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BLUNT ABDOMINAL AND CHEST TRAUMA

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МИНИСТЕРСТВО ЗДРАВООХРАНЕНИЯ РЕСПУБЛИКИ БЕЛАРУСЬ
БЕЛОРУССКИЙ ГОСУДАРСТВЕННЫЙ МЕДИЦИНСКИЙ УНИВЕРСИТЕТ
2-я КАФЕДРА ХИРУРГИЧЕСКИХ БОЛЕЗНЕЙ

А. В. Жура, В. Г. Козлов

ЗАКРЫТАЯ ТРАВМА ГРУДИ И ЖИВОТА
BLUNT ABDOMINAL AND CHEST TRAUMA

Учебно-методическое пособие

Минск БГМУ 2015

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Ж91

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Отражены основные вопросы этиологии, патогенеза, диагностики закрытой травмы живота и груди. В тезисной форме указаны принципы лечения. Приведены основные травматические повреждения брюшной и грудной полостей с отражением особенностей их клинического течения, диагностики и терапии.

Предназначено для студентов 4–6-го курсов медицинского факультета иностранных учащихся, обучающихся на английском языке.

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MOTIVATIONAL CHARACTERISTIC OF THE TOPIC

Total in-class hours: 5.

Blunt trauma is a physical trauma to a body part, either by impact, injury or physical attack without abdominal (chest) wall penetration. Trauma remains the most common cause of death for all individuals between the ages of 1 and 44 years and is the third most common cause of death regardless of age. It is also the leading cause of productive life lost. The majority occurs in motor vehicle accidents, in which rapid deceleration may propel the driver into the steering wheel, dashboard, or seatbelt causing contusions in less serious cases, or rupture of internal organs from briefly increased intraluminal pressure in the more serious, dependent on the force applied. Worldwide, approximately 1.3 millions of deaths occur annually due to the trauma. Road traffic injuries claimed about 3400 lives each day. In Belarus, road traumas cause 13–18 deaths per 100 000 population. For these reasons, trauma must be considered a major public health issue.

The purpose is to study the main causes, incidence, diagnostics, first aid and treatment of blunt abdominal and chest trauma

Objectives are:

1) to learn main etiological causes of blunt trauma;
2) to learn methods of investigations of blunt trauma;
3) to learn common clinical features of abdominal and chest trauma;
4) to make diagnosis of injures of abdominal and chest organs;
5) to be able to assess severity of trauma;
6) to be able to perform first aid to a patient;
7) to know current treatment methods of injures of abdominal and chest trauma.

Requirements for the initial knowledge level.

To learn the topic completely the student must know:

- propaedeutics of internal diseases (methods of clinical evaluation of abdominal and chest organs);
- human anatomy (localization and structure of internal organs);
- topographic anatomy and operative surgery (main surgical approaches to abdominal and chest organs);
- general surgery (basic principles of surgical infections and sepsis, hemorrhage).

Test questions from related disciplines:

1. Normal and topographic anatomy of abdominal organs.
2. Normal and topographic anatomy of chest organs.
3. Clinical evaluation of abdominal and chest cavities.
4. Methods of investigations of abdominal and chest cavities.
5. Surgical approaches to abdominal and chest organs.
6. General signs of hemorrhage.
7. Evaluation of blood loss volume.

Test questions:
1. Classification of abdominal and chest trauma.
2. Blunt trauma pathogenesis.
3. Diagnostics of blunt trauma.
4. Principles of treatment.
5. Anterior abdominal wall injuries.
6. Hollow and parenchymal abdominal organ injuries.
7. Retroperitoneal organ injuries.
8. Rib fractures.
9. Haemothorax and pneumothorax.
10. Trauma of great vessels of the chest.
11. Cardiac tamponade.

STUDY MATERIAL

BLUNT ABDOMINAL TRAUMA

Blunt abdominal trauma comprises 75 % of all blunt traumas and is the most common example of this injury. The most frequently injured organ as a result of blunt abdominal trauma is the spleen (40–55 %), followed by the liver (35–40 %). Although the hollow organs are injured less frequently (15 %), delay in diagnosis results in high rates of morbidity and mortality with these injuries. In patients with lower rib fractures, called the «abdominal ribs», solid organ trauma should be suspected until proven otherwise. Splenic and/or hepatic injury is identified in 10–20 %. As many as 40 % of patients with hemoperitoneum show no findings on initial physical examination.

CLASSIFICATION

By Shott A.V., Shott V.A., Tretyak S.I.

By origin:

a) Vehicle;
b) Criminal;
c) Sport;
d) Accident at work;
e) Off-the-job injury;

By mechanism:

a) Straight impact;
b) Compression;
c) Fall from a height;
d) Explosion wave.

By localization:

a) Anterior abdominal wall injuries:
- Contusion;
- Hematoma;
- Fascial and muscles rupture.

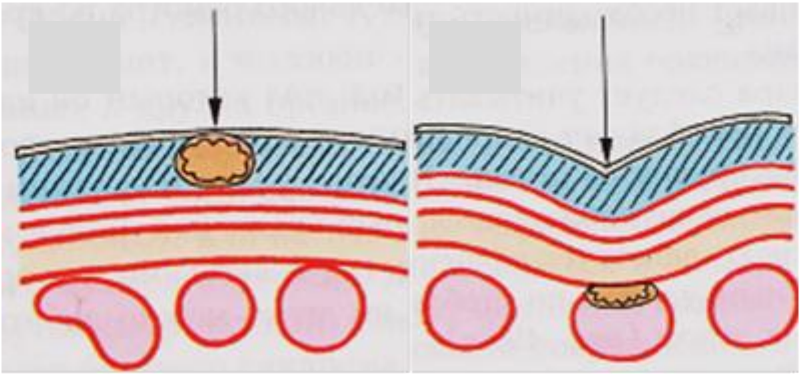
b) Blunt abdominal trauma:
- Hollow abdominal organ injury;
- Parenchymal abdominal organ injury.

c) Retroperitoneal space injury.

PATHOGENESIS

Direct blow mechanism is the influence of brief high-energy blow to abdominal wall and organs**.**

The severity of injuries depends on impacting agent, condition of abdominal wall muscles, strength of influence etc. ***Abdominal wall injuries*** (contusion, hematoma, fascial and muscle rupture, fig. 1, *a*) occur when abdominal muscles are strained and strength of the impact is slight or moderate. When abdominal wall is relaxed, it is usually remained undamaged and all energy of the blow goes to internal organs through it causing their damage (fig. 1, *b*).



a ***b***

Fig. 1. Mechanisms of injuries:
a — the muscles of abdominal wall are tensed; *b* — the muscles of abdominal wall are relaxed

Another mechanism of injure in direct blow is ***hydrodynamic wave*** – high energy wave that spreading throughout filled hollow organ (like stomach and bladder, fig. 2). The wave can result in organ rupture.

Fragments of fractured pelvic bones and ribs may also damage adjacent organs such as bladder, rectum, uterus, spleen, liver etc. (fig. 3).

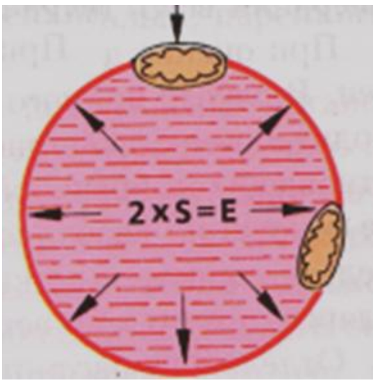


Fig. 2. Hydrodynamic wave

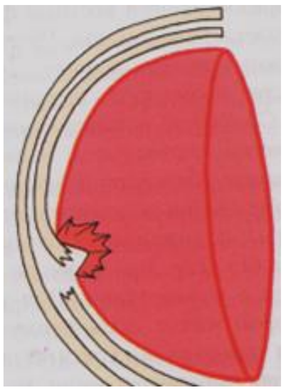


Fig. 3. Rupture of the liver by fractured rib

Compression is a prolonged influence of great strength, for example by a car wheel (fig. 4). Increasing compression leads to crushing of fixed organ (like liver, pancreas, spleen).

Fall from a height. While a body falls from a height it is acquiring a kinetic energy. At the moment of hitting the ground internal organs continue to move, rupturing their walls, ligaments and mesenteries (fig. 5).

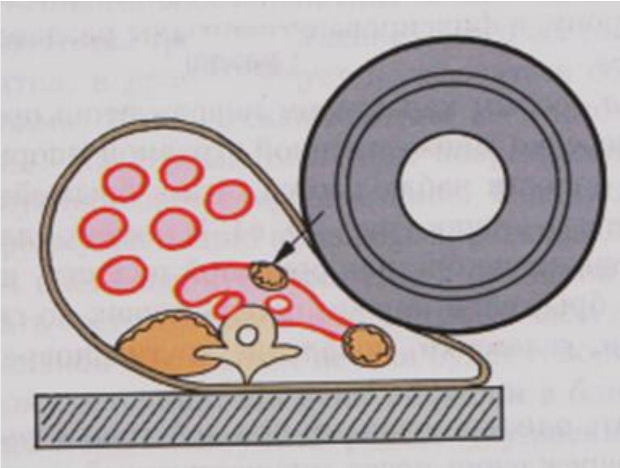


Fig. 4. Mechanism of compression

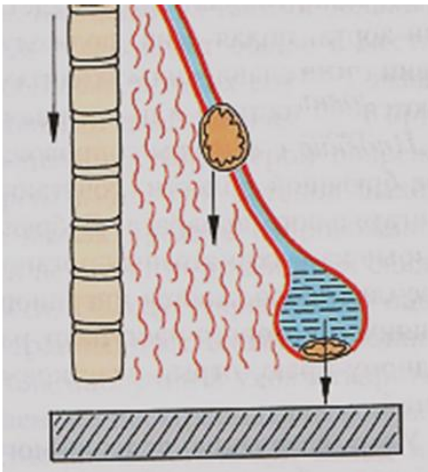


Fig. 5. Fall from a height

Explosion wave ***is a combination of straight impact, compression and fall.***

DIAGNOSTICS

The abdomen is a diagnostic black box. Fortunately, with few exceptions, it is not necessary to determine which intra-abdominal organs are injured, only whether an exploratory laparotomy or laparoscopy is necessary.

Physical examination is a crucial part of the initial evaluation; however, signs of clinically important blunt abdominal trauma are not reliable in severe trauma. Physical examination alone has a sensitivity of only ~35 %, positive predictive value of 30–50 %, and a negative predictive value of about 60 %.

Unreliable physical examination (the sensitivity of the physical examination is only 20 %):

- Alcohol or drug intoxication;
- Spinal cord injury;
- Pregnancy;
- Glasgow coma score < 10;
- Multiple extra-abdominal injuries.

Main symptoms:

- Pain at the site of blow;
- Intra-abdominal hemorrhage up to hemorrhagic shock;
- Peritonitis (blood, hollow organs content);
- Retroperitoneal hematoma and phlegmon (rupture of the retroperitoneal organs — 2, 3, 4 parts of the duodenum, kidney, bladder, rectum).

Radiography. Chest x-ray must be a standard part of the initial evaluation of patients sustaining potential blunt abdominal trauma. Concomitant thoracic visceral injuries may occur and must be considered as well.

Pneumoperitoneum (fig. 6) may indicate hollow viscus injury warranting laparotomy. Just as with the physical examination, the abdominal X-ray can be unreliable in underlying intra-abdominal injury. Nevertheless, review of the abdominal part of a pelvic X-ray screening for pelvic fracture is of potential use, especially in the patient who is unreliable.

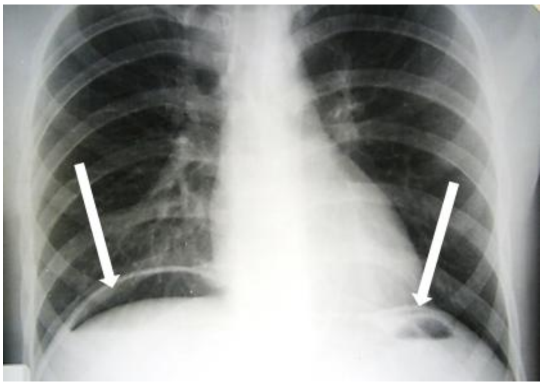
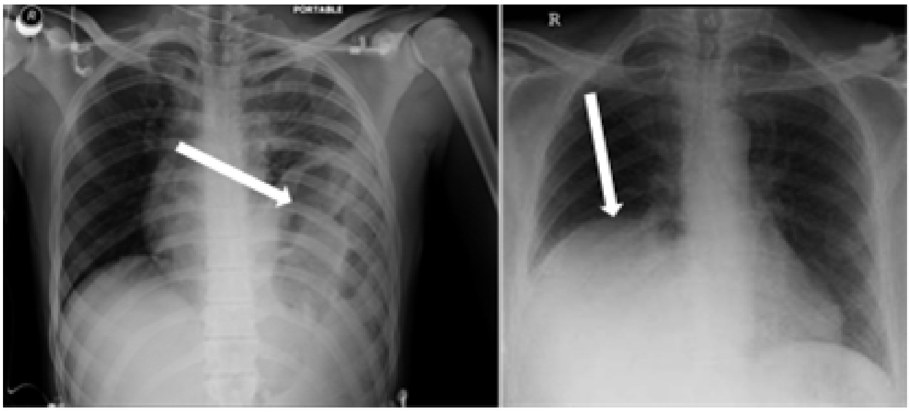


Fig. 6. Pneumoperitoneum. Free gas (arrows) under the diaphragm

Signs of abdominal visceral or diaphragm rupture are rarely seen on X-ray, but an elevated hemidiaphragm, an air/fluid level in the chest, or other findings suggesting the presence of intra-abdominal viscera in the chest require investigation or celiotomy (fig. 7).



a ***b***

Fig. 7. Diaphragmatic rupture:
a — abdominal viscera in thoracic cavity; *b* — elevated right hemidiaphragm

Ultrasonography. With an overall sensitivity of 84 % and a specificity of 99 %, US was most sensitive and specific for the evaluation of hypotensive patients with blunt abdominal trauma (sensitivity 100 %, specificity 100 %), similar to CT and diagnostic peritoneal lavage.

US has become the surgeon's and traumatologist's «stethoscope» for patients with abdominal trauma. The advantages of this technique are that it is relatively easy to learn, cost-effective, noninvasive, takes only a few minutes, has no radiation, can be repeated as many times as needed, and can be performed simultaneously with the resuscitation effort.

The goal of the exam is to detect fluid in easily accessible areas: precordial (intrapericardial), Morrison's pouch, left upper quadrant pouch of Douglas, and the pelvis. US can detect a volume of fluid as low as 200 ml; however, injuries not resulting in hemoperitoneum or hollow visceral injury without extravasation of enough enteric content may be missed. One major advantage is that the US exam can be repeated serially and when clinical status changes.

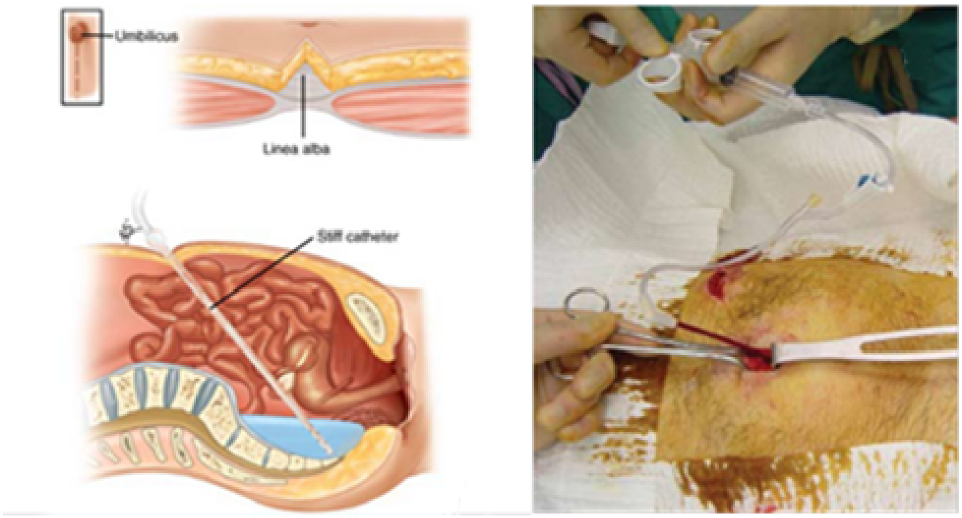
Computed Tomography. CT allows a complete and noninvasive assessment of the abdominal and pelvic cavities, retroperitoneal structures, soft tissues, and bones. CT is especially reliable for assessment of the liver and the spleen.

The accuracy in stable patients with blunt abdominal trauma is excellent, with a reported sensitivity and specificity approaching 98 %. The negative predictive value is 99 %, and thus a negative CT excludes very reliably the need for an immediate laparotomy in the vast majority of patients. For these reasons, CT has become the favored diagnostic procedure in blunt trauma, and should be obtained in most patients, provided they are hemodynamically stable.

CT is particularly useful when the physical examination is unreliable or equivocal. Several additional advantages of CT are that it is noninvasive, can define the location and extent of solid organ or retroperitoneal injuries, can detect ongoing bleeding when intravenous (IV) contrast is used. Unless contraindicated, IV contrast agent should be used when CT is obtained for evaluation of blunt abdominal trauma to get a better definition of solid parenchymal injury, blood flow, and extravasation. Detection of hollow visceral injuries is less accurate and less reliable, even with quality contrast-enhanced CT. Nevertheless, certain findings on CT may suggest strongly the presence of an underlying injury to hollow viscera or to the mesentery; these CT findings include pneumoperitoneum, leak of the contrast agent into the peritoneal cavity, thickening of bowel wall or the mesentery, and free fluid without solid visceral injury. If any of these signs are found or there is other suspicion of hollow viscus injury, an emergent laparotomy should be performed.

Diagnostic Peritoneal Lavage. Prior to the advent of the US exam, DPL had become the gold standard for blunt abdominal trauma. Only 30 ml of blood can produce a microscopically positive test. DPL is very sensitive (sometimes possibly too sensitive) and thus not specific. Currently, with the US exam, DPL is used only rarely unless FAST is either unavailable or equivocal or when CT is contraindicated.

The technique may be performed open or with a needle and wire passed into the intraperitoneal cavity using the Seldinger technique (fig. 8). Under local anesthesia, an incision midline below the umbilicus incision is performed. Once the skin and the fascia are incised, the peritoneum should be incised under direct visualization. After the catheter is inserted, aspiration with a 20 ml syringe is performed. If more than 10 ml of gross blood is obtained, the test is considered positive and terminated. Otherwise, 1,000 ml of 0.9% normal saline is instilled into the peritoneal cavity, and the fluid is drained by gravity.



a *b*

Fig. 8. Technique of Diagnostic Peritoneal Lavage:
a — scheme; *b* — operative photo

The DPL is considered positive when the return fluid is grossly bloody or evidence of enteric content is seen. If the fluid is pink or clear, a sample is sent to the laboratory for quantitative determination of red and white blood cells or signs; the criteria are outlined.

DPL interpretation

Positive:

- RBC more than 100,000 mm^3;
- WBC more than 500/mm^3;
- Bile;
- Bacteria;
- Feces/intestinal content.

Intermediate:

- RBC 50,000–100,000/mm^3;
- WBC 100–500/mm^3.

When the criteria are negative, clinically important intra-abdominal bleeding is highly unlikely. In contrast, DPL is oversensitive in that not all patients with a positive DPL have a serious enough injury to warrant operative intervention. Additional limitations of DPL include the inability to detect retroperitoneal injury or solid organ injury in the absence of hemoperitoneum, and it is contraindicated in advanced pregnancy or with a history of multiple previous laparotomies; a pelvic fracture can produce a false-positive exam in the absence of solid or hollow visceral injury.

PRINCIPLES OF TREATMENT

The very first goal in treatment of a patient with blunt abdominal trauma is to assess the severity of trauma and to found the patient with internal bleeding and hemorrhagic shock who will definitely require emergent surgery to control the bleeding. According to this, the patients are divided into three groups: *stable* patients, *unstable* patients and *agonal* patients. The groups require different management.

Shock classification and initial fluid resuscitation

Classic signs and symptoms of hemorrhagic shock are tachycardia, hypotension, tachypnea, mental status changes, diaphoresis, and pallor (tabl. 1). In general, the quantity of acute blood loss correlates with physiologic abnormalities. For example, patients in class II shock are tachycardic but they do not exhibit a reduction in blood pressure until over 1500 mL of blood loss, or class III shock. Physical findings should be used as an aid in the evaluation of the patient's response to treatment.

Table 1

Signs and symptoms of advancing stages of hemorrhagic shock

	ClASS I	ClASS II	ClASS III	ClASS IV
Blood loss (mL)	Up to 750	750–1500	1500–2000	> 2000
Blood loss (%BV)	Up to 15 %	15–30 %	30–40 %	> 40 %
Pulse rate	< 100	> 100	> 120	> 140
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure (mm Hg)	Normal or increased	Decreased	Decreased	Decreased
Respiratory rate	14–20	> 20–30	30–40	>35
Urine output (mL/h)	> 30	> 20–30	5–15	Negligible
CNS/mental status	Slightly anxious	Mildly anxious	Anxious and confused	Confused and lethargic

Management of stable patients. Patients are judged to be *stable* when their vital signs are normal initially or when the vital signs return to normal after the initial IV bolus. A more detailed clinical history must then be obtained. Careful evaluation is necessary to define the extent of injury. The decision for continued observation or intervention is based on the mechanism of injury and findings on evaluation. The decision to treat by observation requires careful and repeated assessment. As the physical examination may not be reliable in a number of cases, serial examination will be crucial in decision making.

Patients who appear stable but have *risk factors for potential serious injury* mandate particularly careful observation, because delayed clinical deterioration may occur.

Risk factors for potential serious injury (high-energy trauma):

- Fall from higher than 3 meters;
- Ejection from a vehicle;
- Motor vehicle crash at speeds exceeding 60 km/h;
- Motorbike accident;
- Major fracture;
- First rib fracture;
- Lower costal rib fracture;
- Seat belt restraint mark.

Those who fell from more than 3 m, were ejected from a vehicle, were involved in a motor vehicle crash of more than 60 km/h, or were in a motorbike accident must be considered ***high-energy trauma***. Subtle signs such as fracture of the first rib, abdominal wall ecchymosis from the seat belt («seat belt sign»), or major fractures of long bones or pelvis also imply high-energy trauma and warrant close observation. Fractures of the lower «abdominal» ribs should suggest possible abdominal solid organ injury.

In patients with a closed head injury, intoxication, drug abuse, or those who require neurosurgery or orthopedic surgery where the physical examination will be unreliable for several hours because of the anesthetic, some objective evaluation of the abdomen is necessary, such as a US, CT, or DPL.

Low-energy trauma, such as being struck with a club or falling from a bicycle, usually does not result in widely distributed injuries. However, potentially lethal lacerations of internal organs still can occur, because the net energy transfer to any given location may be substantial.

Management of unstable patients. Patients are considered unstable when any vital sign, such as pulse, ventilatory rate, or blood pressure, is significantly abnormal. The instability is produced by either respiratory compromise or hypovolemia, so the initial approach must include the establishment of the airway, ventilation, and circulation with immediate control of any external bleeding and IV access.

After the management of airway and breathing, the next step is *fluid resuscitation* with a warm, balanced salt solution. The goal of fluid resuscitation is to re-establish tissue perfusion. Fluid resuscitation begins with a 2 L (adult) IV bolus of isotonic crystalloid, typically Ringer's lactate. For persistent hypotension, this is repeated once in an adult before red blood cells (RBCs) are administered. Patients who have a good response to fluid infusion (i.e., normalization of vital signs, clearing of the sensorium) and evidence of good peripheral perfusion (warm fingers and toes with normal capillary refill) are presumed to have adequate overall perfusion. *Urine output* is a quantitative, reliable indicator of organ perfusion. Adequate urine output is 0.5 mL/kg per hour in an adult, 1 mL/kg per hour in a child, and 2 mL/kg per hour in an infant < 1 year of age. Because measurement of this resuscitation-related variable is time dependent, it is more useful in the operation room and intensive care unit (ICU) setting than in initial evaluation in the trauma bay.

If stability is achieved, patients are managed according to the algorithm for stable patients. In contrast, if the vital signs do not recover or improve only temporarily with fluid resuscitation and blood transfusion, then ongoing hemorrhage should be suspected, and ***operative intervention should be indicated***.

Emergent abdominal exploration is performed using a generous midline incision because of its versatility. Liquid and clotted blood is evacuated with multiple laparotomy pads and suction to identify the major source(s) of active bleeding. The spleen and liver should be palpated and packed if fractured, and the infracolic mesentery inspected to exclude injury.

Agonal Patients. Moribund patients are those with no spontaneous ventilatory effort, no femoral pulse, and no response to painful stimuli. These patients require an emergent airway and strong consideration of immediate operative intervention for suspected hemorrhage. Accordingly, after assuring airway and breathing, a laparotomy and/or a thoracotomy must be considered.

The patients are taken to an operating room immediately, placed supine, and the abdomen explored with other minimal maneuvers. During abdominal exploration, the finding of significant or ongoing intra-abdominal hemorrhage may require cross-clamping the aorta at the diaphragmatic hiatus. The surgeon must pack and compress the bleeding area(s) and seek more stable conditions by infusing a large amount of IV fluid and blood. Most of these patients require a shortened procedure (so-called ***damage control***) with transfer to a surgical critical care unit for stabilization and later definitive repair of the intraperitoneal injury if they survive.

Non-operative management for solid viscera injury

A major advance in the last two decades has been the use of primary non-operative management for solid viscera injury, as guided by initial imaging and clinical response. Good evidence suggests that *non-operative management in both children and adults is safe, and the results are better than with a laparotomy in selected cases*. Appropriate candidates for non-operative management are those without active bleeding from solid viscera injury without evidence of hollow viscus or mesenteric injury. Observation requires hemodynamically stable patients in whom ongoing evaluation and observation can be performed. Quality CT imaging, a monitored environment, and access to emergent intervention are required. The success rate of non-operative management is high for isolated hepatic injury, but is less in splenic and especially renal injury, and is dependent on the extent of parenchymal injury (e. g., grade of liver and splenic injury). In contrast, ***non-operative management should be abandoned when hemodynamic status cannot be maintained*** after two units of packed red cells during the initial management or four units in the first 48 h.

Requirements for non-operative management

- Hemodynamically stable;
- Absence of peritonitis;
- Contrast-enhanced CT without evidence of active bleeding;
- Monitoring in an intensive care unit;
- Staff available for repeated observation;
- Operation room available 24 h.

ANTERIOR ABDOMINAL WALL INJURIES

Usual signs of slight and moderate abdominal wall injuries are ***bruise***, swelling and local pain. These conditions don't need specific treatment but selected patients with high-energy trauma may require observation in surgical department.

Hematoma is collection of blood enclosed in the abdominal wall. Treatment of hematoma includes local cold, application of anticoagulation unguent (Heparin) since the second day of treatment and puncture when hematoma is big. It usually requires observation in surgical department.

Fascial and muscle rupture occurs when high-energy blow strikes tensed abdominal muscles. It is usually accompanied by injuries of abdominal viscera and may lead to hernia formation. These patients need close observation in surgical department. Repair of rupture is usually performed after several weeks, when connective tissue has grown in the edges of rupture allowing firm suturing of the rupture.

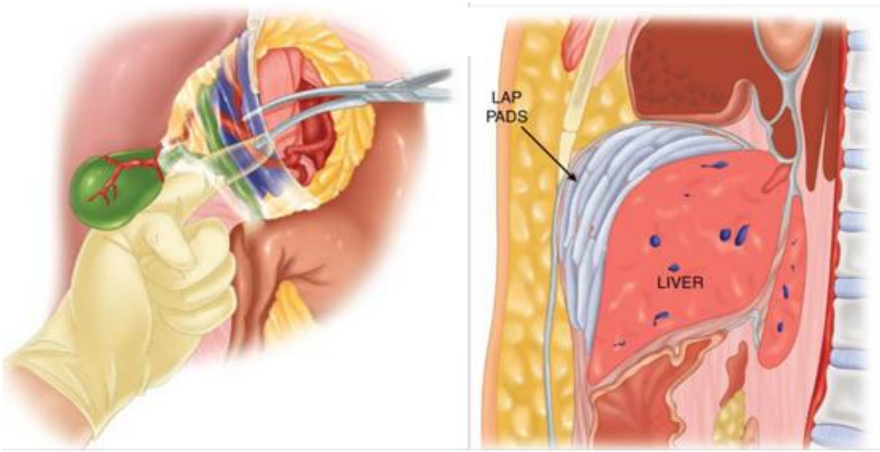
It's important to remember, that ***anterior abdominal wall injuries do not exclude*** abdominal organs damage.

LIVER INJURIES

Large size of the liver makes this organ more susceptible to blunt trauma. The main clinical syndromes are determined by blood and bile leakage into abdominal cavity. Manifestations include signs of hemorrhage up to shock and peritonitis.

Non-operative management of hepatic injuries is possible in hemodynamically stable patients who do not have overt peritonitis or other indications for laparotomy. These patients should be admitted to the ICU with frequent hemodynamic monitoring, determination of hematocrit, and abdominal examination. The absolute contraindication to non-operative management is hemodynamic instability.

In the > 10 % of patients for whom emergent laparotomy is mandated, the primary goal is to arrest hemorrhage. Initial control of hemorrhage is best accomplished using perihepatic packing and manual compression. The Pringle maneuver can help delineate the source of hemorrhage (fig. 9, *a*). Hemorrhage from most major hepatic injuries can be controlled with effective perihepatic packing (fig. 9, *b*). If the patient has persistent bleeding despite packing, injuries to the hepatic artery, portal vein, and retrohepatic vena cava should be considered. Cholecystectomy is performed for injuries of the gallbladder.



a ***b***

Fig. 9. Control of the bleeding from the liver:
a — the Pringle maneuver, performed with a vascular clamp or fingers, occludes the hepatic pedicle containing the portal vein, hepatic artery, and common bile duct; *b* — perihepatic packing packing

Numerous methods for the *definitive* control of hepatic parenchymal hemorrhage have been developed. Topical hemostatic techniques include the use of an *electrocautery* (with the device set at 100 watts), *argon beam coagulator, microcrystalline collagen, thrombin-soaked gelatin foam sponge, fibrin glue, and BioGlue. Suturing of the hepatic parenchyma* is an effective hemostatic technique. However, the «liver suture» may tear the liver capsule, and its use generally is discouraged due to the associated hepatic necrosis. A running suture is used to approximate the edges of shallow lacerations, whereas deeper lacerations are approximated using interrupted horizontal mattress sutures placed parallel to the edge of the laceration (fig. 10). Omentum can be used to fill large defects in the liver and can provide buttressing support for parenchymal sutures.

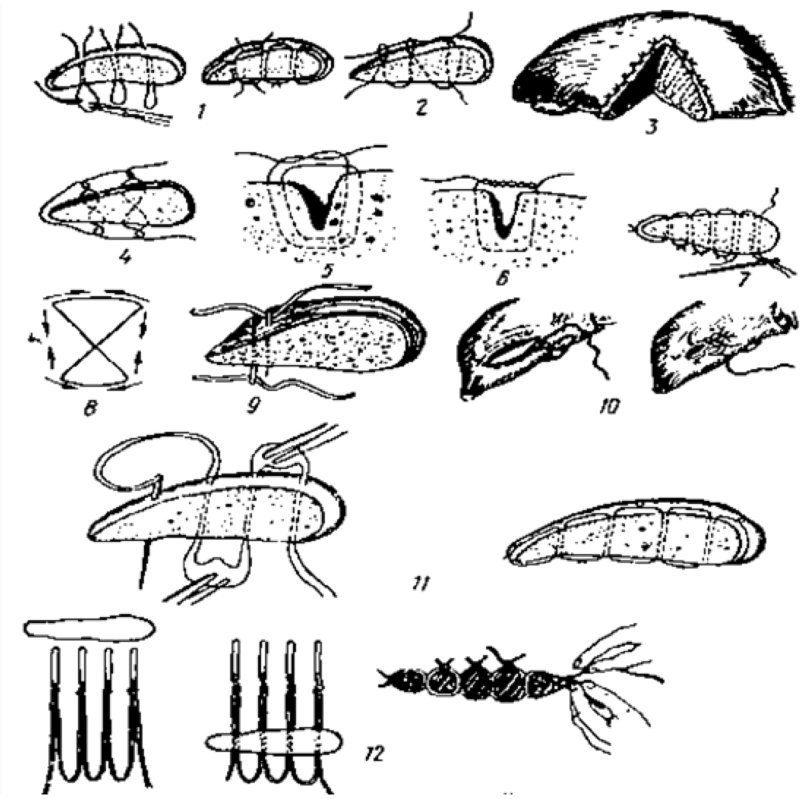


Fig. 10. Types of hepatic sutures

SPLEEN INJURIES

The spleen is the most commonly injured organ in road traffic accidents. The injuries may consist of incomplete parenchymal tears, complete lacerations or severe fragmentation with avulsion of the hilar vessels (fig. 11).

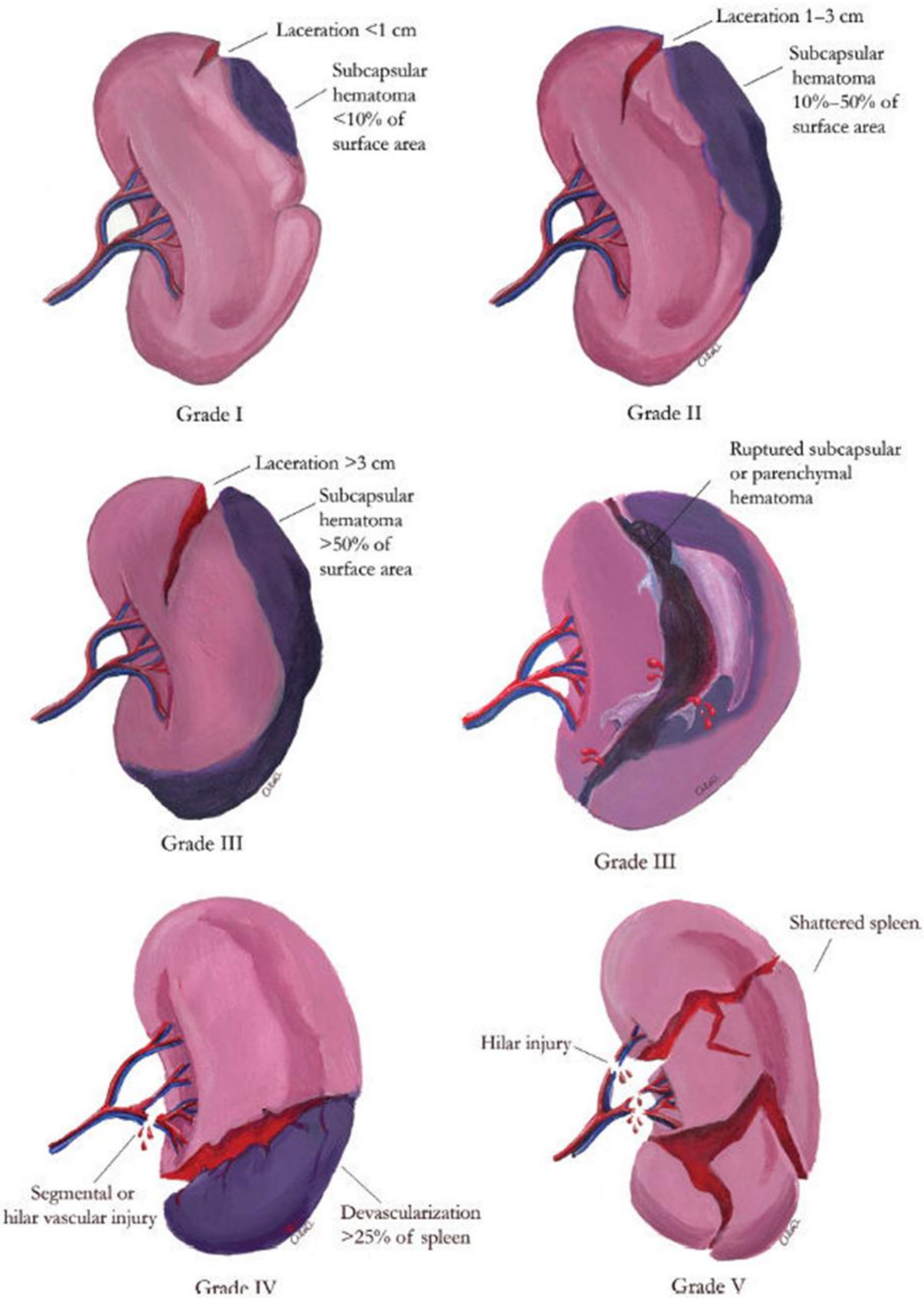
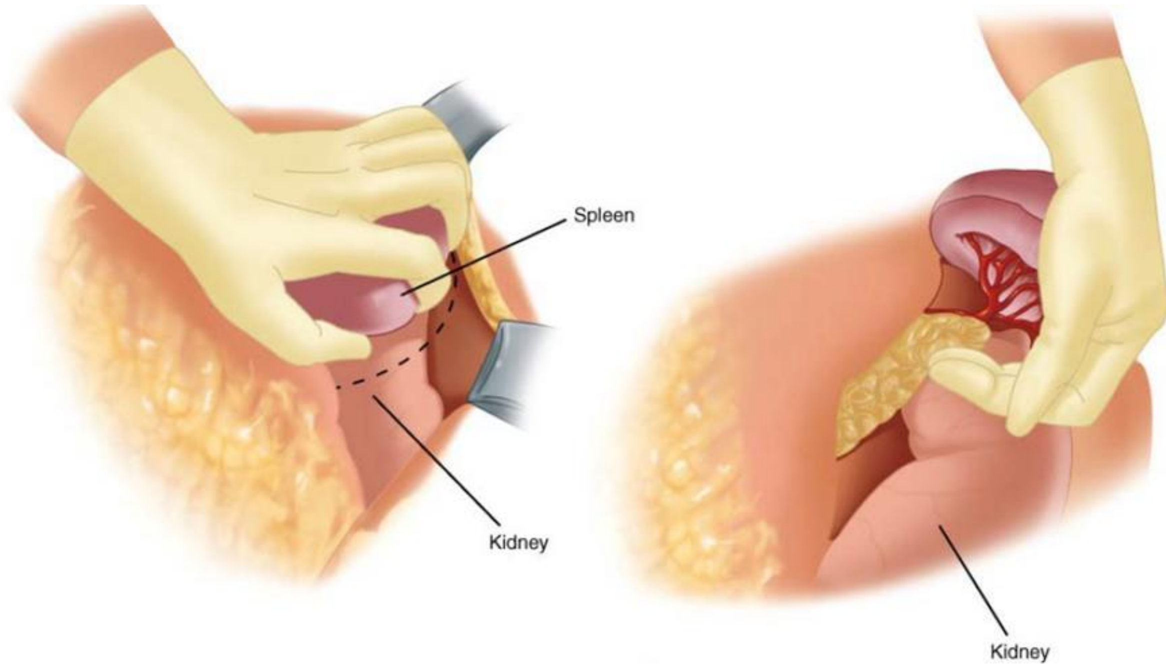


Fig. 11. Five grades of spleen rupture

The main clinical syndrome is massive hemorrhage into abdominal cavity. Clinical features of splenic injury include abdominal tenderness, hypotension and left lower rib fractures. Left shoulder-tip pain, often stressed as a symptom of splenic injury, is in fact rare, being found in only 5 % of patients. Associated chest injuries are very common.

One more mechanism of spleen injury is two-phase rupture. During the ***first phase,*** subcapsular hematoma forms inside the spleen. In few days or even weeks a rupture of the capsule may happen leading to severe intra-abdominal hemorrhage (the ***second phase***).

Splenic injuries are managed operatively by splenectomy, partial splenectomy, or splenic repair (splenorrhaphy), based on the extent of the injury and the physiologic condition of the patient. Until the 1970s, splenectomy was considered mandatory for all splenic injuries. Nowadays, non-operative management has become the preferred method of splenic salvage, only 20 to 30 % of patients with splenic trauma deserve early splenectomy. Splenectomy is indicated for hilar injuries, pulverized splenic parenchyma, or any injury of grade II or higher in a patient with coagulopathy or multiple injuries (fig. 12).



a ***b***

Fig. 12. Splenectomy:
a — mobilization of the spleen by an incision of the endoabdominal fascia 1 cm lateral to the reflection of the peritoneum; *b* — gentle rotation of the spleen allow the spleen to reach the level of the abdominal incision

Autotransplantation of splenic implants (fig. 13) may be performed after the splenectomy to achieve partial immunocompetence in younger patients.

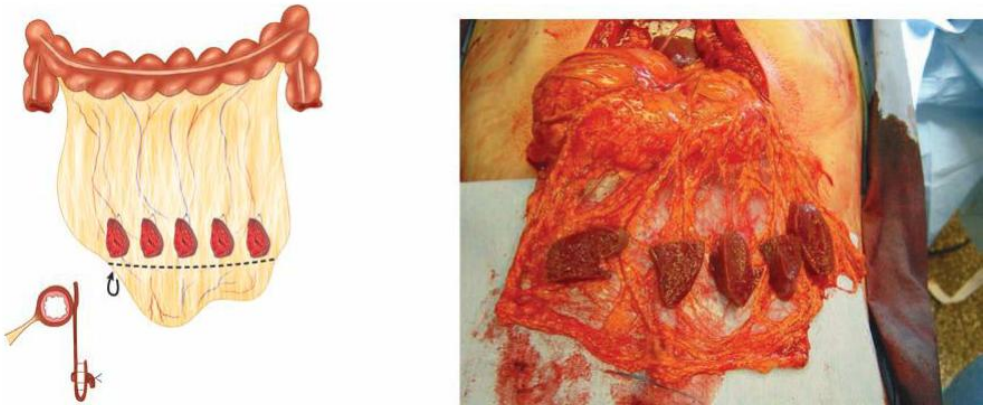


Fig. 13. Autologous splenic transplantation is performed by placing sections of splenic parenchyma, 40 × 40 × 3 mm in size, into pouches in the greater omentum

Partial splenectomy can be employed in patients in whom only the superior or inferior pole has been injured. Hemorrhage from the raw splenic edge is controlled with horizontal mattress sutures, with gentle compression of the parenchyma (splenorrhaphy, fig. 14). As in repair of hepatic injuries, hemostasis may be achieved by topical methods (electrocautery; argon beam coagulation; application of thrombin-soaked gelatin foam sponges, fibrin glue, or BioGlue), envelopment of the injured spleen in absorbable mesh, and pledgeted suture repair.

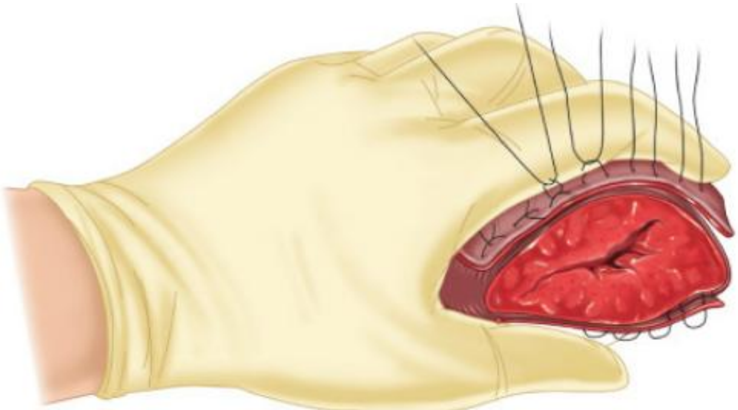


Fig. 14. Interrupted pledgeted sutures may effectively control hemorrhage from the cut edge of the spleen

STOMACH INJURIES

Clinical manifestation of stomach rupture is very close to that in perforated peptic ulcer. It includes intensive pain, generalized abdominal tenderness, and signs of peritonitis. The diagnosis is confirmed by ultrasound (fluid under the right lobe of the liver), chest or abdominal X-Ray (free gas under the diaphragm, fig. 6) and by diagnostic peritoneal lavage.

Gastric wounds can be oversewn with a running single-layer suture line or closed with a stapler. Partial gastrectomy may be required for destructive injuries, with resections of the distal antrum or pylorus reconstructed using a Billroth I or II procedure.

INJURIES OF SMALL INTESTINE

Intestinal injury following blunt trauma may be due to:

- crushing of the intestinal loops between the vertebrae and anterior abdominal wall;
- a sudden increase in the intraluminal pressure of the bowel;
- tears at relatively fixed points along the attachment of the intestinal mesentery.

Main signs of rupture of small intestine are spreading abdominal pain, peritonitis, and pneumoperitoneum (rare). Small intestine injuries can be repaired using a transverse running 3-0 suture if the injury is less than one third the circumference of the bowel (fig. 15, *a*). Destructive injuries occurring close together are treated with segmental resection followed by end-to-end anastomosis (fig. 15, *b*). Mesenteric injuries usually require suturing (fig. 15, *c*), but may result in an ischemic segment of intestine, which mandates resection (fig. 15, *d*).

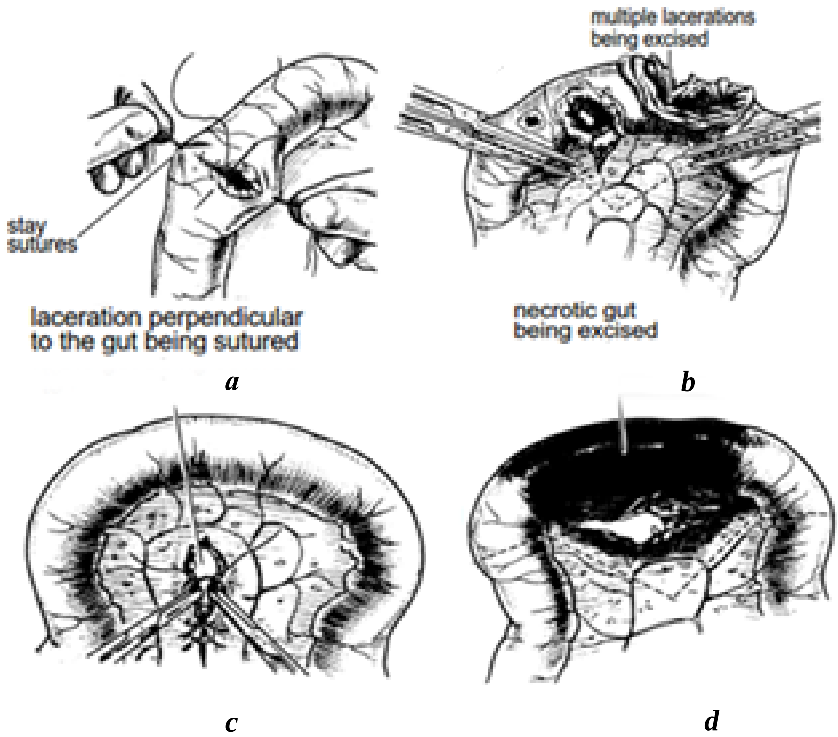


Fig. 15. Repair of small intestine injuries:
a — suturing; *b* — resection of extensive multiple wounds; *c* — suturing the tear in the mesentery; *d* — longitudinal tear of the mesentery and the gangrene of adjacent gut demanding resection

INJURIES OF DUODENUM

The spectrum of injuries to the duodenum includes hematomas, perforation and combined pancreaticoduodenal injuries. Injured duodenum leaks into the peritoneal cavity or behind it and causes a deep seated pain in the epigastrium and back, which gets steadily worse. It is accompanied by severe vomiting, fever, toxaemia, and sometimes by shock. The epigastrium becomes tender, silent, and a little distended.

The majority of duodenal hematomas are managed non-operatively with nasogastric suction and parenteral nutrition. Patients with suspected associated perforation, suggested by clinical deterioration or imaging with retroperitoneal free air or contrast extravasation, should undergo operative exploration.

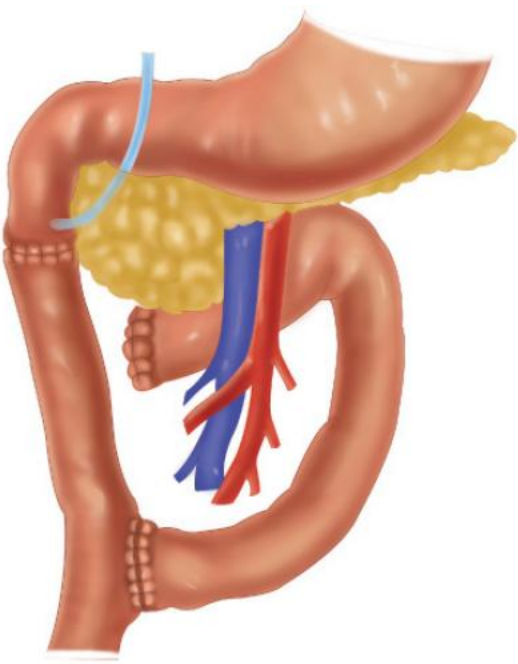


Fig. 16. Roux-en-Y duodenojejunostomy is used to treat duodenal injuries with extensive tissue loss

Small duodenal perforations or lacerations can be treated by primary repair using *a running single-layer suture* of 3-0 monofilament. Extensive injuries of the duodenum can be repaired by *débridement and end-to-end anastomosis*, *resection with placement of vascularized jejunal graft* or by *Roux-en-Y duodenojejunostomy* with the distal portion of the duodenum oversewn (fig. 16). Alternatively, a large Foley drain may be passed down into the duodenal tear for a few weeks.

If a patient hits the steering wheel of his car, he can crush both his duodenum and his pancreas against his spine. The combination of a leaking duodenum and traumatic pancreatitis (combined pancreaticoduodenal injury) may kill him. Diagnosis and treatment are difficult, and may be delayed for days because both organs lie at the back of the abdomen behind the peritoneum. Pyloric exclusion is often used to divert the gastrointestinal stream after high-risk, complex duodenal repairs (fig. 17).

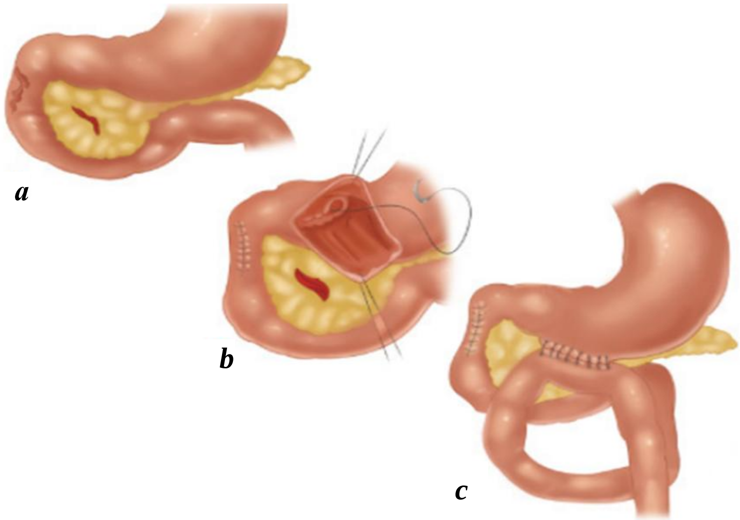


Fig. 17. Pyloric exclusion procedure: *a–c* — steps of the operation

Trauma of Pancreas

These injuries range from mild bruising to a pancreas which has been cut vertically in half. The patient may have few physical signs until a spreading retroperitoneal abscess develops.

Patients with pancreatic *contusions* (defined as injuries that leave the ductal system intact) can be treated non-operatively or with closed suction drainage if undergoing laparotomy for other indications.

Some injuries of the pancreatic head do not involve either the pancreatic or common bile duct; if no clear ductal injury is present, drains are placed. Pancreatic injuries associated with *ductal disruption* require intervention to prevent a pancreatic fistula or ascites. For distal injuries of a pancreatic body and tail a *distal pancreatectomy* should be performed. Ruptures of the duct in a pancreatic head usually require debridement or pancreatectomy and *a Roux-en-Y pancreaticojejunostomy* (fig. 18) or *pancreaticogastrostomy*. The complexity may make the *pancreaticoduodenectomy* more appropriate in patients with multiple injuries.

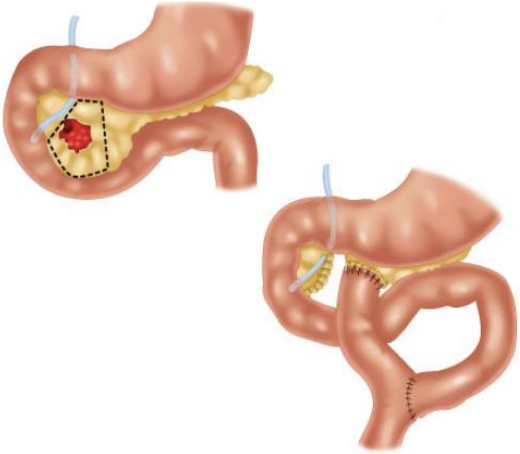


Fig. 18. Central pancreatic resection with Roux-en-Y pancreaticojejunostomy for injuries of the pancreatic head that involve the pancreatic duct

Injuries of the Large Intestine

These injuries are particularly difficult to treat, because:

1. The peritonitis which follows them is more serious than that which follows injuries to the small gut. *Fecal peritonitis is particularly deadly*. Even a small suture line can leak, and its consequences are only partly prevented by a drain.

2. *Retroperitoneal infection* from the ascending and descending colon is at least as dangerous as peritonitis.

3. The patient's gut will not have been prepared for anastomosis.

4. He will probably have a haemoperitoneum which can readily become infected. All these factors make *end-to-end anatomosis particularly dangerous*. For, all these reasons it is a good principle ***never to suture and close any but the smallest wounds of the large intestine***.

Currently, three methods for treating colonic injuries are used: primary repair, end colostomy, and primary repair with diverting ileostomy.

Primary repairs include lateral *suture repair* or *resection* of the damaged segment with reconstruction by ileocolostomy or colocolostomy. All suturing and anastomoses are performed using a running single-layer technique (fig. 19). The proximal loop (diverting) colostomy or ileostomy may be added to protect the suture line and prevent the severe fecal peritonitis in case of anastomotic insufficiency.

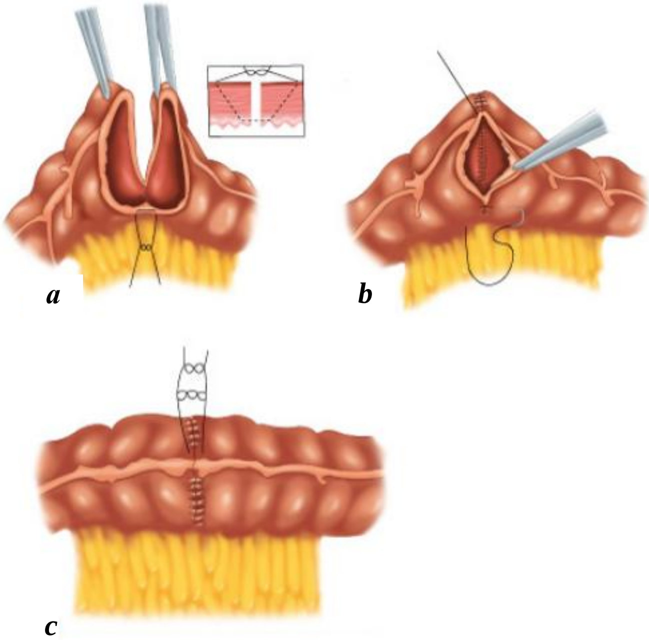


Fig. 19. Technique for large bowel repair and anastomosis: *a* — the running, single-layer suture is started at the mesenteric border; *b* — stitches are spaced 3 to 4 mm from the edge of the bowel and advanced 3 to 4 mm, including all layers except the mucosa; *c* — the continuous suture is tied near the antimesenteric border

Patients with advanced peritonitis and devastating colon injuries require damage control by temporary colostomy. The attempt to primary repair in such conditions will lead to suture leakage and horrible mortality. The appropriate procedures are: creating a loop colostomy by bringing the injured colon outside the patient's abdomen, and a resection of the injury with bringing the ends of the bowel out as a double-barrelled colostomy (fig. 20).

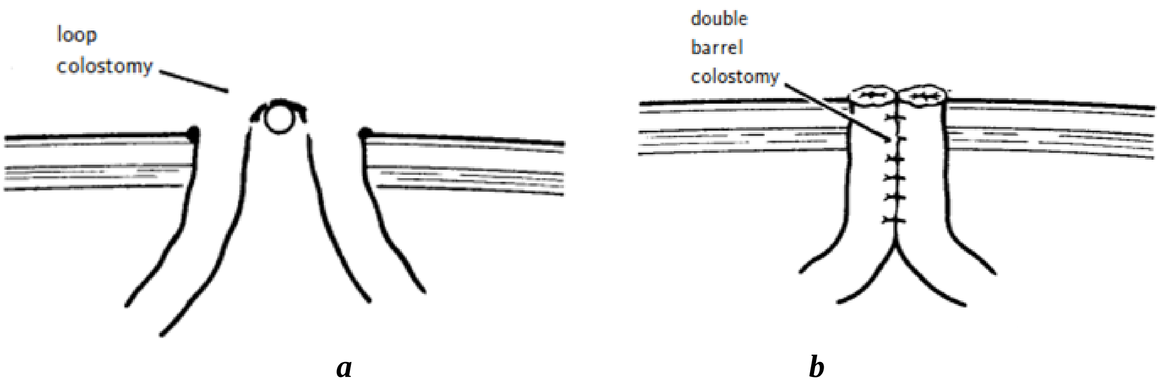


Fig. 20. Techniques of colostomy: *a* — loop; *b* — double-barrel

Rectal injuries are similar to colonic injuries, but access to extraperitoneal injuries is limited due to the surrounding bony pelvis. Therefore, indirect treatment with intestinal diversion is usually required. The current options are loop ileostomy or sigmoid loop colostomy (fig. 21) that completely diverts the fecal flow, allowing the low rectal injury to heal.

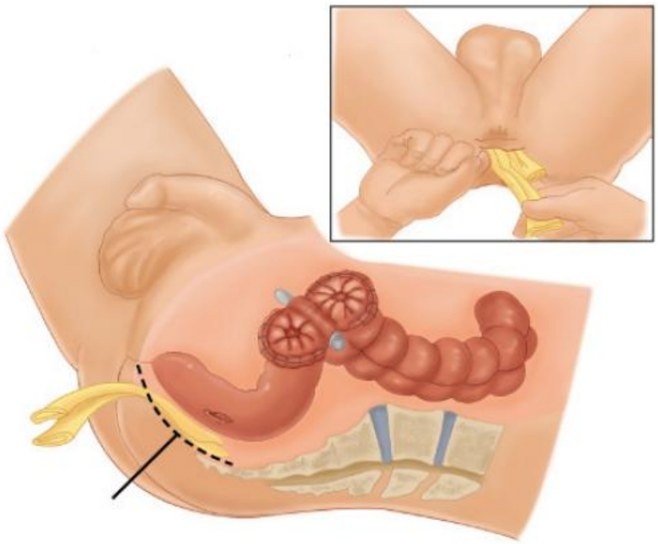
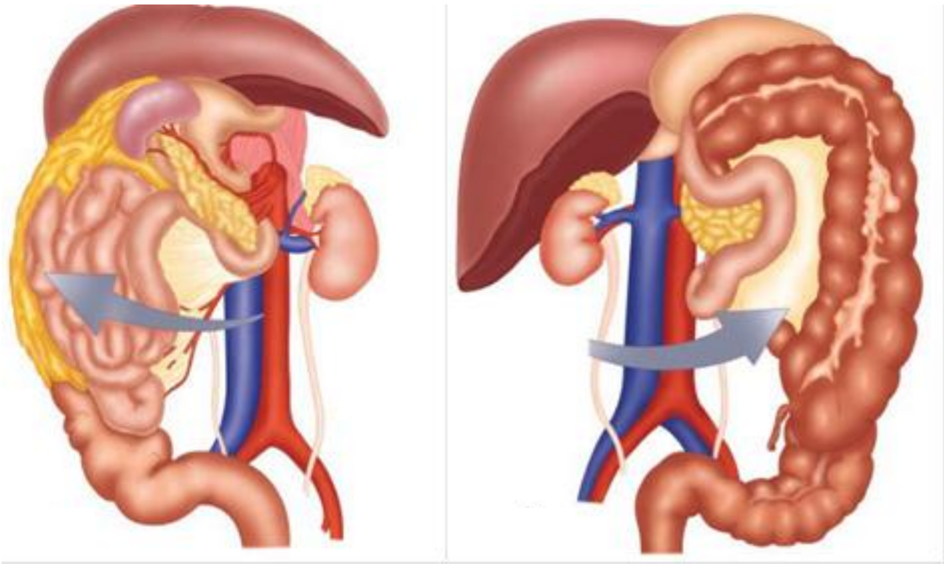


Fig. 21. Treatment of rectal injuries by creating a loop colostomy and presacral draining

INJURIES OF ABDOMINAL VASCULATURE

Injury to the major arteries and veins in the abdomen are a technical challenge. Blunt trauma most commonly involves renal vasculature and rarely the abdominal aorta. Blunt injuries with associated pelvic fractures are the most common scenarios in patients with iliac artery injuries. In general, outcome after vascular injuries is related to (a) the technical success of the vascular reconstruction and (b) associated soft tissue and nerve injuries.

Injuries of the iliac vessels pose a unique problem for emergent vascular control due to the number of vessels, their close proximity, and cross circulation. Proximal control at the infrarenal aorta arrests the arterial bleeding and avoids splanchnic and renal ischemia; however, venous injuries are not controlled with aortic clamping. Tamponade with a folded laparotomy pad held directly over the bleeding site usually will establish hemostasis sufficient to prevent exsanguination. If hemostasis is not adequate to expose the vessel proximal and distal to the injury, sponge sticks can be strategically placed on either side of the injury and carefully adjusted to improve hemostasis. The aorta, celiac axis, proximal superior mesenteric artery (SMA), and left renal arteries can be exposed with a left medial visceral rotation (fig. 22, *a*). Inferior vena cava injuries are approached by a right medial visceral rotation (fig. 22, *b*).



a ***b***

Fig. *22*. Methods to achieve retroperitoneal space:
a — left medial visceral rotation; *b* — right medial visceral rotation

GENITOURINARY TRACT INJURIES

A blow in a patient's loin can injure his kidneys. Mild kidney injuries are common. They cause a small break in the renal capsule, a small hematoma, and hematuria. More severe kidney injuries tear the renal capsule, pelvis, and calyces; they can tear away the poles of a patient's kidneys, and pulp them, or they can tear his kidneys from their pedicles. The perirenal fascia usually keeps the escaping blood close to the injured kidney.

Hematuria is the major sign; it is usually mild, and stops spontaneously. If a patient passes blood in his urine after an accident, but has no other signs, it is probably coming from his kidneys. If bleeding is more severe, blood may clot in a ureter and block it, so that the passage of blood stops. Kidney injuries do not usually cause much shock, so if a patient is severely shocked, suspect some other disaster also, such as a rupture of his spleen, or liver.

Over 90 % of all blunt renal injuries are treated nonoperatively. Hematuria typically resolves within a few days with bed rest. Persistent gross hematuria may require embolization, whereas urinomas can be drained percutaneously. Operative intervention after blunt trauma is limited to renovascular injuries and destructive parenchymal injuries that result in hypotension.

Parenchymal renal injuries are treated with hemostatic and reconstructive techniques similar to those used for injuries of the liver and spleen: topical methods (electrocautery; argon beam coagulation; application of thrombin-soaked gelatin foam sponge, fibrin glue, or BioGlue) and suture repair. The collecting system should be closed separately, and the renal capsule should be preserved to close over the repair of the collecting system (fig. 23). For destructive parenchymal or irreparable renovascular injuries, nephrectomy may be the only option.

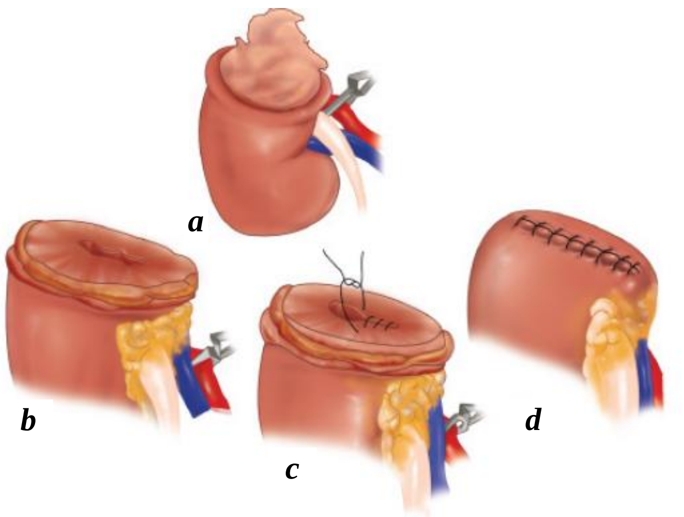


Fig. 23. Renorrhaphy: *a* — vascular occlusion controls bleeding; *b* — debridement with renal capsule preserved; *c* — separate closing of the collecting system with absorbable suture; *d* — closing of the capsule

Injuries to the ureters are uncommon but may occur in patients with pelvic fractures. An injury may not be identified until a complication (i. e., a urinoma) becomes apparent. Injuries are repaired using 5-0 absorbable monofilament. In damage control circumstances, the ureter can be ligated on both sides of the injury and a nephrostomy tube placed.

Bladder injuries are subdivided into those with *intraperitoneal* extravasation and those with *extraperitoneal* extravasation. Ruptures or lacerations of the intraperitoneal bladder are operatively closed with a running, single-layer, 3-0 absorbable monofilament suture. Extraperitoneal ruptures are treated non-operatively with bladder decompression for 2 weeks. Urethral injuries are managed by bridging the defect with a Foley catheter, with or without direct suture repair.

CHEST TRAUMA

Blunt trauma to the chest may involve the chest wall, thoracic spine, heart, lungs, thoracic aorta and great vessels, and rarely the esophagus.

Thoracic injury accounts for 25 % of all severe injuries. In a further 25 %, it may be a significant contributor to the subsequent death of the patient. In most of these patients, the cause of death is haemorrhage. Chest injuries are often life-threatening, either in their own right or in conjunction with other system injuries. About 80 % of patients with chest injury can be managed non-operatively. The key to a good outcome is early physiological resuscitation followed by a correct diagnosis.

DIAGNOSTICS

Most of thoracic injuries can be evaluated by *physical examination* and *chest radiography*, with supplemental *CT scanning* based on initial findings. The diagnostic *bronchoscopy* may be useful in rupture of main bronchi. The main diagnostic steps are listed below.

Anamnesis. If possible, it is necessary to know the history of a chest injury. The greater the force, the greater the chances that patient has a severe injury to thoracic organs.

Examination. If a patient is conscious and breaths easily, he can describe the pain and show exactly where it is. If unconscious, he should be undressed and examined carefully. Trauma signs (bruise, skin abrasion, hematoma) may indicate the site of injury. The next step is assessment of the rate and depth of the patient's breathing. Cyanotic skin, great respiratory efforts and paradoxical respiration speak of pneumothorax, flail chest, bronchus ruptures etc. Low arterial pressure indicates hemothorax, aortic rupture.

If the ribs are broken, patient's attempts to take a deep breath will lead to sharp pain in the affected area. Abnormal distention of the patient's jugular veins is the sign of the inadequate venous return to the heart due to the: tension pneumothorax, mediastinal shift, and especially cardiac tamponade. Cyanosis of the skin, mucous membranes and finger nails indicates severe damage and breathing insufficiency whereas paleness shows massive internal bleeding.

Palpation may reveal the areas of sharp pain, which are usually located at the site of impact. The pain in broken ribs is intensified by springing the ribs with gentle but sharp pressure on the sternum. One of the signs of a pneumothorax is subcutaneous emphysema described as following. The skin over the trunk, neck and sometimes face gives a peculiar crackling feel to the examining fingers (crepitation) and, in severe cases, the face and neck may become grossly swollen.

On *percussion* of the chest a dull sound indicates the presence of blood in thoracic cavity whereas a hyperresonant sound is the sign of pneumothorax.

Auscultation of the chest also gives important information about thoracic injuries. Failure to auscultate or very weak breathing sounds indicate pneumo- or hemothorax. Muffled heart sounds are signs of cardiac tamponade.

Chest X–ray. The radiography may confirm rib fractures (fig. 24), and will identify underlying lung damage or haemorrhage (fig. 25) that might not have been suspected from the trivial nature of the patient's symptoms.

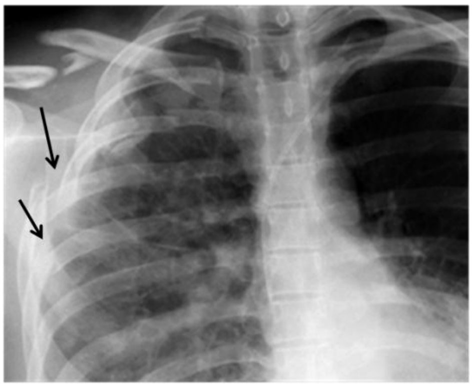
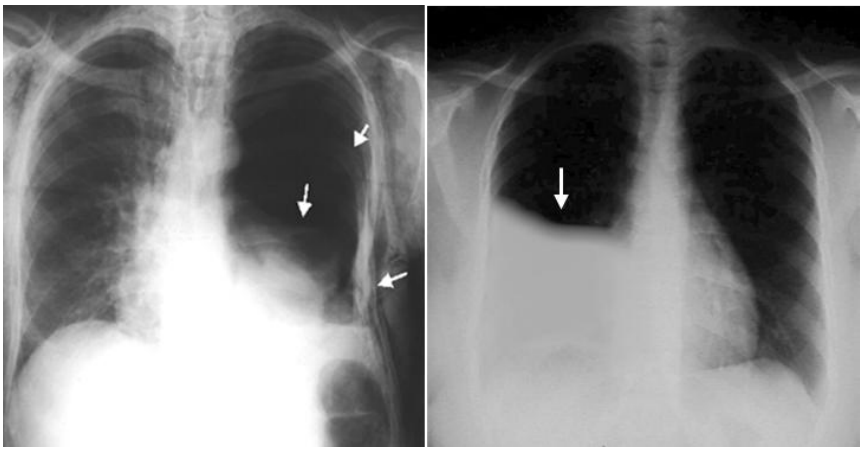


Fig. 24. Fractures of the ribs (arrows)

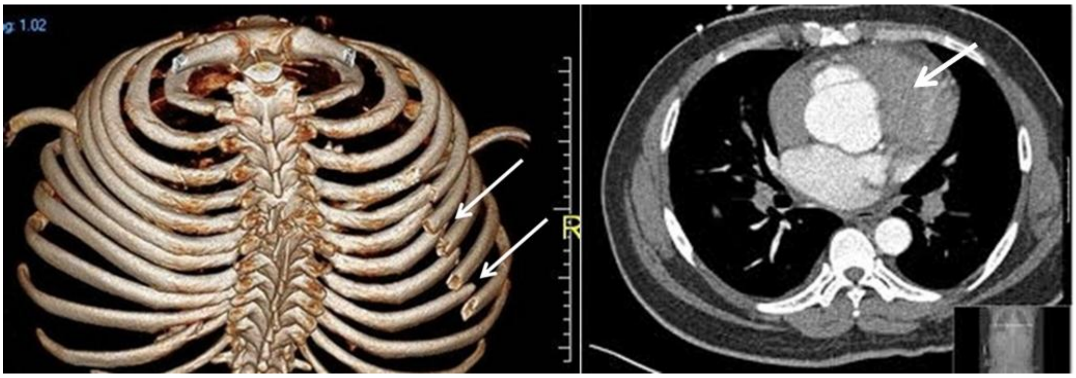
A chest X–ray may not always demonstrate a fracture. X–rays show only about half of the fractures that exist. If the patient has clinical signs of fractured ribs, he or she should be treated for this condition in spite of a negative X–ray. A repeat X–ray at 2 weeks may show fracture callus and confirm the diagnosis.



a ***b***

Fig. 25. Complications of chest trauma: *a* — pneumothorax due to the rib fractures (arrows); *b* — hemothorax (arrows)

Computed tomography. CT scans are more sensitive at detecting fractures, especially pathological fractures, they may also reveal metastatic tumor deposits elsewhere in the skeleton, or be suggestive of metabolic bone disease. CT is especially important in diagnosis of such severe complications as hemo- pneumothorax, cardiac tamponade, rupture of esophagus, aorta and main veins, diaphragmatic rupture etc. (fig. 26).



a ***b***

Fig. 26. Chest CT: *a* — bone scans identify rib fractures (arrows); *b* — hematoma in mediastinum (arrow) due to the aortic rupture

Fig. 27. Blood in pleural cavity (arrow)

Chest ultrasound. Ultrasound of a chest is not common investigation procedure because of large amount of air contained in lungs, which makes difficulties in passing of ultrasound beam. Nevertheless, chest ultrasound may found blood or exudate in pleural sinuses and assess its quantity (fig. 27).

PRINCIPLES OF TREATMENT

The first step in management of such a patient is *assessment of a severity of the chest injury*. Uncomplicated fracture of rib usually needs pain control and observation. Severe complicated trauma is indication to surgery in majority of cases. The procedure that is likely needed most urgently is to have blood and air drained from a pleural cavity through a chest tube – rapidly and, if necessary, on both sides. This is the critical procedure in thoracic surgery. ***More than 85 % of patients can be definitively treated only with a chest tube.***

However, the thoracotomy has to be performed when significant initial or ongoing hemorrhage from the chest tube and specific imaging-identified diagnoses. One caveat concerns the patient who presents after a delay. Even when the initial chest tube output is 1.5 L, if the output ceases and the lung is re-expanded, the patient may be managed through observation. Patients with persistent pneumothorax, large air leaks after tube thoracostomy, or difficulty ventilating should undergo fiber-optic bronchoscopy to exclude a bronchial injury.

Indications for Operative Treatment of Thoracic Injuries

- Initial tube thoracostomy drainage of > 1500 mL
- Ongoing chest tube drainage of > 200 mL/h for 3 consecutive hours
- Caked hemothorax despite placement of two chest tubes
- Selected descending torn aortas
- Great vessel injury (endovascular techniques may be used in selected patients)
- Pericardial tamponade
- Cardiac herniation
- Massive air leak from the chest tube with inadequate ventilation
- Tracheal or main stem bronchial injury diagnosed by endoscopy or imaging
- Open pneumothorax
- Esophageal perforation

Thoracic incisions. An anterolateral thoracotomy, with the patient placed supine, is the most versatile incision for emergent thoracic exploration. The location of the incision is in the fifth interspace, in the inframammary line (fig. 28, *a*).

For control of the great vessels, the superior portion of the sternum may be opened and extension of the incision into the neck considered. A method advocated for access to the proximal left subclavian artery is through a fourth interspace anterolateral thoracotomy, superior sternal extension, and left supraclavicular incision («trap door» thoracotomy, fig. 28, *c*).

Median sternotomy (fig. 28, *b*) is of limited utility. Typically, these patients have pericardial tamponade and undergo placement of a pericardial drain before a semiurgent median sternotomy is performed. Patients in extremis, however, should undergo anterolateral thoracotomy.

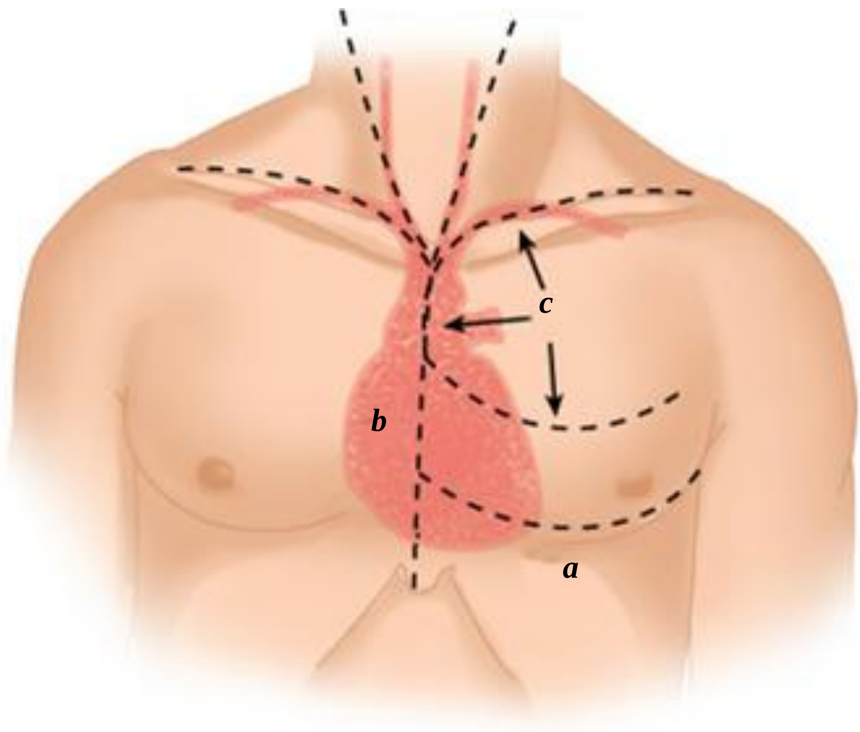


Fig. 28. Main thoracic incisions:
a — anterolateral thoracotomy; *b* — sternotomy; *c* — «trap door» thoracotomy

FRACTURES OF THE RIBS

The commonest injury to the chest is fracture of the ribs by a direct blow. The most commonly affected ribs are the seventh, eighth and ninth, in which the fracture usually occurs in the region of the midaxillary line. The patient complains of pain in the chest overlying the fracture and this pain is intensified by springing the ribs with gentle but sharp pressure on the sternum. A thoracic injury usually breaks the ribs of an older patient. But if a patient is young, his ribs may be so elastic that he can have severe internal injuries without breaking them. By themselves broken ribs are not important and soon heal. One or two fractured ribs can be treated at home. Four and more broken ribs usually need observation and treatment in hospital because of high risk of internal injuries.

The main treatment modalities of uncomplicated rib fracture are listed below:

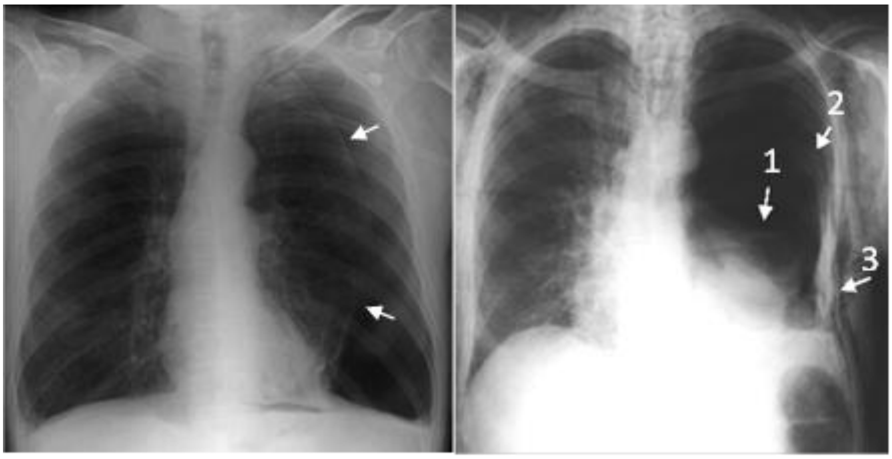
– pain relief may be achieved by analgesics, particularly non-steroidal anti-inflammatory drugs (NSAIDs), by the injection of local anesthetic in the paravertebral region to block the intercostal nerves or by a thoracic epidural block, which can be maintained by means of an infusion into an indwelling plastic catheter.

– vigorous physiotherapy is administered to encourage deep breathing.

– strapping of the chest wall inhibits thoracic movement and encourages pulmonary collapse; it should be avoided.

PNEUMOTHORAX

Air in a pleural cavity (*pneumothorax*) usually comes from a patient's lungs. Bony spicules of a broken rib penetrate the lung and air escapes into the pleural cavity (fig. 29). It can also come from patient's damaged trachea or bronchi.

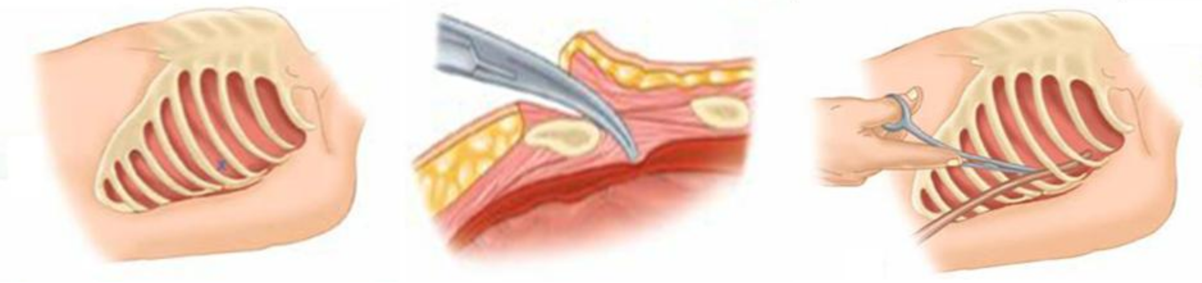


a ***b***

Fig. 29. Pneumothorax, chest X-ray:
a — moderate left pneumothorax, arrows show the edge of partly collapsed lung; *b* — severe pneumothorax: 1 — edge of completely collapsed lung, 2, 3 — broken ribs

A small pneumothorax is usually asymptomatic except pain at the site of an impact. Typical clinical picture of a severe pneumothorax includes pain on a side of affected lung, tachypnea, cyanosis, failure to auscultate or very weak breathing sounds. When a fractured rib tears the overlying soft tissue and allows air from the pneumothorax to enter the subcutaneous tissues, subcutaneous (surgical) emphysema will result.

A small pneumothorax is usually harmless and resolves spontaneously. Moderate and severe pneumothorax requires insertion of a chest tube that is definitive procedure for 85 % of the patients (fig. 30).



a ***b*** ***c***

Fig. 30. Tube thoracostomy:
a — site of drainage insertion; *b* — heavy scissors are used to cut through the intercostal muscle into the pleural space. This is done on top of the rib to avoid injury to the intercostal bundle located just beneath the rib; *c* — a 28F chest tube is directed superiorly and posteriorly with the aid of a large clamp

After the drainage active vacuum aspiration or underwater drain seal is used. In latter air escapes from the pleural cavity on expiration but cannot be sucked back through the water seal on inspiration (fig. 31). The water bottle is placed below the level of the chest to ensure fluid does not reflux into the thoracic cavity.

Patients with persistent pneumothorax, large air leaks after tube thoracostomy, or difficult ventilation should undergo fiber-optic bronchoscopy to exclude a tracheobronchial injury or presence of a foreign body.

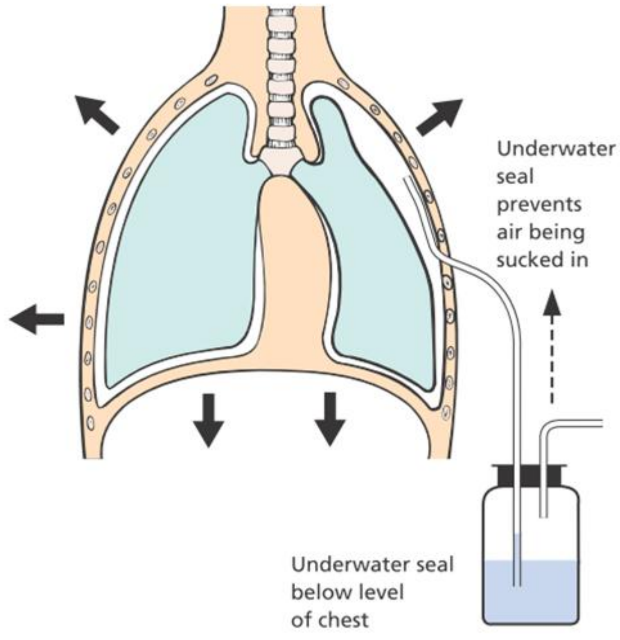


Fig. 31. Underwater seal of a chest tube

A tension pneumothorax. The air in pleural cavity may be under pressure when a wound of the lung acts as a valve and allows air to get in but not out. More air is trapped each inspiration. The lung on the injured side collapses, the mediastinum moves towards the normal side, and restricts the movement of that lung too (fig. 32). The bronchi may kink and make breathing even more difficult. The heart rotates about the superior and inferior vena cava; this decreases venous return and ultimately cardiac output, which culminates in cardiovascular collapse.

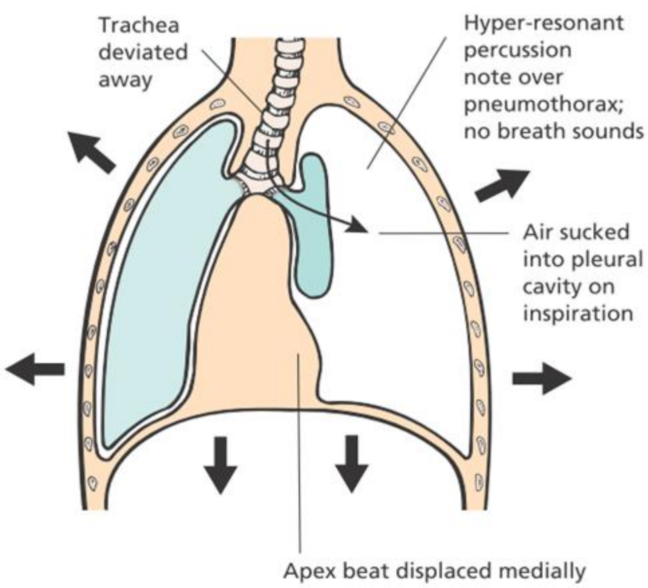


Fig. 32. Tension pneumothorax

A tension pneumothorax produces rapidly increasing dysp noea; the trachea and the apex beat are displaced away from the side of the pneumothorax; and, on the left side, cardiac dullness may be absent. The chest on the affected side gives a tympanic percussion note with bulging of the intercostal spaces.

The diagnosis of tension pneumothorax is presumed in any patient manifesting respiratory distress and hypotension in combination with any of the following physical signs: *tracheal deviation* away from the affected side, *lack of or decreased breath sounds* on the affected side, and *subcutaneous emphysema* on the affected side. Patients may have *distended neck veins* due to impedance of venous return, but the neck veins may be flat due to concurrent systemic hypovolemia.

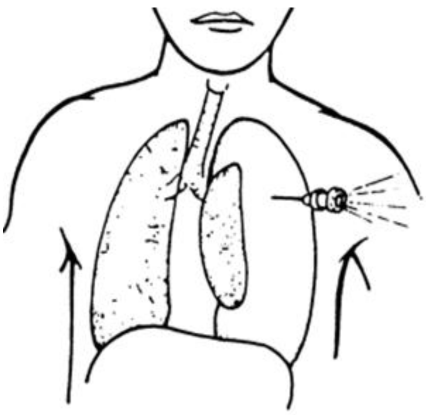


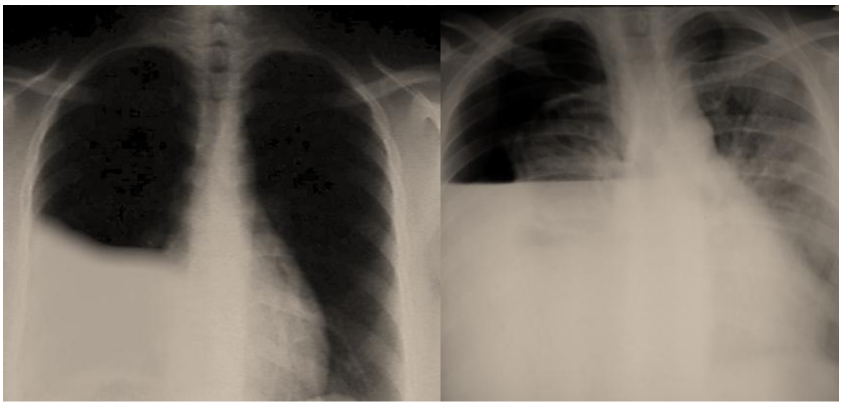
Fig. 33. Releasing a tension pneumothorax with a needle

Immediate needle thoracostomy decompression (fig. 33) with a 14-gauge catheter or ***emergent inserting a tube drain*** (fig. 30) in the second intercostal space in the midclavicular line may be indicated in the field. Recent studies suggest the preferred location for decompression may be the 5th intercostal space in the anterior axillary line due to body habitus. A bronchopleural fistula , due to rupture of a bronchus into the pleural space, should be suspected if the pneumothorax persists. It may require a thoracotomy to repair.

HEMOTHORAX

Hemothorax is the blood in a pleural cavity. It can come from a chest wall or from lungs. Hemothorax often accompanies chest injury and may be associated with pneumothorax (hemopneumothorax). The bleeding is usually from an intercostal artery in the lacerated chest wall or from underlying contused lung, but on occasions may result from injury to the heart or great vessels. Retropleural bleeding may compress the thoracic viscera without breaching the pleural cavity. Bleeding can occur slowly over several days, so it is often overlooked, especially if a patient has multiple injuries. Hemothoraces can be defined as small or massive. A massive haemothorax is one where there is rapid accumulation of more than 1 L of blood in the chest cavity.

Typical clinical picture includes decreased percussion note and decreased breath sounds and usual signs of internal bleeding (tachycardia, low systolic pressure, pale skin etc.). Best diagnoctic method of hemothorax is direct chest X–ray (fig. 34).



a ***b***

Fig. 34. Hemothorax:
a — oblique level of liquid in simple hemothorax; *b* — straight level of liquid and collapsed lung in hemopneumothorax

Initial management involves the insertion of a large-bore chest tube into the 6–7 intercostal space in the midaxillary line. In case of hemopneumothorax two drains may be used, the bottom one is to remoove blood, the top one is for air (fig. 35). If you don't remove blood urgently, it will clot, organize, and prevent the lung re-expanding. When this happens, it can be expanded again by decorticating at thoracotomy.

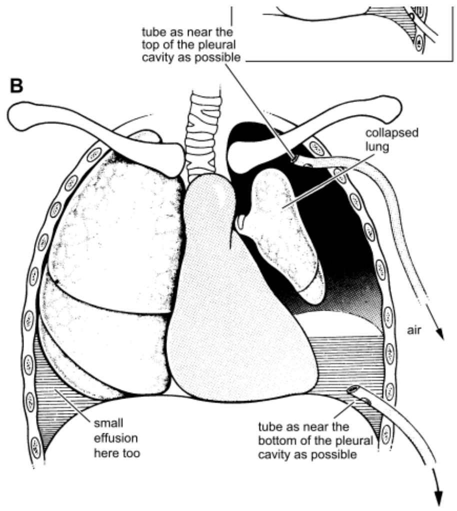


Fig. 35. Draning of a hemopneumothorax

If a massive hemothorax is suspected, the blood from the chest can be used for autotransfusion. The subsequent management of the patient depends on the volume of blood loss. If over 1500 mL is immediately drained from the thoracic cavity, the patient requires an early thoracotomy. If less than 1 L is drained, the patient can be managed expectantly, with the decision for surgery based on the rate of continuing blood loss. If the rate of blood loss is 200 mL/h over the subsequent 2–4 h, the patient should be considered for thoracotomy for damage control.

FLAIL CHEST

Multiple fractures of ribs can cause a large part of a chest wall to move independently of the rest of it, or allow it to be pushed inwards (stove-in chest, fig. 36).

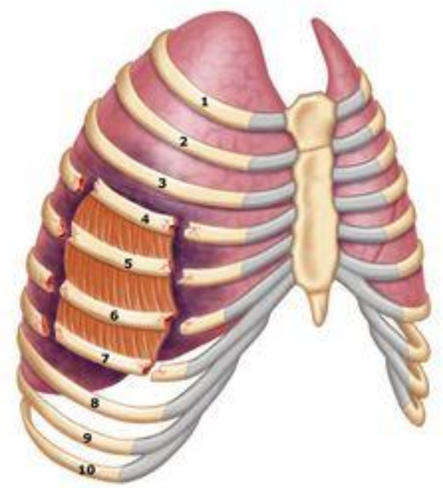


Fig. 36. A detached segment of a chest due to the multiple fractures of 4–7 ribs

On inspiration, the flail part of the chest wall becomes indrawn by the negative intrathoracic pressure, as it is no longer in structural continuity with the bony thoracic cage. Similarly, on expiration the flail part of the chest is pushed out while the rest of the bony cage becomes contracted. This is ***paradoxical movement*** (fig. 37). The result is that the air, which should be replaced with each respiration, merely moves from one lung to the other. The patient becomes grossly hypoxic due to the failure of adequate expansion of the affected side and also because of shunting of deoxygenated air from the lung on the side of the fracture into the opposite side. Pendulum movements of the mediastinum also produce cardiovascular troubles so that the patient becomes rapidly and progressively shocked.

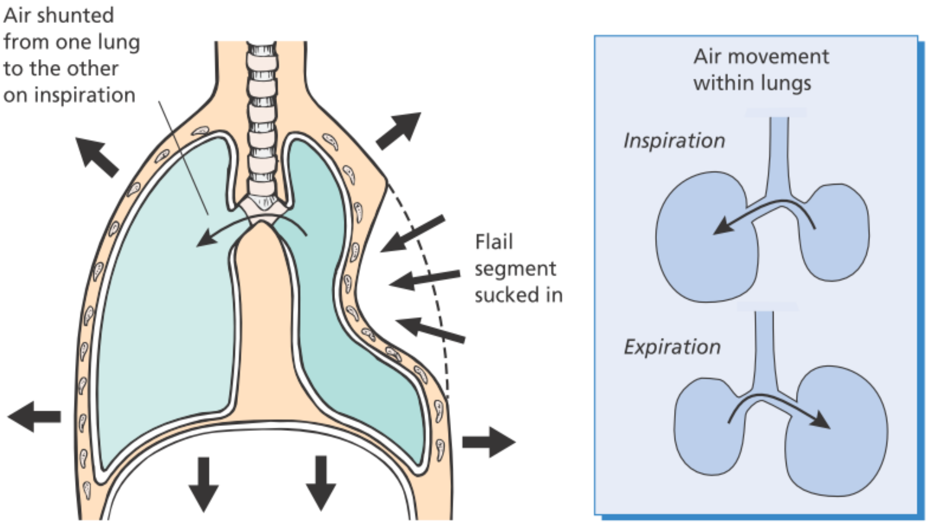


Fig. 37. The mechanism of a flail chest. On inspiration, the detached segment of a chest wall is sucked inwards, producing paradoxical movement, and inhaled air shunts back and forth between lungs

Support the flail segment in an emergency by means of a firm pad held by strapping (fig. 38). This stops the paradoxical movement and air shunting. Endotracheal intubation and positive — pressure ventilation on admission to hospital will stop the paradoxical movement, as the chest wall now moves as a single functional unit. The treatment is continued for about 10 days until fixation of the chest wall develops. In cases of gross instability, wire fixation of the chest wall may be necessary.

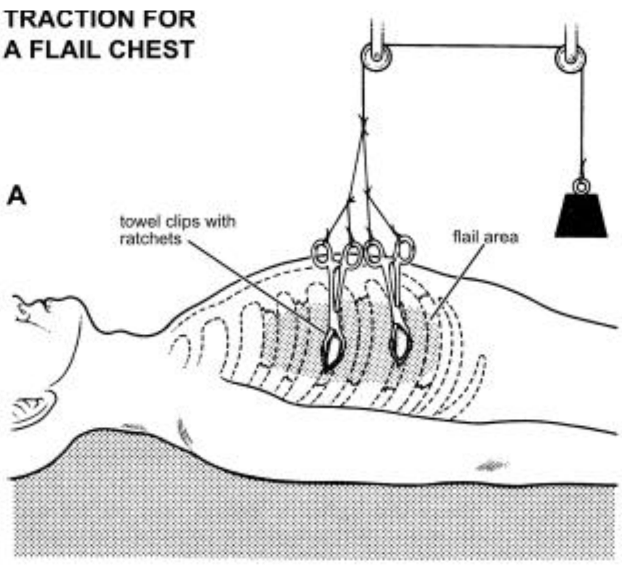


Fig. 38. Traction for a flail chest

DIAPHRAGMATIC RUPTURE

Injuries to the diaphragm can occur as a result of huge compressional forces that cause the diaphragm to be torn from its attachments. Blunt diaphragmatic injuries may also result in a linear tear in the central tendon of a diaphragm. Ruptured diaphragm can't keep the viscera in the abdominal cavity and make breathing moovement properly. When a large tear of the diaphragm occurs there are usual signs of breathing insuffitency.

Diaphragmatic trauma is an injury that is often missed or diagnosed late. Some patients may present years later with herniation through previous diaphragmatic defects caused by trauma. On chest X-ray these injuries may be recognized by an elevated diaphragm and observing a stomach or bowels in a chest (fig. 39).

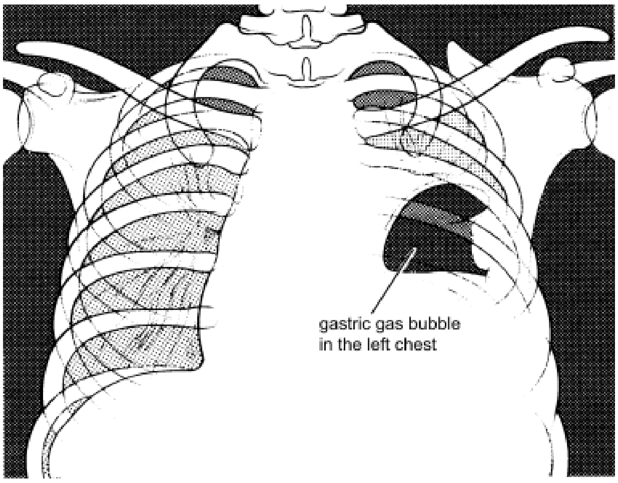


Fig. 39. Rupture of a diaphragm

Acute diaphragmatic injuries are usually repaired surgically through an abdominal approach to manage potential associated intraperitoneal visceral injury. After delineation of the injury, the chest should be evacuated of all blood and particulate matter, and thoracostomy tube placed if not previously done. Allis clamps are used to approximate the diaphragmatic edges, and the defect is closed with a running № 1 polypropylene suture. Occasionally, large wounds with extensive tissue loss will require polypropylene or biologic mesh to bridge the defect. Alternatively, transposition of the diaphragm cephalad one to two intercostal spaces may allow repair without undue tension.

CARDIAC TAMPONADE

This rare, treatable emergency occasionally follows a blunt trauma, which causes bleeding into the pericardial cavity (fig. 40). This prevents the heart filling normally, which (Beck's triad):

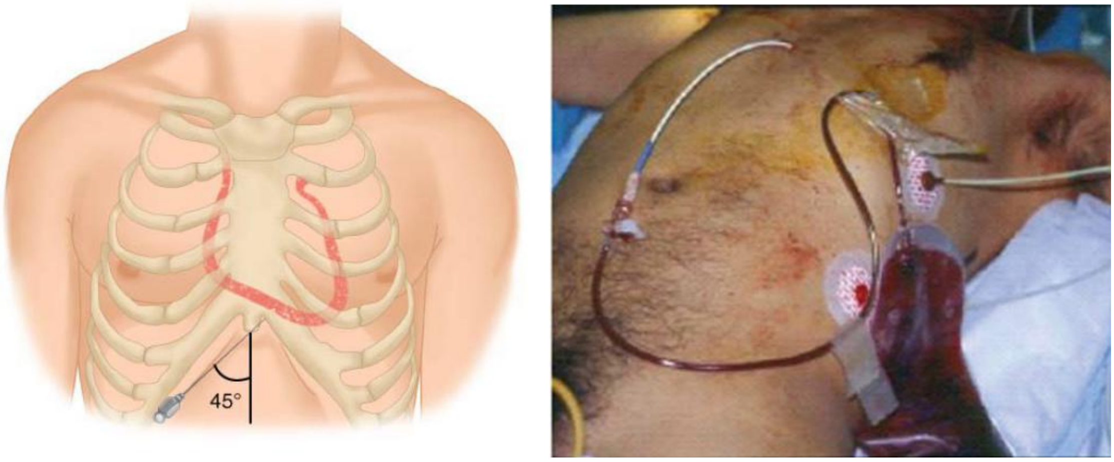
- raises jugular venous pressure,
- makes heart sounds faint,

– causes pulsus paradoxus. Normally, the peripheral pulse becomes stronger on inspiration, because the lower intrathoracic pressure increases the venous return. In pulsus paradoxus the peripheral pulse is stronger on expiration.

When there is blood in the pericardial cavity, X–rays show a widening of the heart shadow, especially in the cardiophrenic angle. Screening shows diminished excursion of the borders of the heart. Central venous pressure is usually elevated more than 150 mm H_2O. On electrocardiography there is elevation of ST-segment. The most informative method is echocardiography (ultrasound of a heart) that may show blood in the pericardial cavity, compression of the right atrium and ventricle, and widening of an inferior vena cava.

Fig. 40. Cardiac tamponade

Pericardiocentesis is indicated for patients with evidence of pericardial tamponade. Access to the pericardium is usually obtained through a subxiphoid approach, with the needle angled 45 degrees up from the chest wall and toward the left shoulder. Seldinger technique is used to place a pigtail catheter. Blood can be repeatedly aspirated with a syringe or the tubing may be attached to a gravity drain. Evacuation of unclotted pericardial blood prevents subendocardial ischemia and stabilizes the patient for transport to the operating room for sternotomy and damage control. Pericardiocentesis is indicated for patients with evidence of pericardial tamponade (fig. 41).



a ***b***

Fig. 41. Pericardiocentesis:
a — access to the pericardium; *b* — pigtale catheter in a pericardial cavity

TESTS

1. In a traumatic patient, pneumothorax may develop in:

a) rupture of the lung;
b) simple rib fracture;
c) cardiac tamponade;
d) diaphragmatic rupture.

2. Transverse level of fluid and absence of lung structure on the chest X-Ray in a traumatic patient tell about:

a) hemothorax;
b) pneumothorax;
c) hemopneumothorax;
d) cardiac tamponade.

3. The management of a patient with a tension pnemothorax must include:

a) Tight bandage of the chest;
b) Local anesthesia;
c) CT of the chest;
d) Immediate chest draining.

4. In hemothorax, chest drain should be inserted through:

a) 2–3 th intercostals space on the middle clavicular line;
b) 5–7th intercostals space on the midaxillary line;
c) two tubes: at 2–3 th intercostals space on the middle clavicular line and 5–7th intercostals space on the midaxillary line.

5. In a patient with the trauma of low ribs at the left side, the minimum of investigations should include:

a) Chest X-Ray;
b) Computer tomography;
c) Endoscopy;
d) FAST exam (Focused Assessment with Sonography for Trauma);
e) X-Ray with contrast media.

6. Signs of a tension pneumothorax on the chest X–Ray are:

a) Lung collapse;
b) Atelectasis;
c) Dislocation of the mediastinum;
d) Tumor like mass in the lung.

7. Signs of a «flail chest» are:

a) Paradoxical breathing;
b) Dislocation of the mediastinum;
c) Cyanosis;
d) High arterial pressure;
e) Three or more contiguous ribs are fractured in at least two locations.

8. Signs of ongoing intrathoracic hemorrhage are:

a) Hypotension;
b) Tachycardia;
c) Subcutaneous emphysema;
d) Cyanosis.

9. Trauma of the solid abdominal organs is dangerous because of:

a) Possibility of two-phase rupture;
b) Severe chemical peritonitis;
c) Intraabdominal bleeding;
d) Intestinal obstruction by the clots.

10. Signs of rupture of a stomach in abdominal trauma are:

a) Free gas under the diaphragm;
b) Hemorrhagic shock;
c) Blumberg sign;
d) Collapse;
e) Large bruise at the epigastrium.

Answers: **1** – A; **2** – C; **3** – D; **4** – B; **5** – A, D; **6** – A, C; **7** – A, C, E; **8** – A, B; **9** – A, C; **10** – A, C.

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