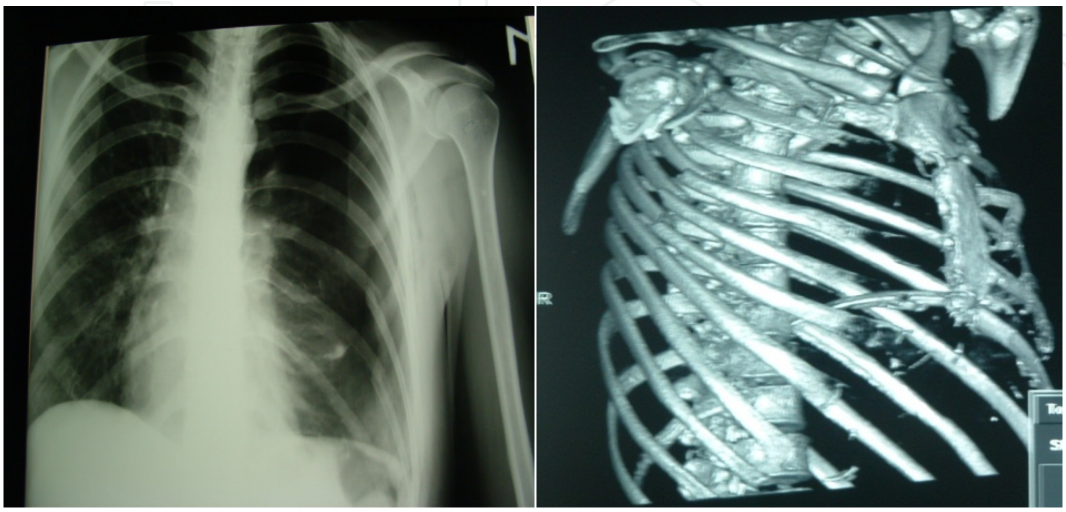

Figure 2. Serial fracture of ribs. Chest radiograph findings and MSCT

experience with unilateral fixation using adhesive materials (wide-strip leucoplast), in patients with individual rib fractures followed by severe pain. Fixation is performed during respiration in end-expirium by placing leucoplast between the edge of the sternum and the spine on the side of the fracture. Physical therapy is indicated in patients with serial rib fracture, and in more complex cases frequent bronchoaspiration is recommended for better hygiene of the tracheobronchial tree and prevention of atelectasis.

11.3. Flail chest

Flail chest is a medical condition when several adjacent ribs are double-broken unilaterally or bilateral fractures occur in the costochondral area associated with/without sternum fracture. The frequency of flail chest is about 5%, and road crashes account for most flail chest injuries. Pathophysiologically, the segment of the chest wall moves paradoxically, during the inspiratory phase it is drawn inward, while the expiratory phase it is drawn outward, preventing the air flow to the injured side. Firstly, deoxygenated air is retained within the injured side, but later it moves to the unharmed side, which leads to the disorders of ventilation and low vital capacity. According to the location, flail chest may be: anterior, lateral, bilateral and posterior. Anterolateral and posterolateral types also occur. Flail chest is diagnosed on the basis of physical examination of the injured, chest radiography and computed tomography of the chest. The treatment of flail chest can be divided into conservative and operative. In spontaneously breathing patients with posterior type or other types of flail chest where there are no difficult ventilation problems, analgesics and early physical therapy will help. In patients with severe disorders of ventilation, the application of mechanical ventilation with positive end-expiratory pressure (PEEP) will result in chest wall stabilization. Surgical treatment of the flail chest includes internal stabilization of the chest wall and can be early and late. Early internal stabilization is applied during the first 24 hours after injury, while late stabilization is performed 48-72 hours following injury.

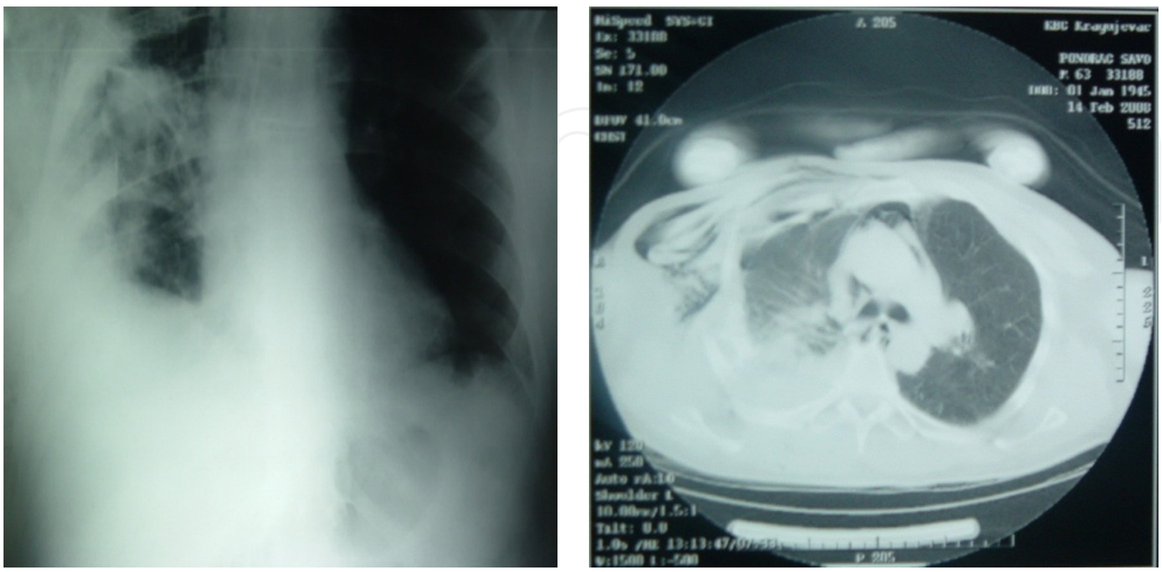

Figure 3. Right flail chest with right-sided pulmonary contusion. Chest radiograph findings and chest CT

Figure 4. Anterior right-sided flail chest. Mechanically ventilated patient (internal stabilization). Right sided flail chest drainage and internal and external stabilization

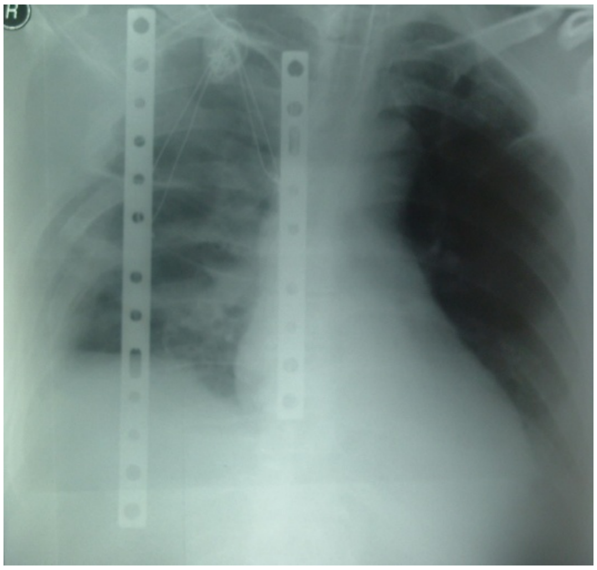

Figure 5. Patient's condition after the treatment of flail chest

11.4. Fractures of the sternum

Sternal fractures result from severe blunt trauma. They are often associated with multiple rib fractures. Sternal fracture is typically transverse and localized to the upper and middle parts of body of sternum. Mediastinal organs distortions may be expected with sternal fracture, primarily myocardial contusion (with typical precordial pain and dyspnoea). The fracture may be diagnosed on physical examination, detection of swelling, deformity and local tenderness. It can be confirmed with cephalometric chest radiographs, because the dislocations can be difficult to see in the anteroposterior projection. Sternal fracture is treated with rest, analgesics and airway hygiene. If the broken fragments were pushed over to the mediastinum because of the costochondral disruption, reduction surgery and internal fixation would be indicated.

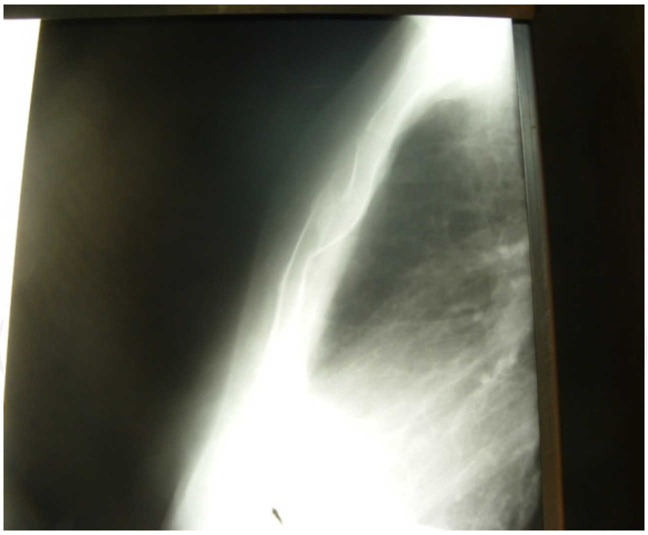

Figure 6. SterNal fracture

11.5. Lung parenchymal injuries

11.5.1. Lung contusion

Lung contusion is the most common manifestation of blunt chest trauma and represents parenchymal laceration accompanied by intra-alveolar haemorrhage. A pulmonary contusion is caused directly by blunt trauma to the chest wall, seriously damaging the parenchyma along with interstitial oedema and haemorrhage, and leading to hypoventilation in poorly ventilated parts of the lungs. Contusion may cause damage to a segment, several segments, or an entire lobe of the lung. Intrapulmonary haematoma occurs when larger blood vessels in the lung are injured. The diagnosis of pulmonary contusion is based on anamnesis, physical examination (gurgling sounds on auscultation), chest radiography and CT. Chest radiography may show irregular nodular infiltrates, homogeneous infiltrates and diffuse parenchymal infiltrates which disappear soon after the injury. Chest CT is much more detailed than standard radiography, and four types of lesions may be observed. Type I lesions are small parenchymal cavitary lesions or hydroaeric fluid collections. Type II lesions are hydroaeric and air cavitary lesions in parts of the lung in the paravertebral region. In type III besides hydroaeric and air cavity lesions in the peripheral lung fields there are always rib fractures. Type IV lesions result from the avulsion of pleuropulmonal adhesions, where the lung is drawn back due to a sharp blow to the chest wall. Complications of lung contusions may be immediate and secondary. Immediate complications include bronchopleural fistula, pneumothorax, haemothorax, subcutaneous emphysema, mediastinal emphysema, intrapulmonary haematoma, air embolism, haemoptysis, hypoxemia, arterio-venous shunt, and pulmonary hypertension. Secondary complications are atelectasis, pneumonia, empyema, sepsis, ARDS, lung abscess, and barotrauma. Pulmonary contusions require patient-specific treatment. Respiratory hygiene and pain relief are particularly important. A contusion involving more than 30% of lung parenchyma requires mechanical ventilation. Emergency surgery is needed in 5% of lung contusion cases, i.e. the injuries with a massive air leak, injuries with massive intra-thoracic haemorrhage (1500ml of blood on insertion of the thoracic drain and 200ml of blood every 3-4 hours, with continuous replacement), unilateral injuries with massive haemoptysis, and air embolism.

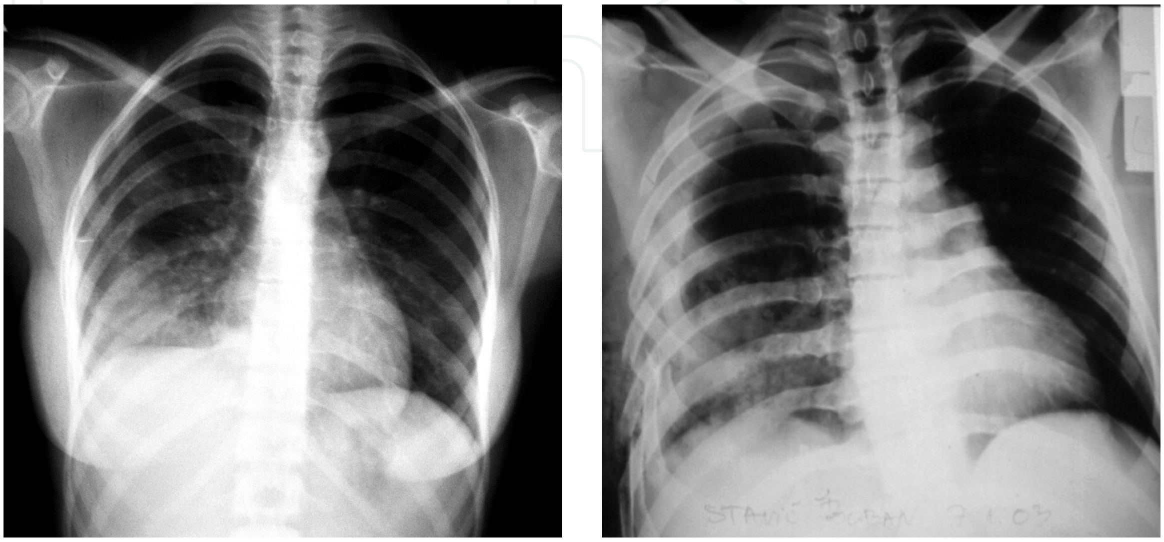

Figure 7. Lung contusion

11.5.2. Traumatic injuries of the trachea and bronchi

Traumatic injuries of the trachea and bronchi may occur as a result of blunt chest trauma, which is more often, or as a result of penetrating chest trauma in more rare cases. Blunt chest trauma may result in cleavage between the trachea and bronchi as a consequence of anteroposterior compression of the chest and the rapid increase in intraluminal pressure producing the airway rupture, or chest trauma may cause a sudden chest expansion with lung sliding laterally and, eventually, over-expansion and airway rupture. Traumatic ruptures of the bronchus are four times more likely than rupture of the trachea and usually occur within 1-2.5cm of the tracheal carina. The clinical manifestations of traumatic injuries to the trachea and bronchi are non-specific and variable. The clinical features may be divided into early and late symptoms and clinical signs. Early symptoms include haemoptysis, localized pain, neck contusion, subcutaneous emphysema, hoarseness, inspiratory stridor, progressive dyspnoea and auscultatory findings of "crackling" synchronized with the heartbeat and breathing (Hamman 's sign). Late signs and symptoms are dyspnoea and stridor (from scarring and stenosis) and distal infections of the lung parenchyma. Traumatic injuries of the trachea and bronchi are not often diagnosed immediately, but a few days, months or even years after the injury. Diagnosis is based on clinical findings, X-ray, CT and bronchoscopy. Acute injuries of the trachea and bronchi are amenable to surgical treatment, by means of suture, and chronic stenosis of the trachea and bronchi is treated with bronchoplastic reconstruction.

Figure 8. Rupture of the trachea - iatrogenic injury

11.5.3. Foreign bodies in the Tracheobronchial tree

Aspiration of the foreign body in the tracheobronchial tree is often seen at the injured with lost consciousness, at patients with the swallowing disorder, at intoxicated patients and small children. Clinical picture of the aspiration can be divided in three stages: first (acute) stage, second (asymptomatic) stage and third (late) stage. In the first stage, immediately after aspiration, symptoms of acute obstruction of the tracheobronchial tree occur in the form of a fit of coughing and cyanosis. After some time acute symptoms cease and there is an asymptomatic phase in duration of a few days, months or years. In the late stage the appearance of the high temperature, cough, wheezing – as well as the hemoptisis is present. Diagnosis is based on the standard radiography of the chest, in case of a radiosensitive foreign body, while the final diagnosis is made by the brochoscopy. Treatment includes

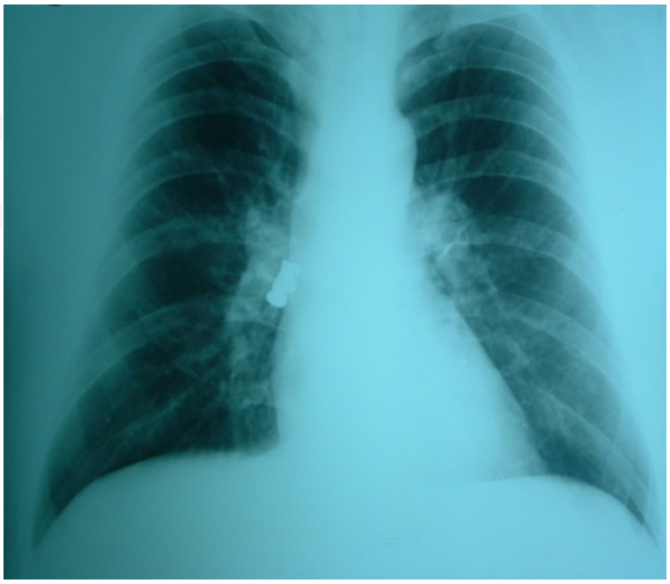

Figure 9. Foreign body in intermediate broncus

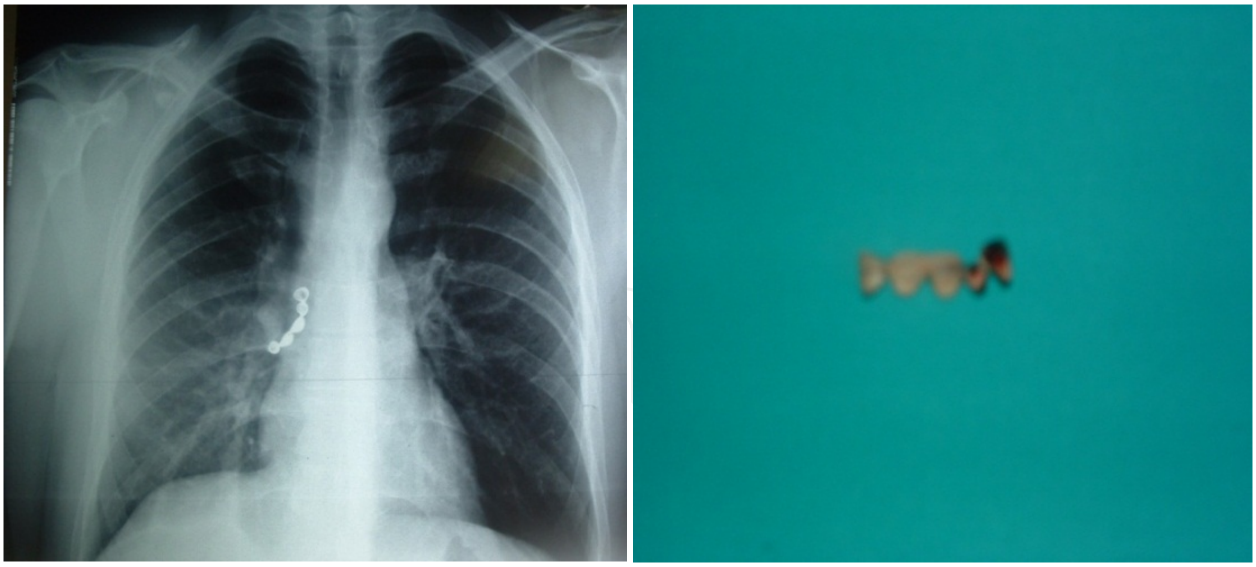

Figure 10. Foreign body in right main stem bronchus (dental prosthesis)

bronchoscopic extraction of the foreign body, specially in the case of fresh aspiration. At chronical foreign bodies, with developed granular tissue around the foreign body, the attempt of the bronchoscopic extraction can cause copious bleeding or perforation of the tracheobronchial tree, and in that cases mostly the operative treatment is applied, thoracotomy and brochotomy, or resection of lung parts distally from the area of obstruction.

11.5.4. Traumatic Injuries of Diaphragm

Traumatic injuries of diaphragm occur as a consequence of blunt and penetrating injuries of the chest, while the iatrogenec injuries of diaphragm are extremely rare. At blunt trauma around 1% to 4% of the injured occur, at penetrating injuries of the lower one third of the chest there are 15% of stab wounds and around 45% gunshot wounds. Mechanism of the diaphragm injury occurrence is explained by the deceleration. Injuries of the left diaphragm are more frequent due to the protective role of the liver toward the right diaphragm. In case of the left diaphragm injury, depending on the localization and rupture size, the stomach, omentum, small and large intestine, spleen, kidney can prolapse into the chest, while at the rupture of the right diaphragm the liver prolapses into the chest. Clinically the traumatic injury of diaphragm is manifested by early and late symptoms, when clinical picture may vary from the complete absence of symptoms to the stage which directly endanger the life of the injured. At the prolapse of intraabdominal organs into the chest, the combined respiratory and digestive symptoms occur. As the result of the prolapse of intraabdominal organs into the chest, most frequently of stomach, the paradoxal breathing with development of compressive gastrothorax, lungs collapse, hypoventilation and hypoxia occur. Late symptoms, that can occur after a few years or decades from the injury, are strong pain within the chest, dyspnea and signs of obstruction in small and large intestine. Diagnosis is made based on the clinical picture and radiographic findings. In some cases, by the auscultation the intestinal peristalsis can be heard in the chest. Final diagnosis is made by radiography methods. At these injuries, hydroaeric collection can be noticed on the native radiography, which must dyagnostically differ from the hydropneumothorax. Diagnosis of the stomach prolapse is made by the placement of nasogastric tube with contrast. Also, in diagnosis can be applied CT scan of the chest, MRI, liver scintigraphy and ultrasonographic examination of the thoracoabdomial region. Treatment of the traumatic rupture of diaphragm is surgical, it is adviced to treat fresh ruptures by the approach through laparotomy, while at old ruptures the adviced approach is through thoracotomy, due to adhesions in the chest.

Figure 11. Traumatic rupture of the right diaphragm

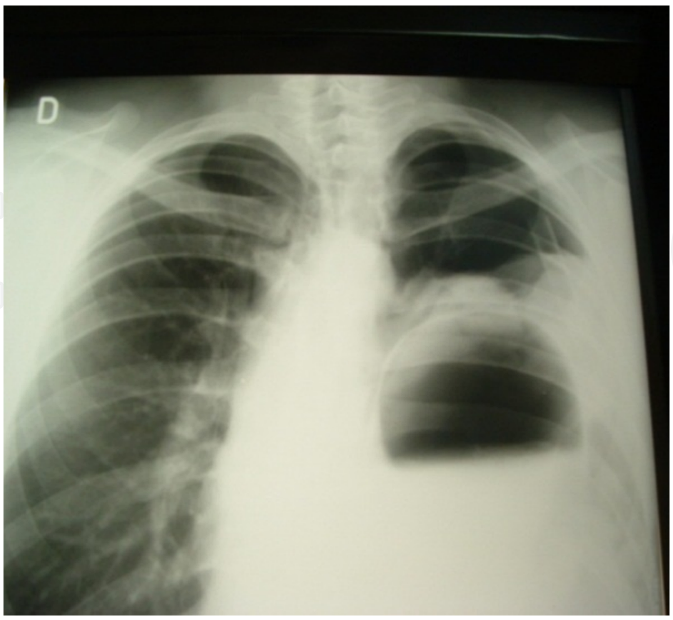

Figure 12. Traumatic rupture of the left diphragm, with the prolapse of stomach (visible after placement of left - sided thoracic drainage tube)

Figure 13. Posttraumatic right - sided diaphragmatic hernia (traffic accident)

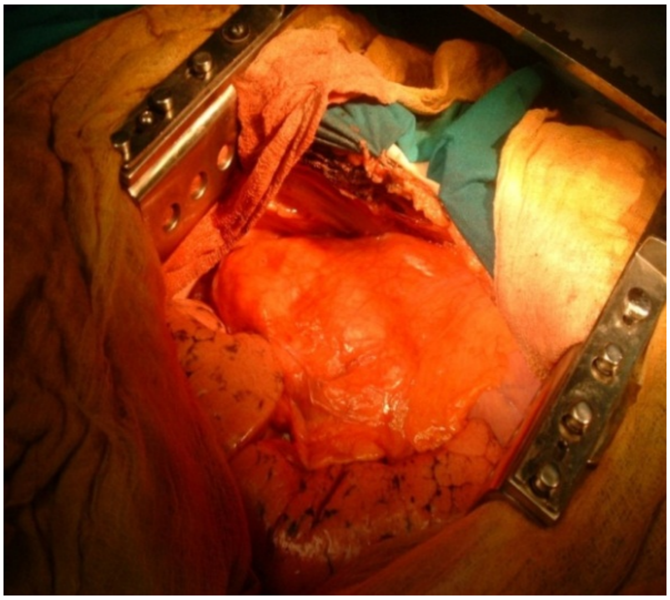

Figure 14. Post - traumatic right - sided diaphragmatic hernia (intraoperative findings)

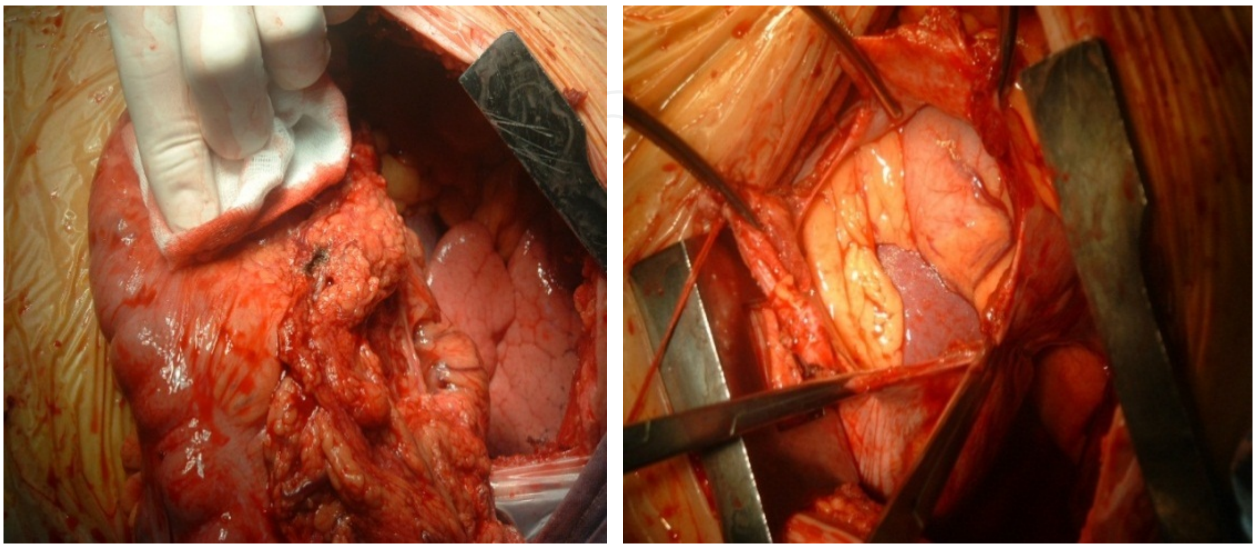

Figure 15. Traumatic rupture of the left diaphragm, with prolapse of intraabdominal organs

11.5.5. Traumatic pneumothorax

Pneumothorax marks the presence of air in the pleural space. Traumatic pneumothorax occurs as a consequence of blunt or penetrating injury of the chest, it can be developed at the time of injury, soon after injury or afterward. At the blunt injury of the chest, associated with the rib fracture, the laceration of the parietal and visceral pleura is most frequently caused by the fractured and/or dislocated rib ends. Laceration of visceral pleura and lung parenchyma has as the consequence the occurrence of pneumothorax, and the laceration of parietal pleura can contribute to the development of subcutaneous emphysema. However, at most injured with traumatic pneumothorax there is no the associated rib fracture. Mechanism of the pneumothorax occurrence in such cases can be explained on one of the following ways:

- During sudden chest compression, the increase of alveolar pressure occurs and it may cause the alveolus rupture. Air that comes out in the interstitial area by dissection toward the visceral pleura or mediastinum results in pneumothoracs or mediastal emphysema.
- Increase of pressure in the tracheobronchial tree, in the phase when the glottis is closed, has the impact on the increase of pressure especially in the level of the bifurcation of the trachea and/or bronchial tree, where lobar bronchi separate. Due to that the rupture of the trachea or bronchi may occur. Laceration of the lung tissue is rare, but possible.

Mechanism of the pneumothorax occurrence at the penetrating injury of the chest is easy to understand, for the wound in thoracic wall enables the communication with external surroundings and the air directly enters in the pleural space. In such cases the visceral pleura is often injured, enabling the entry of air from alveoli to the plural area. Blunt injuries of the chest in peacetime conditions often occur due to the traffic accidents. In traffic traumatology the five types of collisions are common: head - on, lateral, rare -end, rotating (turning around) and rollover. Each of mentioned types has its characteristics, but the mutual characteristic for all types is that they cause decelerational injuries. Mechanism that causes deceleration injuries is the same at falls from height (accidental or suicidal). During haulting of the object which moves with huge speed, the blow in the chest suddenly increases intrathoracic pressure, compresses lungs and with instinctive closed glottis, the disintergration of the lung parenchyma and central respiratory paths. Beside the chest injury in these situations injuries of thoracic wall structures are apparent, as other mediastinal organs (aorta, heart, trachea).

Penetrating injuries occur by the effect of firearms or cold weapons. Injuries' seriousness depend on the damage of interthoracic structures.

Penetrating wounds of thoracic wall may be classified in three groups:

1. « Blind » injuries without exit wound
2. Perforating wounds with the entrance and exit wound
3. Wounds where projectile passed through the whole intrathoracic area and stopped near the skin or in the extrathoracic soft tissues

At injuries of the chest by firearms the important fact is if the injury were developed by projectile of high or small speed. Mutual pathophisiological mechanism for penetrating injuries is creating of communication between pleural space and external surroundings. Immediate consequence of such communication is the occurrence of pneumothorax. Large defect on the chest wall as a consequence has the occurrence of open pneumotorax. Treatment of the broadly open wounds on the chest wall proceeds in two phases:

1. Operative debridement with removal of devitalized tissue and foreign bodies
2. Closing of the opening of thoracic wall

Pneumothorax is surgically treated by the thoracic drainage. Narrow penetrating wounds of the chest wall are often spontaneously closed, due to the muscle contraction or the tamponade occurs by blood coagulation. Air in the pleural space enters during the penetration or immediately after that. Penetrating injuries can provoke massive contamination of the pleural space, since in the moment of creating the communication with external surroundings it comes to the air suction with it, parts of the cloths and devitalized tissue. Presence of foreign bodies in the pleural space is favourable for development of a bacterial infection that can seriously complicate further course of the treatment. Pressure in the pleural space is negative in comperison with the atmospheric pressure during entire respiratory cycle. Negative pressure is a consequence of mutual relation between the lung tendency to collapse and thoracic wall to be expanded. Alveolar pressure is always higher than the pleural pressure. When communication arises between the alveolar and pleural spaces, the air passes from alveoli into pleural space, until there is a gradient of the pressure or until the communication is not closed. Air letting through into the pleural space is limited by the lung collapse and effect of closing the lung lesion. Most important pathophysiological consequence of the pneumotorax are decrease of the vital capacity and partial oxygen pressure in blood. Decrease of the vital capacity is well tolerated by the injured who were healthy before pneumotorax development. However, in case when the lung function is damaged by the previous lung diseases, any decrease of the vital capacity can cause the respiratory insufficiency with alveolar hypoventilation and respiratory acidosis. Lung collapse of 10% and less does not create more substantial ventilation disorders. Such collapse is marked as the minor pneumotorax. Moderate pneumotorax has the collapse of 10 - 60%, and large pneumotorax has over 60%. From pathophysiological point of view, the most important is the classification of traumatic pneumothorax to the following categories:

1. Simple or partial
2. Open or absorbing
3. Tension

Any injury of the chest can result with one of the mentioned types of pneumothorax. However, open pneumothorax is often associated with penetrating injury, while tension and simple pneumothorax are mainly seen at the blunt injury of the chest.

Simple pnemothorax often develops due to the laceration of the lung parenchyma fractured rib ends, or due to the gunshot wounds and stab wounds. Increase of the interalveolar pressure due to the effect of trauma causes rupture of alveoli and entry of the air into pleural space. Open pneumothorax appears due to the direct communication between pleural space and external surroundings. Disorder of the physiology of breathing in such a case depends on the size of perforation on the chest wall. Course and severity of pathophysiological changes depends on the age of the injured, state of respiratory system before injury, fixed condition of mediastinum, adhesions. Tension pneumothorax occurs when the pressure in the pleural space becomes positive in all phases of the respiratory cycle. Since the affected lung collapses, accumulation of an air from the external surroundings causes development of the positive pleural pressure that further pushes mediastinum toward healthy side. Positive pleural pressure can be so high to push or cause the inversion of ipsilateral diaphragm. Mechanism for development of the tension pneumothorax is connected with the specified type of a one-way-valve (valve mechanism). Valve is open during inspirium, so that the air enters into pleural space, and it is closed during expirium.

Traumatic pneumothorax occurs due to the entry of air in the pleural space, thus disintegrating the following structures:

- External part of thoracic wall
- Lung parenchyma
- Tracheobronchial tree out of the part covered by the mediastinal pleura
- Oesophagus and mediastinal pleura
- Diaphragm and associated perforations of intestines

At traumatic pneumothorax, the most frequent symptom is pain due to the chest wall injury. Occurrence of isolated traumatic pneumothorax apart from the pain may be followed by a certain degree of dyspnea which does not endanger the injured. Clinical picture of the open pneumothorax is significantly distinct, dyspnea and pain are dominant (specially locally in the area of wound on the chest wall). Often the sound of air suction through the wound can be heard during the inspirium. Locally, in the area of wound, a certain degree of subcutaneous emphysema is distinct. By inspection, decrease of respiratory mobility of affected hemithorax is noticiable. Percutaneously there is hypersonority, weaken or inaudible murmur is heard by auscultation. Pulse is accelerated, the fall of arterial pressure is present in case of distinct haemorrhage. Tension pneumothorax directly endangers the life of the injured and it belongs to the group of medical emergencies. Pathophysiology of the tension pneumothorax is not explained in its entirety, but it is considered that the basic disorders are related to the decrease of heart beat volume and progressive hypoxia. For diagnosis the clinical examination of the injured is often sufficient and only possible. Radiographic confirmation of the diagnosis requires a certain time, that is intolerable risk in some cases for the injured. Typical clinical picture of the tension pneumothorax shows a sever respiratory disorder of the ventilation, distinct tachypnea, cyanosis of the head and neck, tachycardia, hypotension, distension veins on the neck and profuse perspiration. By inspection it is obvious that affected hemithorax is significantly expanded in comparison with the opposite side, with distinct presence of subcutaneous emphysema. Percutaneously there is a tympanism, while auscultatory findings on lungs show an absence of breathing murmur on affected side. At atypical clinical picture, the tension pneumothorax may imitate the state of acute tamponade of the heart or massive hemothorax. Radiography is a basic additional diagnostical method in diagnosis of the chest trauma. Position of the injured during the imaging has the impact on the quality of the chest radiography and possibility for correct interpretation. General state of numerous injured, specially the polytraumatized patients, has the impact on the position for imaging. It is desirable that the imaging is performed in the standing position, when it is not possible, it can be the sitting position or semi-lying position. Correct interpretation of the chest radiography includs the assessment of the bony structure state of the chest, position and shape of the diaphragm and phrenicocostal sinuses, position of the mediastinum and trachea and the state of the lung parenchyma from the apex to the lung base. Radiographic diagnosis of the pneumothorax is made easily, when the line of visceral pleura is approved on the PA chest X - ray. Definitely radiological recognition of the pneumothorax depends on the lung collapse degree. Small pneumothorax is better presented on the standard radiography in the standing position during maximal expirium. In fact, in such a way radiological density of the collapsed lung parenchyma increases, while the density of air in the pleural space is not changed. Radiography of the chest in position of a lateral decubitus enables that the free air in the pleural space is lifted. Increased distance between the lungs and thoracic wall is present, for the easily identification of the visceral pleura line. When the air enters into the pleural space, lungs collapses, thoracic cavity is expanded. Radiographic air is presented as a zone of homogenous light with absence of the lung ornaments at the periphery. Collapsed lung is separated from this zone by the line of the visceral pleura.

At the side of pneumotorax, the pleural pressure gets to be less and less negative, i.e. it increases. Pleural pressure within the cotralateral pleural space is unchanged so that the mediastinum can be removed toward that side. Ipsilateral diaphragm is lowered due to decrease of the transdiaphragmaic pressure. Interpretation of radiographic imaging made in lying positions is more difficult. By initial radiological examination of the injured in lying position, the pnumothorax can be overlooked, in case of development of the tension pneumothorax can be fatal for the injured. Pain is a dominant symptom at the chest injury, causing the unproper ventilation presence and the standstill of the secretion in the tracheobronchial tree. For this fact it is necessary, during treatment and first aid administration of the injured, to realize proper analgesia with holding of passage for respiratory paths. Progressive dyspnea and cyanosis point to the development of the tension pneumothorax. First aid at the tension peumothorax is comprised of decompression, by the needle placement of the large diameter through second inter-rib area in the midclavicular line. Needle should stay « in situ » in the pleural space up to the definitive treatment of the pneumothorax. By procedure of needle placement, the tension pneumothorax becomes the open pnumothorax, easier to bear. At the open pneumothorax hermetisation of the wound is performed on the chest wall, taking into account to prevent development of the tension pneumothorax. Methods of treatment of traumatic pneumothorax are an observation, exsufflation (needle aspiration) and thoracic drainage. Observation is rarely applied.

Figure 16. Traumatic right - sided hemopneumothorax

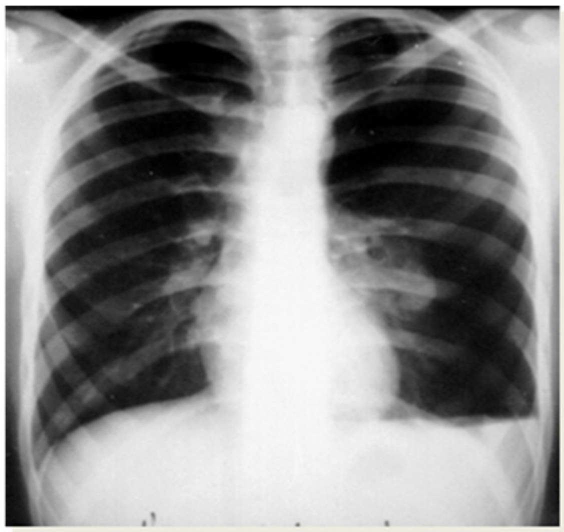

Figure 17. Traumatic left-sided hemopneumothorax

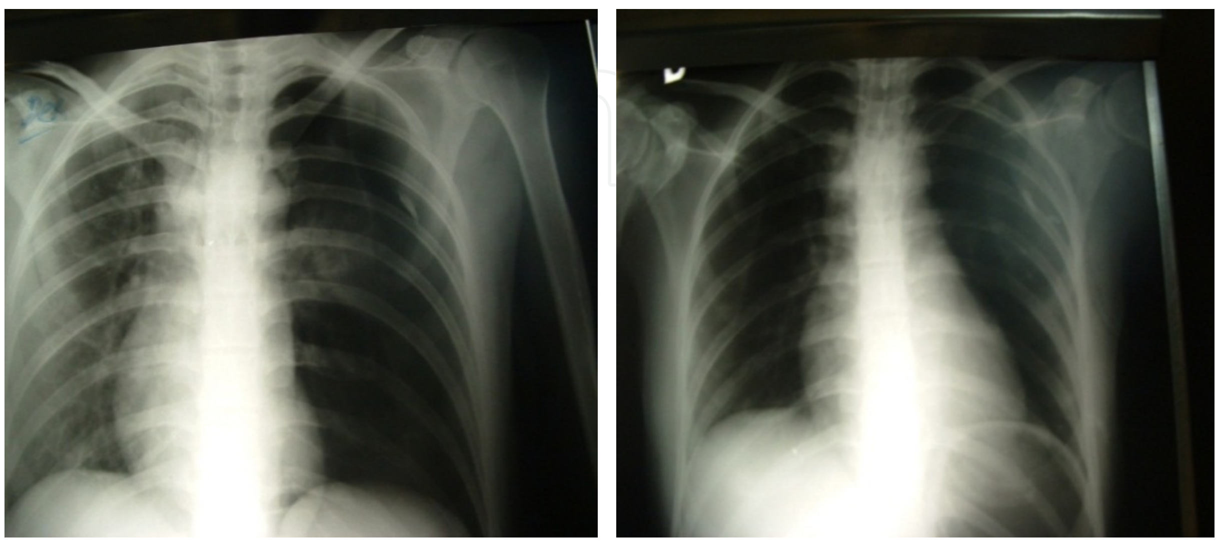

Figure 18. Tension left - sided pneumothorax and control radiography after left - sided thoracic drainage

Exsufflation is suitable for fine decompression of the pleural space at the tension pneumothorax, when it is not possible to perform thoracic drainage. However, a method is rarely applied as the definite procedure for solving of traumatic pneumothorax. Thoracic drainage is a method often used during definite treatment of the traumatic pneumothorax.

11.5.6. Subcutaneous emphysema

Subcutaneous emphysema defines the presence of the air within the subcutaneous tissue, and at traumatized patients it is most frequently, but not only, associated with the chest injury and occurrence of pneumothorax. Air in the subcutaneous tissue may be the consequence of:

- Wound that results in interruption of integrity of soft tissue of the chest wall
- Injuries of parietal and viscelar pleura enable that air from the chest or pleural space enters into subcutaneous tissue
- Mediastinal or retroperitoneal air which by dissection pass up to the chest wall, neck and face, or down toward loins and abdominal wall
- Infection at which occurs the gas formation.

Subcutanous emphysema may expend very quickly up to the neck and face or down to the scrotum. Clinical diagnosis of subcutaneous emphysema can be made palpably according to the characteristic sign of crepitation. At each injured patient with the subcutaneous emphysema, the radiography of the chest is necessary for the diagnosis of possible pneumothorax (often followed by such an occurrence). In terms of therapy the approach to the patient with subcutaneous emphysema is aimed to solving of basic leison, being the cause of the subcutaneous emphysema. In case when the emphysema occurs due to the injury of chest and parietal pleura and consequential pneumothorax, the thoracic drainage is identified. Wounds on the chest wall, through which the air can penetrate into subcutaneous tissue, must be treated according to surgical principles.

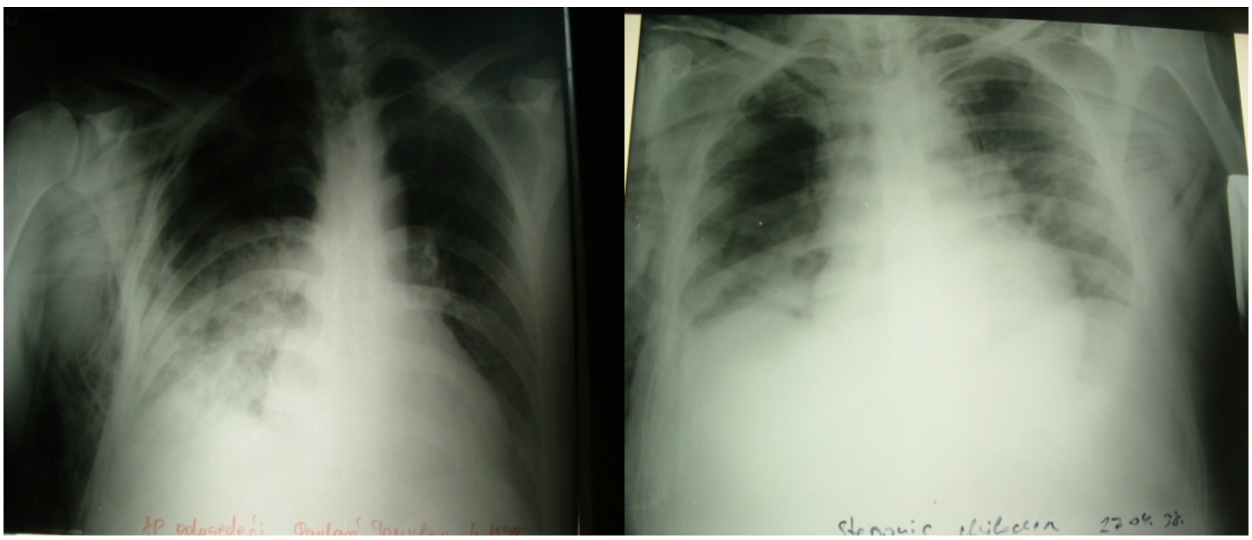

Figure 19. Subcutaneous emphysema – traffic accident

Pneumomediastinum marks the presence of the air in the mediastinum, and it can be caused by:

- Injuries of tracheobronchial tree or oesophagus
- Lung barotrauma with alveolar disruption
- Retroperitoneal air which by dissection enters mostly in mediastinum

11.5.7. Traumatic hemothorax

Hemothorax marks the presence of blood within the pleural space. Mostly hemothorax occurs as a consequence of the penetrating or blunt trauma of the chest. In rare cases, hemothorax can be a consequence of iatrogenic injury for example, during placement of catheter into the subclavian artery, or internal jugular vein or during translumbar aortography. Hemothorax is rarely a consequence of the pulmonary embolism or rupture of undiagnosed aneurysm of thoracic aorta. Blood can get to the pleural space after injury of the chest wall, diaphragm, lungs or mediastinum (in the first place of large blood vessels). After injury of thoracic spine, especially vertebrae at the level Th4 - Th6, the hemothorax can be developed, even a few days after the injury. Blood that gets into the pleural space quickly coagulates, but most frequent is an occurrence of the defibrinogenation of coagulation due to the heart and lungs movement, when the blood accumulation is slow and in smaller quantity. Localization, i.e. encapsulation of accumulated blood occurs relatively quickly and when the blood collection is not found and removed, the development of empyema is possible. In case that the bloody leak in the pleural space occurs related to a certain disease, diagnostical procedure, in terms of defining of the clean blood presence, is aimed at determining of haematocrits of pleural fluid. In most cases, however the pleural fluid is macroscopic with blood characteristics, the haematocrit of pleural fluid is under 5%. Hemothorax is diagnosed in such cases when the haematocrit of pleural fluid is at least 50% from the haematocrit in the peripheral blood. Traumatic hemothorax is the frequent findings within the surgical centers that treat the trauma. Incidence of the hemothorax is high at the blunt trauma, up to 37%, associated with the pneumothorax (hemopneumothorax) even up to 58%. Occurrence of the hemothorax is almost equally frequent without rib fracture (35%) or associated with rib fracture (38%). At patients with rib fracture, the occurrence of hemothorax is more frequent when the fractured rib-ends are dislocated.[29] When during the occurrence of hemothorax the arterial bleeding is diagnosed, there is no doubt that the thoracotomy will be applied as a therapy. Massive intrathoracic haemorrhage indicates an urgent thoracotomy and treatment of the bleeding place.[30] Hemothorax causes locally an atelectasis of lungs due to the compression causing that way, when the bleeding is massive, respiratory disorders. In some cases of massive hemothorax, the movement of mediastinum in opposite side is possible. Beside the local compressive effect, hemothorax causes hypovolemic problems which are expressed in a degree that depends on the quantity of lost blood in the pleural space.[32] Diagnosis of traumatic hemothorax must be taken into account at each blunt or penetrating chest injury. Hemothorax, after thoracic trauma, is often diagnosed by findings of pleural fluid at radiography of the chest. However, this method is not sufficient in all cases, or at least it is not proved to such a degree that it can be the only one during the examination of the injured. Smaller intrapleural collections can be hardly noticed at classical radiography, especially when the quantity of the discharged blood is small or when smaller leaks occur on both sides. Difficulties in such cases occur in the interpretation of radiography. When a patient is in the lying position, only slightly shadowing of hemithorax is recorded as a consequence of blood spillage along the back chest wall. Through such a shadow, the silhouette of the lung blood vessels can be obviously seen. Presence of a small hemothorax is hard to define in the lying position, especially when the noticeable contusion injuries of lungs are present and at subcutaneous emphysema, because it should be thought of the presence of a certain lung collapse. It is recommended to perform the radiography of the chest wall in standing position whenever it is possible, although hemothorax does not have to be found initially in that position. At imaging performed in standing posterioanterior (PA) or side position of a patient, free pleural fluid is collected by the effect of gravitation in the back costophrenic sinus, shadowing the costophrenic angle. In rare cases blood can be collected in the subpulmonary way between lungs and diaphragm when the costophrenic sinus is free, and the outline of diaphragm is partially changed. When the imagining is performed in PA position, the apex of diaphragmatic cupola is directed laterally toward the chest wall and the mistake in interpretation that it is the rupture of diaphragm is possible. However, at the side radiography the shadowing of the back costophrenic sinus is found and the angulation of the anterior shadow area of the alleged diaphragm, i.e. leak in the level of union with a large incision. Development of traumatic hemothorax can occur immediately after injury or the bleeding into thoracic cavity occurs later, i.e. after a few hours, even a few days later. Postponed occurrence of hemothorax is recorded after blunt and also after penetrating injury of the chest wall.[33,34] Patients with thoracic trauma, particularly those with assessment that it is potentially severe injury, should be followed by radiography in the period of at least -6 hours after the injury. In that period a small hemothorax and pneumothorax can be found. At penetrating injuries, with initially found hemothorax, development of pneumothorax can be found in over 80% cases.[35,36] Ultrasonography of the chest is an useful method in finding out of smaller pleural blood leaks, particularly at the lying patients and patients without consciousness. Computerized tomography (CT) is a very sensitive method for finding out even small intrapleural collections of fluid. It is proved method for differentiation of hydrothorax from hemothorax.[21] However, this method is rarely applied at the acute injured patients. CT of the chest can be used later for evaluation and differentiation of the lung atelectasis, rupture of diaphragm or finding out of extrapleural haematoma. Such states in the native radiography are manifested by shadowing hardly differentiated from the presence of the free fluid in the pleural cavity. CT of thorax is useful method and during the control of treatment effect, particularly in cases of the occurrence of encapsulation of hemothorax and ineffective drainage. Therapeutic approach of a surgeon toward each inury of the chest must be active, regardless of the known fact that in most cases may come to the spontaneous hemostasis. Such an attitude includs the constant observation of the injured, evacuation of collected blood, fight against atelectasis and follow up of effects of applied surgical treatment. Basic aims of the hemothorax therapy are: evacuation of collected blood from the pleural space, realization of the full reexpansion of lungs and realization of tamponade of the bleeding area by bringing lungs in an immediate contact with parietal pleura. Compensation od the lost blood is performed, in terms of therapy, parallelly with local treatment of hemothorax. It depends on the volum of lost blood.[36,37] Treatment of traumatic hemothorax depends on many parameters as: general state of the injured, state of the vital functions, character of the injury, i.e. is it the question of isolated thoracic injury or the injury is a part of politrauma, states of the injured part of the chest (unilateral, bilateral) and the occurance of bony structure fractures, combideness of many associated intrathoracic injuries, quantity of lost blood and possible area of bleeding, if the bleeding is recorded immediately after admission or it is determined a few hours or days after injury, if it is possible to apply conservative or it is necessary to apply immediately operative treatment, if there is associated pneumothorax with hemothorax, ect.[29,38,39] Most cases of traumatic hemothorax are treated without application of thoracotomy. By thoracentesis (pleural punction with application of large - bore needle) or thoracic drainage it is possible to solve hemothorax, i.e. evacuate entire quantity of blood from the pleural space. Attitudes related to the application of these therapeutical models are not clearly separated, particularly in relation to the thoracentesis. Thoracentesis is often applied at a uncomplicated hemothorax with smaller quantity of blood and at the injured where the shadow of the leak without the lung collapse is present during the clinical observation. In most cases they are patients with injuries caused by the effect of a weaker blunt stricking force and those with fractures of one to three ribs. Basic precondition for success of this method is that the blood in the pleural space is not coagulated. Some chest surgeons apply thoracentesis in diagnostical purposes as the first method for the recorded leak in order to orient themselves referring to the character of bleeding, i.e. to define if the obtained blood was immediately coagulated. Thoracic drainage is applied in most cases not only as the first therapeutic method but it is most frequently definitive therapeutic procedure. By thoracic drainage 85% of patients with chest injury are treated. At right diagnosed indications for thoracic drainage, the possibility of occurence of later complications is decreased.[40-42] Success of the thoracic drainage depends on several factors:

- General state of the injured
- Indication for drainage
- Choice of diameter and quality of thoracic drains and drainage systems
- Control of functioning of the entire drainage system, chest drains passing through and early detection of the problem in relation to that.

Indications for thoracic drainage are divided to absolute and relative.

Absolute indications for thoracic drainage at thoracic trauma are the following:

- Traumatic pneumothorax regardless of the degree of collapse
- Tension pneumothorax
- Pneumothorax on both sides regardless of the degree of lung collapse
- Massive hemothorax previously proved
- Associated collection of blood and air - hemopneumothorax, one - sided or on both sides.

In later clinical course of hemothorax, indications for drainage, i.e. re - drainage are related to the occurence of complication:

- At development of acute empyema of pleura
- Encapsulated hydroaeric collections
- Other collections of fluid and air.

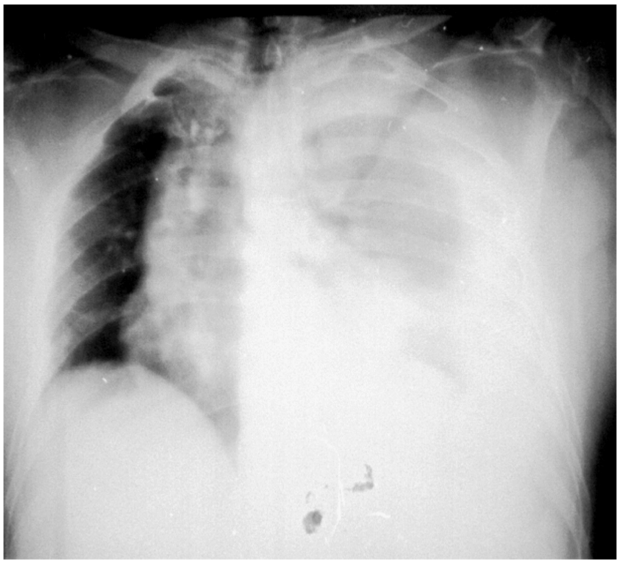

Figure 20. Left - sided traumatic hemothorax – Traffic accident

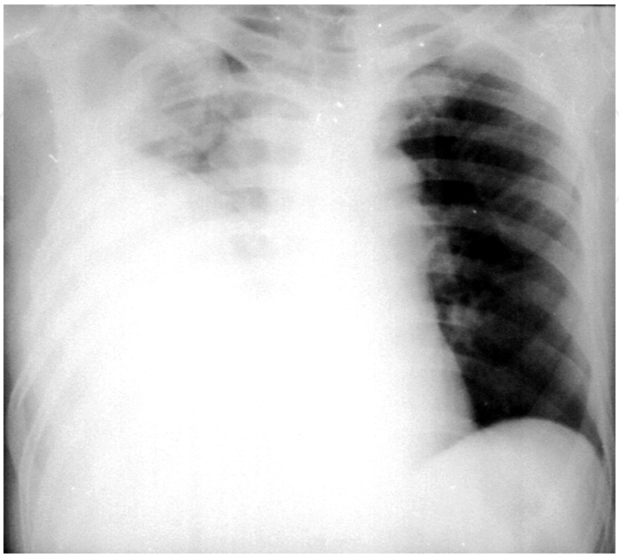

Figure 21. Right - sided traumatic hemothorax – Traffic accident

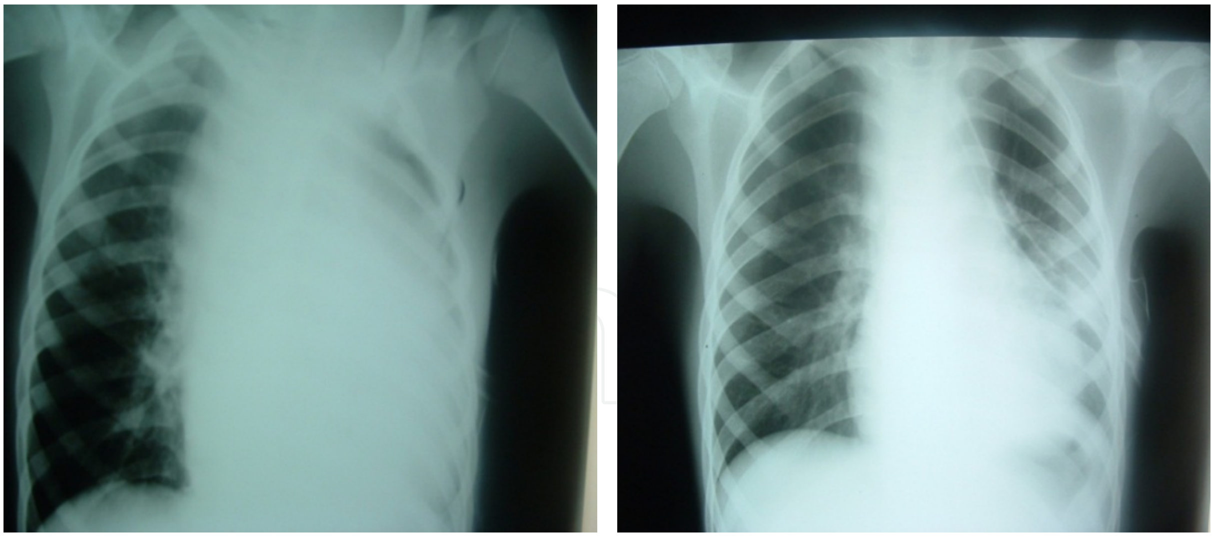

Figure 22. Fall from the height – traffic accident (child 8 years)

When the general endotracheal anaesthesia is planned for the surgery on the out thoracic organs at injured patients with the thoracic trauma or when the artificial ventilation by positive pressure is indicated, the attention should be paid to the possibility of development of the tension pneumothorax that in the aim of solving requires an urgent thoracic drainage. Preventive drainage of the thorax is not indicated when the obvious signs of pneumothorax are not present.

11.5.8. Types of drainage systems of pleura

There is more drainage systems used during thoracic drainage. In order to use in full the therapeutic effect of each system it is necessary to know the working principles each of them. Basic working principle of each drainage system is to: provide continued one-way evacuation, drainage of air and fluid from the pleural space into drainage collector, in the way that there is no possibility for an air circulation or fluid in the opposite direction, i.e. toward the pleural space. Basic aim of thoracic drainage is to evacuate the pleural content (air and fluid) and to achieve full reexpansion of lungs.

Classical drainage system is comprised of one bottle, which at the same time serves for collection of drainage content and as the water valve. Opening of the thoracic chest tube is connected to the rigid tube, passing through the stopper of sterile bottle. Top of the rigid tube is dived for around 2 cm under the surface of the physiological salt solution poured into the bottle. On the stopper of a bottle there is one more opening through which the tube is inserted, used for air egress (air valve). Top of the tube is above the fluid level. Such a system can be used for so-called submerged drainage, without active suction, or the tube of a valve is connected with the active suction, when the system is used for the active aspiration. Drainage system with two bottles is more reliable for the drainage of large quantity of fluid pleural content. Bottle which is closer to the patient serves as the collector of drainage fluid content, with second bottle the system of water valve is provided, similary to the system of one drainage bottle. Drainage system with three bottles is marked as the system for controlled suction of the pleura fluid content. Third bottle, added to the system of two bottles, serves for control of the active aspiration. It is connected to the second bottle that has the function of the water valve. Bottle for the pressure control for performance of the active suction has rigid tube, similar to the one on the second bottle, and on the stopper there is the connection linked with the source of active suction. System with three bottles is quite massive and it is not practical for patients who need transport. Commercial systems, for one-time usage, are designed according to the principle of functioning of the system with three bottles and they are considered to be fully proper for successful thoracic drainage. These systems are manufactured sterile and they are made of the plastic material, simple and practical for use. Most famous are Pleur-Evac and Argyl Double-Seal Units.

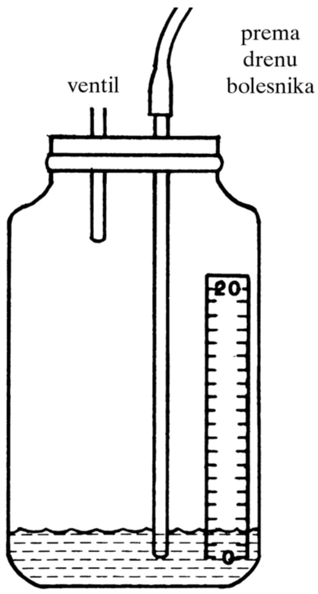

Figure 23. Drainage system one - bottle

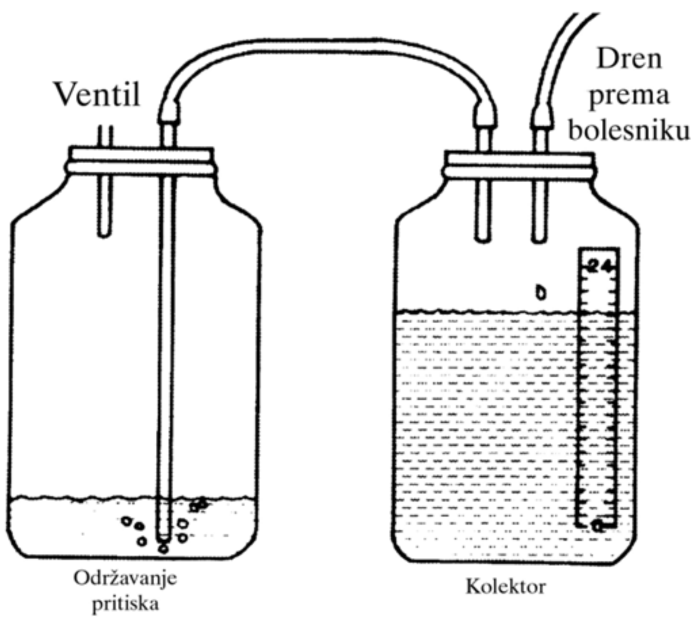

Figure 24. Drainage system two - bottles

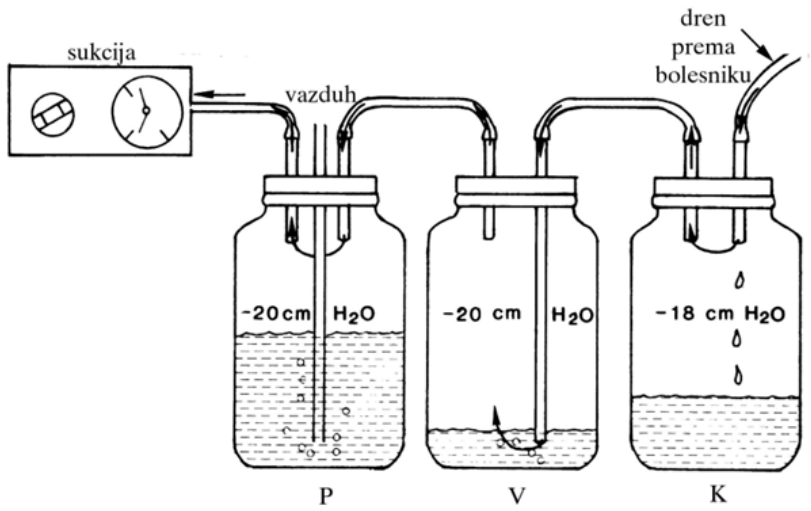

Figure 25. Drainage system three - bottles

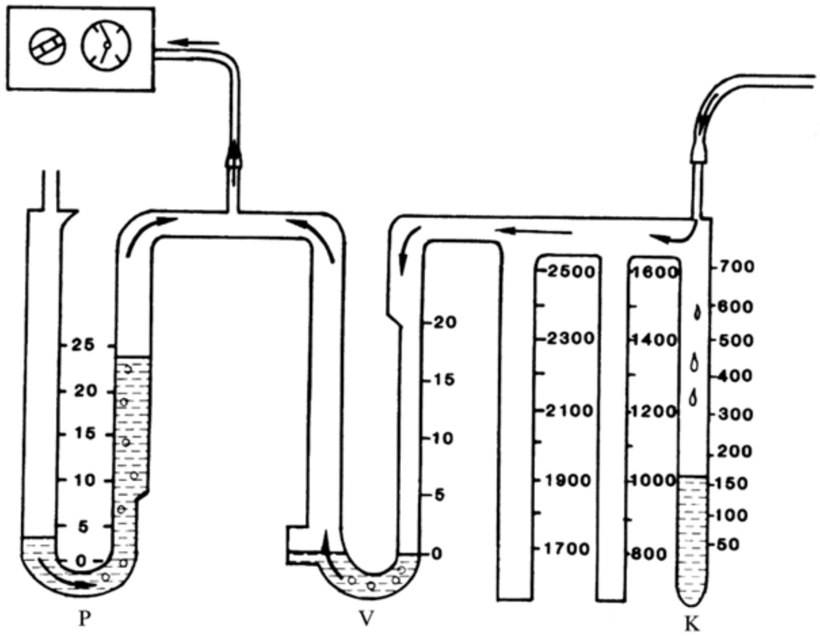

Figure 26. Commercial drainage system

11.5.9. Types of thoracic drainage

Practically, thoracic drainage can be performed in two different ways by:

- Operative thoracostomy – by classical incision of thorax in general or intravenous anesthesia, dissection and blunt preparation and placement of large-bore thoracic drain under finger control. Position of the patient is the lying, in decubitus on healthy side.
- Trocar thoracostomy – drainage is performed in local anesthesia by placemnt of the chest tube of narrow lumen through a metal thoracic trocar. Through previously performed incision on the chest wall, it is penetrated by sharp stiletto into the pleural space. During performance of drainage there is no possibility of digital control of the

lung parenchyma position in relation to the top of stiletto of the trocar. Variant of drainage by the trocar is the application of the commercial trocar catether, where the trocar is placed inside of thoracic drain. By trocar thoracostomy the chest wall is less damaged and the intervention is performed significantly more rapid, compered with the operative thoracostomy. Patient position is the sitting position with antebrachial region leaned against the backed chair or it is the lying position on the back.

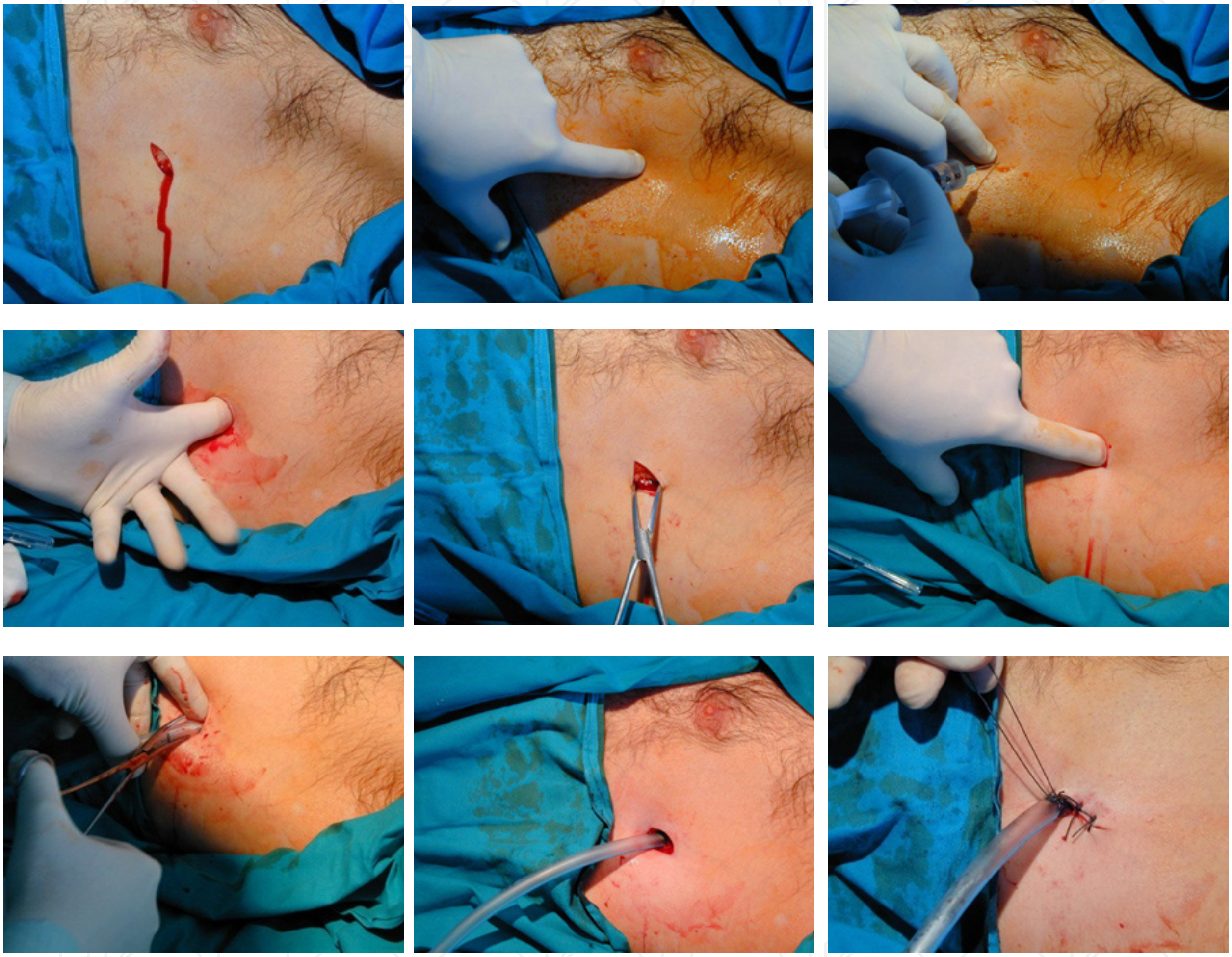

Figure 27. Operative thoracostomy

Proper premedication of a patient is obligatory regardless which of the mentioned ways is used by the suregeon. Position of the patient during performance of thoracic drainage is mostly defined by his general state.

By placement of thoracic chest tube, several favors are realized in hemothorax treatment:

- In most cases the complete evacuation of blood from the pleural space is possible
- It is possible to stop the bleeding completely that occurs due to the damage of pleural space
- Easy and simple control of the quantity of lost blood and assessment of the bleeding degree are possible, important for defining of the volume necessary for restoring

- Possibility for the occurence of bacteria infection is decreased due to the encapsulation of hematoma and development of empyema, i.e. fibrothorax
- Finally, in modern conditions there is a possibility of the blood autotransfusion, evacuated by the thoracic drain

Choice of thoracic chest tubes at fresh bleeding is mostly aimed in direction of placement of drains of a large-bore lumen (Fr 30 - 32, and according to some autors even Fr 36 - 40) for in that way the possibility of drains blockage with bloody coagulum is decreased. Recommendation for the massive hemothorax is to place a large - bore thoracic drain through IV and V interspace of ribs in the midiaxillary line. Drain is placed upward, for during drainage there is a possibility of the diaphragm damage due to its elevation caused by trauma, or within the thoracic cavity prolapsed intra-abdominal organs can be damaged at cases with the diaphragm rupture. Control of thoracic drain function is important and it is necessary to be constant. Passage of drains and quantity of evacuated content are controlled. It is necessary to control radiographic and roentgenoscopic states of extended lungs, diaphragm position and drain position. Control of functioning and efficiency of drains is important in order to prevent infection and development of empynema and if needed, when the thoracic drainage does not achieve a goal, to apply other models of treatment, i.e. thoractomy in the aim of haematoma removal and stopping of bleeding. Best way of prevention in infection development is an urgen and complete evacuation of blood from the pleural cavity. [29-31,33,40] It is useful to apply parenteral therapy of antibiotics. Indication for urgent thoracotomy is often connected with the occurence of massive hemothorax due to injuries of intrathoracic organs that can not be treated in a conservative way. Urgent thoracotomy is indicated at the hemothorax, complicated by a heart tamponade, injury of large intrathoracic blood vessels, primary pleural contamination, debridement of devitalized tissue, open thoracic wounds and at the tracheobronchial injuries.[41 – 44] Indications for urgent thoracotomy are special. After placement of thethoracic chest tube and assessment of the volume of continued pleural bleeding, i.e. quantity of lost blood in continuity through the thoracic drain. General rules include the rule that urgent thoracotomy is indicated in case if the constant loss at thoracic chest tube is 200ml per hour, in case that there is no indications to stop the bleeding. Of course, in order to make decision related to the thoracotomy and assess the state in the pleural cavity in such cases it is necessary to perform control by the radiography and radioscopy. When the continued loss of blood at the thoracic drain is determined and radiographic findings of hemothorax shadowing, the thoracotomi is necessary.[40,45] Indications for urgent thoracotomy are identical at the blunt and penetrating injuries. At each patient it is necessary to observe carefully all parameters, supposed for indication for surgical treatment, i.e. thoracotomy. Resectional lung surgery are rarely applied, mainly in cases of increased laceration of lung parenchyma and development of increased intrapulmonary haematoma, devitalization of lung parenchyma and injury of lung bood vessels.[43,44] It is proved that pneumonectomy should in any case be avoided, for the mortality rate after such an operation is almost 100%, i.e. such a resection should be performed only if there is no other choice. [46 – 48] Wedge - shaped resection is most often, resection of segments and lobectomy, it is possible to apply staplers. [43,44] At the presence of associated hemothorax and pneumothorax one should think of the possibility of injury of large respiratory paths, trachea and bronchi. When their fissure is determined, an urgent thoracotomy is indicated and the sutura of respiratory paths with caring for the site of bleeding. Thoracotomy is necessary at the traumatic hemothorax at around 20% of the injured. In medern conditions in cases of the occurence of hemothorax the video-assisted thorascopic surgery (VATS) can be applied, but up to recently experiences are still rather modest that it can be accepted that this surgical method belongs to the routine therapeutic methods.[49,50] Main pleural complications of traumatic hemothorax are: retention of blood coagulum in the pleural space, infection in the pleural space, effusion of the pleura and fibrothorax. In most cases surgical recommedation is to remove surgically the formed coagulum from the pleural area due to possible complications, in the first place the infection and development of empyema and fibrothorax.[51] Development of empyema can be expected at 1% - 4% cases. Application of antibiotics during the treatment of hemothorax by thoracic drainage is useful in the reduction of the occurence of empyema and pneumonia. If the thoracic trauma is combined with abdominal trauma, at extended thoracic drainage the possibility of the occurence and development of the pleural infection i.e. empyema is more definite. Complications of the pleural empyema are solved by the thoracotomy and decortication of the lung.[52,53] Occurence of the pleural effusion is possible after completed treatment and removal of thoracic drain. Development of leak is possible, regardless of the fact that residual hemothorax is present or not, but it is significantly more rare, when it is not present (at around 13% without residual hemothorax and around 34% of cases with the retention of the residual hemothorax, i.e. formed coagulum that can not be removed by thoracic drain).[54] Occurance of pleural leak is an indication for pleural punction (thoracocentesis), with the aim to determine the character of pleural fluid and to prevent development of the empyema. After completed treatment of the

Figure 28. Penetrating injury – firearms

Figure 29. Penetrating injury – knife wound

hemothorax, in the period of a few weeks or months, due to the noticiable adhesions, the fibrothorax can be developed. Fibrothorax is developed at around 1% of treated patients from hemothorax and it is more frequent at patients with hemopnemotorax, or when in the early phase after injury the pleural infection appears. Complications due to the fibrothorax can be solved by the lung decortication.

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