CHEST TRAUMA

Minireview

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Abstract

Chest trauma can affect any one or all components of the chest wall and thoracic cavity (bony skeleton, lungs and tracheobronchial tree, heart and great vessels, esophagus and diaphragm). This review is focused on the pathophysiology, diagnostic and treatment of blunt and penetrating thoracic injuries.

Keywords: Chest trauma, penetrating chest trauma, blunt chest trauma, hemothorax, pneumothorax, thoracic traumatology

Introduction

The amount of tissue damage is directly related to the amount of energy exchange between the penetrating object and the body part. The density of the tissue involved and the frontal area of the penetrating object are the important factors determining the rate of energy loss.

Thoracotomy may be indicated for acute or chronic conditions. Acute indications include the following:

- Cardiac tamponade;
- Acute hemodynamic deterioration/cardiac arrest in the trauma center;
- Penetrating truncal trauma (resuscitative thoracotomy);
- Vascular injury at the thoracic outlet;
- Loss of chest wall substance (traumatic thoracotomy);
- Massive air leak;
- Endoscopic or radiographic evidence of significant tracheal or bronchial injury;
- Endoscopic or radiographic evidence of esophageal injury;
- Radiographic evidence of great vessel injury;
- Mediastinalpassage of a penetrating object;
- Significant missile embolism to the heart or pulmonary artery;
- Transcardiac placement of an inferior vena caval shunt for hepatic vascular wounds.

Patients who arrive in cardiac arrest or who arrest shortly after arrival may be candidates for emergency resuscitative thoracotomy. A right chest tube must be placed simultaneously. The use of emergency resuscitative thoracotomy has been reported to result in survival rates of 9-57% for patients with penetrating cardiac injuries and survival rates of 0-66% for patients with noncardiac thoracic injuries, but overall survival rates are approximately 8%.The proportion of patients with PCT who can be treated without operation has been reported to vary from 29-94%.

Chronic indications for thoracotomy include the following:

- Nonevacuated clotted hemothorax;
- Chronic traumatic diaphragmatic hernia;
- Traumatic cardiac septal or valvular lesion;
- Chronic traumatic thoracic aortic pseudoaneurysm;
- Nonclosing thoracic duct fistula;
- Chronic (or neglected) posttraumatic empyema;
- Infected intrapulmonary hematoma (eg, traumatic lung abscess);
- Missed tracheal or bronchial injury;
- Tracheoesophageal fistula;
- Innominate artery/tracheal fistula;
- Traumatic arterial/venous fistula.

Thoracic traumatology, indications, surgical consequences

The consequences of blunt chest trauma are dependent on the energy of the trauma. The severity of injury to soft tissue of the chest wall, pain, skeletal fractures, and especially injury to intrathoracic organs determine the resulting respiratory and circulatory disorders. In addition to dysfunction of respiratory mechanics and traumatic injury to the heart and lungs, vital functions are endangered by hemorrhagic shock, possible pneumothorax or hemothorax, mediastinal shift, impaired venous return and associated injuries. Severe chest trauma leads to acute respiratory distress syndrome (ARDS); injury to the esophagus induces septic complications. Fractures of the first ribs or sternum are often associated with severe injuries to the heart, trachea or great vessels, which usually result in exsanguination or asphyxiation in the pre-hospital phase. Fractures of the distal ribs (9.-11.) indicate possible injury to the liver or spleen. They thus serve as an indicator of the severity of the trauma and of the probability of multiple (not only thoracic) injuries.

Diagnosis

Symptomatology is given by the mechanism of injury, its energy and form of organ injury. It may range from shortness of breath, pain to cardio-respiratory failure and severe shock. History, witness or police statements, may aid in selecting appropriate diagnostic steps. When severe hemorrhage is suspected, the first step is to crossmatch an adequate number of blood units. Obligatory laboratory tests include blood count, thrombocyte level and coagulation parameters, blood gases and acid-base equilibrium and urinalysis. If cardiac injury is suspected, cardioselective enzymes may be analyzed, prior to angiography a non-protein nitrogen sample may be collected, habitually mineral levels and possibly liver tests may be performed. Lactate values enable monitoring tissue perfusion, CRP septic complications.

Imaging methods

Ultrasonografphy is a valuable tool for emergency room physicians; during the initial diagnostic procedure, it serves to confirm or rule out with a great degree of reliability a larger hemothorax, pneumothorax, as well as hemoperitoneum or injury to intraabdominal parenchymal organs. In cases of non-severe injuries, the diagnostic procedure begins with X-ray with instructions based on the symptoms (to exclude pneumothorax, hemothorax, fractures of the thoracic skeletal structures, etc). A CT is indicated if injury to the intrathoracic organs is suspected or in cases of polytrauma. If the condition of the patient and workplace facilities allow, spiral and full body CT with application of contrast agent is best. When cardiac injury is suspected, echocardiography may be performed; esophagus perforation may be demonstrated on esophagogram with water-soluble contrast.

Endoscopy

Bronchoscopy is indicated in cases of mediastinal emphysema or if other signs of tracheobronchial injuryare present; esophagoscopy is not commonly indicated in traumatology. Videothoracoscopy in the acute phase is of marginal significance- as an alternative to a conservative approach or as a method of confirming non-severity of the injury in patients with an overall good condition.

Indications

Indications for surgical intervention after chest trauma (blunt and penetrating trauma) used to be quite clear and strict. With the rapid development of diagnostic and intervention methods, as well as due to advances in anesthesiology, emergency medicine and intensive care, some previously absolute criteria have been made relative. An actual list of indications and contraindications is summarized in the tables 1-4.

Table 1 *Indications for emergency thoracotomy*

- Hypotension with systolic pressure below 60 torr non-responsive to adequate therapy
- Traumatic „thoracotomy“
- Exsanguinating hemorrhage (over 1500 ml from drain)
- Hemopericardium or penetrating cardiac trauma
- Large tracheobronchial trauma
- Esophageal trauma
- Traumatic arrest (with previously confirmed cardiac activity)
- Massive air leak

Table 2 *Relative indications for emergency thoracotomy*

- Confirmed injury to the great vessels (consider an endovascular approach)
- Traumatic cardiac arrest without previously confirmed cardiac activity in penetrating trauma
- Pre-hospital resuscitation lasting more than 10 minutes
- Massive air embolism
- Projectile embolization

Contraindications for emergency thoracotomy were defined by the American College of Surgeons – Committee for trauma. Under our health care conditions, these contraindications are relevant only under specific conditions under the context of time urgency in decision-making and not always exhausted diagnostic possibilities.

Table 3 *Contraindications of emergency thoracotomy*

- Blunt chest trauma without previously confirmed cardiac

activity • Multiple blunt trauma • Severe brain trauma

Table 4 *Indications for postponed thoracotomy (including relative)*

• Residual coagulated hemothorax • Posttraumatic lung hematoma or abscess • Posttraumatic lung empyema • Traumatic valvular, septal lesions • Persistent fistula of the thoracic duct • Bronchopleural, tracheoesophageal fistula • Pseudoaneurysm of the aorta, great vessels (possibly intravascularly) • Missed tracheobronchial lesion

Blunt chest trauma requires surgical intervention in less than 10% of cases, the remaining cases may be treated conservatively or semi-invasively (chest tube, pneumatic splint, pericardiocentesis).

Therapy

In patients with life-threatening chest trauma, surgical intervention may be a life-saving procedure, which must be performed even in situations where the diagnostic protocol is not quite complete. A necessary requirement is ensuring the airways and adequate number of blood transfusion units, and continuous monitoring and support of circulation and ventilation. In cases where the patient's condition allows it, exhausting all diagnostic possibilities regarding the injury and possible affiliated injuries is extremely desirable.

RIB CAGE FRACTURES

Rib fractures and lysis of costochondral junctions

They are the most common result of blunt chest trauma. Fractures of individual ribs do not require surgical intervention, therapy is based on sufficient pain management so that ventilation is not limited. In the majority of patients, oral analgesic therapy is sufficient, usually non-steroidal anti-inflammatory drugs will suffice. However, if the pain limits respiratory movements and expectoration, it is possible, in cases of only a small number of fractures, to perform an intercostal nerve block with long-lasting local anesthetic (Marcaine); it is also appropriate to treat the intercostal space above and below the affected segment. In cases of multiple fractures, an epidural is more appropriate. Early respiratory rehabilitation and expectoration facilitation shorten treatment time and prevent pulmonary complications. Surgical intervention is rarely indicated in cases of severe bleeding from lacerated intercostal or mammary vessels or in cases of lung lacerations caused by sharp broken rib fragments. In cases of uncomplicated injury of the first ribs, it is sometimes necessary to remove sharp fragments endangering subclavian vessels or the brachial plexus.

Instability of the chest wall

When 4 or more neighboring ribs are fractured in two lines, respiratory mechanics are disturbed due to the newly created open segment of the chest wall which drops into the thorax

at inspiration and during expiration is pushed outwards (flail chest). If the fracture lines are unilateral, this is referred to as lateral instability. If the fracture lines are bilateral, the paradox respiratory movements are performed by the anterior segment of the chest wall- anterior instability. These types of fractures are caused by high-energy trauma, often associated with other injuries to intrathoracic organs (pneumothorax, hemothorax, contusion of the heart or lungs, tracheobronchial injury). This ultimately results in respiratory failure and need for artificial positive pressure ventilation. This type of treatment is referred to as pneumatic splint and is reserved primarily for patients with severe comorbidities. If flail chest is the main cause of borderline respiratory insufficiency or if it is not possible to take the patient off the ventilator due to a large instable segment of the chest wall (or sternum), stabilization of the chest wall is indicated. Stabilization of the chest wall is obviously suitable also when performing thoracotomy indicated for other reasons. A variety of stabilization methods exists, from simple extensions behind the sternum or substernal plates in cases of anterior instability, to external splints for lateral instability to osteosynthesis of the ribs by preformed splints.

Fractures of the sternum

A fracture of the sternum in itself is not dangerous, however, it indicates possible associated intrathoracic trauma (contusion of the heart and lungs, injury to the aortic arch and its branches, tracheal or esophageal lesions). Fractures of the ribs, long bones, pelvis, spine and craniocerebral injuries may simultaneously be diagnosed. Non-dislocated fractures may be missed during primary diagnosis; dislocated fractures are clear on lateral X-ray projection. Clinically the patient feels pain at the location of the fracture, crepitation, pathological movement, soft-tissue hemorrhage. Non-dislocated fractures without associated injuries may be treated conservatively; small dislocations may sometimes be repositioned in hyperlordosis. If surgical treatment is necessary, fixation by metal (titanium) splint provides very good results.

Penetrating chest trauma

The issue of open trauma is given by anatomical consequences. Besides the chest wall, any intrathoracic organ may be affected (heart, great vessels, greater respiratory tract, lungs, esophagus, thoracic duct, diaphragm), either individually, or simultaneously, and also with any structure outside the thorax. In this area it is therefore more important than elsewhere to have a thorough topographical anatomical understanding and orientation in the pathophysiology of the traumatic event. It is essential to thoroughly examine the patient even in areas, where the injury may go unnoticed (axillas). Stab wounds distal to the nipples and scapula may reach intraabdominally, proximally located wounds may injure cervical structures. In this respect gunshot wounds are even less predictable, it is necessary to take into account projectile migration in the pleural cavity or intravascularly. Furthermore it is necessary to take into account the consequences of absorbed kinetic energy around the gunshot canal.

Emergency measures

Symptomatology of penetrating trauma may be minimal, but also very dramatic, and the shift between these two extremes may take place in a very short time. Emergency measures must therefore focus on preventing shock, determining precise diagnosis and planning the sequence of therapeutic procedures. It is necessary to ensure ventilation, intubation is indicated for apnea, asphyxiation, insufficient ventilation or deep shock. In cases of clinical signs of tension pneumothorax, decompression is necessary, preferably by chest drainage; open pneumothorax must be treated with occlusive dressing with one-way valve or drainage and closure of the wound. Hemothorax must be drained – in addition to

decompressing the intrathoracic space, measuring the volume of secretion aids in monitoring blood loss. Volumotherapy and blood loss substitution, correction of coagulopathy and care for the internal environment take place concurrently. If the circulation parameters of the injured patient do not improve despite anti-shock therapy and massive volume substitutions and if other causes of the unimproving condition are ruled out (tension pneumothorax, pericardial tamponade, intrabdominal bleeding), immediate surgical revision and an attempt at surgical hemostasis provides a better chance than continuing the suboptimal circulation resuscitation.

Indications

Indications for emergency thoracotomy are somewhat modified by pathophysiological and clinical findings in open trauma (may have a quicker course, chance of fast, life-saving surgical reparation), which is why they are clarified in the following table:

Table 5 *Indications for emergency thoracotomy in penetrating chest trauma*

- Traumatic cardiac arrest (in-hospital or with earlier confirmed cardiac activity)
- Cardiac tamponade, hemopericardium
- Great vessel trauma (consider endovascular procedure)
- Traumatic „thoracotomy“
- Shock, hypotension with systolic pressure below 60 torr unreactive to adequate therapy
- Exsanguinating bleeding (more than 1500 ml from drain)
- Tracheobronchial trauma, large air leak
- Esophageal trauma
- Embolization of the projectile into the heart or pulmonary artery
- Massive air embolism

Therapy

We remind that in addition to the chest wall, trauma may occur to any intrathoracic organ (heart, great vessels, large respiratory tract, lungs, esophagus, thoracic duct, diaphragm), either individually, or simultaneously, even along with any structure outside the thorax. Many traumas may be treated conservatively- patients with minimal clinical findings, if paraclinical examinations show non-risk findings and a good overall condition. In the past, in cases of open trauma to the chest, as well as in penetrating abdominal trauma, if trauma to intrathoracic structures could not be ruled out, explorative thoracotomy was a necessity. Today, since it is possible to carefully monitor the patient, repeatedly study developing trends by ways of imaging methods and possibly videothoracoscopically verify the correctness of a conservative approach, the number of useless thoracotomies has decreased. Many patients may be treated solely by chest drainage, which may even aid in the indication of thoracotomy. Pericardiocentesis or small pericardiotomy may be useful in cases of blunt chest trauma; tamponade in penetrating trauma is indicated for surgical revision. Rapid development of endovascular techniques allows elective treatment of most traumas to great vessels; however, when pressed for time, is dependent on availability of instruments, specialist, and of adequate stent, which may be limiting in dramatic situations. Therefore surgical revision remains the golden standard of treating penetrating chest trauma fitting the above-mentioned indication criteria. Large defects of the chest wall are treated by primary defect closure sometimes with the use of synthetic material or skin and muscle flaps. Stabilization of the chest wall deserves

more extensive discussion. Lesions of individual intrathoracic structures and their treatment are very specialized topics and will be discussed individually, also in regard to blunt chest trauma.

LUNG TRAUMA

Lung contusion

Lung contusion is the most common result of blunt chest trauma. It may be caused by injury exerting on the lung parenchyma through the chest wall directly or by deceleration or as part of a high-energy injury which absorbs the kinetic energy of the gunshot. The pathophysiological correlation of contusion is hemorrhage of the interalveolar septa and resulting edema of the surrounding lung tissue. Clinical manifestation includes shortness of breath; hemoptysis, cyanosis, hypotension may also be present. The risk of systemic inflammatory response syndrome (SIRS) and resulting respiratory insufficiency increases based on the severity of the contusion, and especially on the severity of accompanying injuries and preoperative morbidity. Further development may lead to acute respiratory distress syndrome (ARDS) or secondary pneumonia, namely in ventilated patients. Prognosis of isolated lung contusions is quite good; however, in combination with other injuries mortality reaches up to 50 %.

Lung laceration

Lung lacerations may be of varying extent, from small peripheral lesions of the pleura or adjacent parenchyma in blunt and open traumas, to uncomplicated stab wounds and gunshot wounds to severe lung lacerations affecting the lung hilus after high-energy gunshot wounds. X-ray plays a pivotal role in diagnosis; lung trauma is manifested by pneumothorax, hemothorax or hemopneumothorax. Clinically significant pneumothorax should be visible on X-ray.

Pneumothorax

A pneumothorax is considered closed if the chest wall remains undisturbed. Penetrating trauma to the chest wall creates an open pneumothorax. If the lesion in the chest wall, trachea or lung acts as a valve, this means that at inspiration a larger volume of air enters the pleural cavity than can be evacuated during expiration, this is referred to as tension pneumothorax. Defects of the chest wall that are larger than the diameter of the trachea severely disturb respiratory mechanics; at inspiration air enters into the injured hemithorax and causes a shift of the mediastinum towards the healthy side, during expiration the mediastinum is contrarily pushed towards the injured side. This phenomenon is called mediastinal flutter. The lung of the affected side is collapsed, the lung parenchyma of the other side is also dysfunctional and only ineffectively follows the movements of the chest wall and diaphragm. This is a serious, life-threatening condition, similarly to tension pneumothorax. Both of these conditions are considered an acute thorax. While the primary cause of respiratory failure in open pneumothorax is a dysfunction in respiratory mechanics, in cases of tension pneumothorax, a dysfunction in venous return to the heart dominates. The introduction and accumulation of air into the pleural cavity through a valve in the chest wall (or lung, tracheobronchial tree) lead to gradual compression of the according lung to the hilum, the final consequence is the pushing of the mediastinum to the opposite side where it creates a compression and strangulation of both caval veins, also, of course, compression of the second lung. First aid during tension pneumothorax is chest drainage or at least conversion of tension pneumothorax to open pneumothorax by thoracentesis using thick needles.

Hemothorax

Hemothorax becomes apparent when the volume exceeds 250 ml. In asymptomatic patients with negative X-ray, it is recommended to repeat the X-ray after a 6-12 hour interval. If findings are unclear, CT can detect even minimal PNO or a small amount of fluid. Wound revision is not recommended for risk of causing PNO and contaminating the pleural cavity. In cases of confirmed PNO or findings of fluid after penetrating trauma, chest drainage is indicated. It is the best prevention of residual hemothorax, allows monitoring the time trend of the bleeding and, if necessary, may indicate surgical revision.

Massive bleeding from the chest drain requires thoracotomy, minimal prolonged drain secretions may be treated thoracoscopically in hemodynamically stable patients. Thoracotomy indications in relation to the volume of evacuated blood continues to be discussed. Emergency thoracotomy is usually indicated if the volume of drained blood exceeds:

- at one time 1500 ml;
- 300 ml in 3 hours following drain introduction.

Stricter authors state that mortality rapidly increases when total secretion exceeds 1500 ml in 24 hours, and thus this volume is again determining for revision.

The great majority of lung traumas requiring thoracotomy are treatable at a price of minimal loss of parenchyma (coagulation, suture, stapler suture or non-anatomic lung resection, the use of tissue glues). Anatomical resections are necessary in cases of severe lacerations with non-reparable injury to secondary hilar structures. Pneumonectomy for bleeding is suitable only after all other available options have been depleted, as ultimumrefugium, and is associated with a high mortality.

Tracheobronchial trauma

Tracheobronchial trauma is rare, occurring in about 1 % of injured patients, often in combination with lesions of other structures. Except for insignificant small fissures with no or minimal accompanying symptoms, these injuries require obligatory surgical reparation. Over three-quarters of penetrating injuries (usually cutting or stab wounds) affect the cervical portion of the trachea; the same proportion affects the distal trachea above the bifurcation in cases of blunt thoracic injuries. Along with direct mechanisms of injury, tracheal traumas are caused by compression in the area of the upper thoracic aperture, usually along with injury to the surrounding structures, deceleration forces in hyperkinetic accidents typically tear the trachea immediately above the bifurcation. The high air pressure in the greater respiratory tract also contributes to these forces. Clinically these injuries present with hoarseness, mumbling, subcutaneous emphysema, hemoptysis, pneumothorax, a “fallen lung” may be seen on X-ray and/or pneumomediastinum. If pneumothorax is confirmed, a massive air leak may be observed from the chest tube, this indicates injury to the large bronchi coursing intrapleurally. If injury to the trachea is suspected (massive pneumomediastinum and subcutaneous emphysema, absence of air-leak), it is suitable to intubate the patient with the use of a bronchoscope, which also serves for definitive diagnosis. In case of tracheal trauma, first aid consists of intubating under the defect navigated by bronchoscopy. For lesions of the large bronchi, it is necessary to intubate the undisturbed bronchus, and if possible, block the injured one. It is equally important to perform extensive airway hygiene. The technique and tactic of reparation of the injured airways is analogous to elective operations. Access to the upper third of the trachea is possible via collar incision which may be extended by sternotomy; transpericardial access is also an option. A right-sided thoracotomy allows the best access to the distal trachea and both mainstem bronchi. Injuries to more distal segments of the airways may repaired by way of bronchoplastic operations, sometimes anatomical resections are necessary. Pneumonectomy is very rarely required, and is associated with a

very poor prognosis. These injuries are not always detected primarily; postponed treatment is associated with typical complications- stenosis or atelectasis and infectious complications due to obstruction.

Great vessel trauma

Thoracic great vessels include the aorta and branches of the aortic arch, the superior vena cava and its tributaries, the intrathoracic inferior vena cava, the pulmonary arteries and pulmonary veins. Over 90% of their injuries are penetrating; severe injury to the great vessels usually ends fatally in the field. Chances at successful intervention are counted in minutes, therefore diagnosis is limited to a minimum, in stable patients an X-ray, CT, possibly CT Angiography may be managed. Patients with severe hemorrhagic shock, sometimes after initial resuscitation, are immediately rushed to the operating room. Depending on the site of injury, an immediate thoracotomy (sternotomy) is performed along with manual compression of the injury and possible clipping of the bleeding vessel. In some cases a balloon catheter introduced intravascularly may help. Definitive treatment is performed by standard technique. Selecting the access route may be problematic. The ascending aorta is accessible from sternotomy, the descending aorta from left-sided thoracotomy. Pulmonary arteries are treated from the corresponding thoracotomy. The superior vena cava is accessible via sternotomy or right-sided thoracotomy, the inferior vena cava from sterno- or sternophrenolaparotomy. Arteries from the aortic arch are accessible via supra- or infraclavicular approach, transclavicularly, from sternotomy, from hemiclamshell or trap door incision.

Trauma to the aorta often ends by exsanguination. The ascending aorta cannot be closed off without extracorporeal circulation, if it is not available, some injuries may be managed and definitely treated with suture on large lateral wall clamps. The descending aorta may be clamped and sutured, or if necessary, a vascular prosthesis may be interposed. In emergency situations, prevention of spinal chord ischemia is not standard. For injuries of the great pulmonary vessels, the first step is to place a tourniquet on the pulmonary artery; the pulmonary veins may be treated similarly. After adequate hemostasis is achieved, reparation of the injured structures is performed. It is imperative to avoid pneumonectomy at all costs.

Vena cava injury must be repaired and patency preserved, ligation of either of the caval veins is fatal. One-sided ligation of the brachiocephalic vein is possible; a sufficient collateral circulation is expected.

Injuries to the arteries of the aortic arch are common in stab wounds in the area of the neck and possible during blunt trauma to the upper thoracic aperture. They are treated by suture or reconstruction or by-pass by prosthesis or venous grafts.

In patients with a prolonged course, endovascular therapy gains significance. However, the availability of instruments and radiologist and necessary stentgraft at the given place and required time remains a basic problem.

Cardiac trauma

Blunt cardiac injury accompanies chest trauma in approximately 20% of cases. It is usually the result of car accidents, the chest hitting the steering wheel is a typical mechanism of injury, causing deceleration and compression of the heart between the sternum and spine with the contribution of rapid overflow of venous blood to the heart after compression of the lower half of the body. Fractures of the sternum or multiple contiguous fractures of the anterior rib segments along with the sternum indicate the probability of cardiac injury or injury to other intrathoracic structures. Only about 10% of the most severe cases (ventricular rupture, pericardial rupture with cardiac herniation, left-sided valvular lesions, injury to coronary arteries) require treatment.

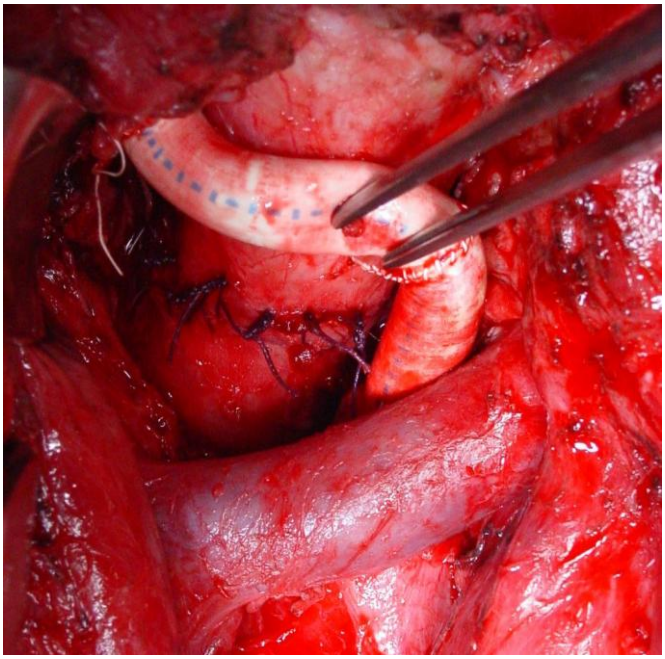

Figure 1 *Replacement of the brachiocephalic trunk and suture of trachea after polytrauma*

A trauma score was created to evaluate the severity of blunt cardiac injury (Tab.6).

Table 6 *Trauma score of cardiac injury*

One point • Pathophysiological or anatomical deviations without findings on ECG • ECG abnormalities • Elevation of cardioselective enzymes Two points • Cardiac wall or septal hematoma • Septal defects Four points • Traumatic valve insufficiency Five points • Rupture of the cardiac wall • Cardiac herniation • Injury to the coronary arteries

Diagnosis is complicated, symptoms are not specific, with the exception of pain, tachycardia, crepitations accompanying sternum fractures, decreased heart sounds during tamponade or audible murmurs in cases of septal or valvular lesions, there are no typical signs accompanying cardiac injury. Pathological findings on ECG and elevation of cardioselective enzymes (creatine kinase – myocardial fraction, troponins I,T) can further warn of possible myocardial injury. The most accurate and available diagnostic method is echocardiography (transparietal or preferably transesophageal).

Penetrating cardiac injury is a leading cause of traumatic death in both pre-hospital and in-hospital stages. They may be caused directly (stab wounds, gunshot wounds), or indirectly (sharp fragments of broken rib or sternum). More than a third of these injuries affect the right ventricle, a similar number of injuries encompass several cardiac compartments, in

about a quarter of cases there is isolated left ventricular injury. While in the case of blunt trauma, it is usually possible to allot a certain time interval for diagnosis, in penetrating chest injuries to the precordium and epigastrium with hemodynamic instability, there are only minutes remaining for immediate surgical revision. The first signs of cardiac tamponade are tachycardia, high venous and low arterial pressure and decreased heart sounds. Tamponade may not be present in cases of large pericardial lesions (slash or gunshot wounds). Findings of even a small volume of fluid in the pericardium or injury to the cardiac compartments are indicated for immediate surgical revision. Pericardiocentesis has a very high percentage of false positive as well as false negative results and is not used in the acute phase. Subxiphoidpericardiotomy may be a quick diagnostic method in stabilized patients to verify and evacuate hemopericardium and for digital examination of the injury at the cardiac apex. Patients in hemorrhagic or cardiogenic shock require immediate sternotomy and revision of the entire heart; an alternative, especially in cases where the necessary cardiosurgical equipment is not available, is a left-sided thoracotomy through the fourth intercostal space, which allows clamping of the distal aorta to centralize blood circulation to the arteries of the aortic arch and coronary arteries, and may be extended transsternally to the right.

Minimally-invasive methods are not appropriate in the acute phase. Treatment of the individual injuries follows cardiosurgical principles. Ventricular lesions may be repaired by sutures using braided or monofilament sutures of strength 2-0, 3-0 with corresponding needle through Teflon or pericardial pad. It is recommended to first place 1 to 2 strong deep hemostatic sutures to manage the bleeding, then perform the definitive repair. The use of balloon catheter is preferred by some authors, others reject it for danger of air embolism and interference with valves and chordae tendineae. A 3-0 or 4-0 monofilament suture is sufficient for atrial lesions; pericardium may be used to close larger lesions. Lesions of the main stems of the coronary arteries are usually fatal, in the early course due to exsanguination and tamponade, later on due to myocardial ischemia. Direct suture of the coronary arteries on a beating heart is difficult to perform, ligation or suturing the artery shut are last resorts with anticipated serious results and high mortality. They may be performed as a first step in achieving hemostasis as an alternative digital inspection prior to connecting the patient to extracorporeal circulation. If the course of the operation allows and in cases of larger stems, the goal is to construct the bypass distally to the ligated area. Distal segments of coronary arteries may be ligated or sutured shut.

Valvular injuries require acute reparation except in the case of injury to the pulmonary artery valve. The operation requires extracorporeal circulation, a valvularplasty or suture of the chordae tendineae is rarely performed, usually the quickest solution is valvular replacement.

Septal lesions usually manifest with a latency, ventricular lesions must be repaired with suture or patch, usually at a subsequent time.

Cardiac herniation may occur into both hemithoraxes ortransdiaphragmatically. If the neck of the hernia is small, without operation the condition quickly becomes fatal. Reposition and direct suture with small fenestration is not complicated, a patch is rarely required.

Treatment of injuries to intrapericardial vessels (aorta, pulmonary artery, vena cava) is unimaginable without extracorporeal circulation (with the exception of small lacerations allowing the use of wall clamps and suture). Such injuries rarely reach the operating room and even then are usually fatal. Foreign objects must be removed from the heart compartments, especially from the left ventricle.

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