Abdominal Trauma

Ghidirim Gh., Mishin I., Zastavnitsky Gh., Vozian M.

Abdominal trauma is an injury to the abdomen.

- Trauma is the leading cause of death under the age of forty.
- Of all traumatic deaths, abdominal trauma is responsible for 10%.

The care of the trauma patient is demanding and requires speed and efficiency. Evaluating patients who have sustained blunt abdominal trauma remains one of the most challenging and resource-intensive aspects of acute trauma care.

Jansen JO., et al.: *BMJ*. 2008;336(7650):938-42.

- Abdominal injuries acquire approximately 15%
- Correlation between male/ female is 5/1
- Age between 15 and 44 years

- Traffic accidents (up to 50%)
- Industrial accidents
- Sport related trauma
- Injuries in urban environments

CLASSIFICATION

Abdominal trauma may be blunt or penetrating (wounds) and may involve damage to the abdominal organs.

Blunt trauma, refers to a type of physical trauma caused to a body part, either by impact, injury or physical attack.

Penetrating trauma is an injury that occurs when an object pierces the skin and enters a tissue of the body, creating an open wound.

CLASSIFICATION

Blunt abdominal trauma is often referred to as the most common type of trauma, representing 50-75 % of all blunt traumas.

Blunt abdominal injuries are divided into three types:

- **Blunt trauma with injuries of the abdominal wall (contusion).**
- **Blunt trauma with injuries of the intraabdominal organs (solid or hollow).**
- **Blunt trauma with injuries of the retroperitoneal located organs and structures.**

CLASSIFICATION

An injury in which an object enters the body or a structure and passes all the way through is called a perforating injury, while *penetrating trauma* implies that the object does not pass through.

Blank-Reid C. Crit Care Nurs Clin North Am. 2006;18(3):387-401.

Wounds are divided into:

- **Non-penetrating (injury limited to the abdominal wall).**
- **Penetrating, but non-perforating (peritoneal lesion).**
- **Perforating (injury of the abdominal organs).**
- **Through organ wall injury (entrance and exit wounds in the same organ are present).**

CLASSIFICATION

Abdominal injuries (including blunt and penetrating), which are associated with organ lesions may be divided into:

- **Injuries of the intraperitoneal organs.**
- **Injuries of the extraperitoneal organs.**
- **Injuries of the intraperitoneal and extraperitoneal organs.**

CLASSIFICATION

According to the number of affected (injured) organs, abdominal trauma may be divided into:

- **Isolated (simple) trauma (injury of a single organ).**
- **Multiple trauma (Injuries of several organs form the same system).**
- **Associated trauma – (polytrauma) – (Injuries of several organs form different systems).**

FREQUENCY OF ORGAN INJURY IN BLUNT ABDOMINAL TRAUMA IN ADULTS

Organ	Injury frequency (%)
Liver	30
Spleen	25
Retroperitoneal hematoma	13
Kidney	7
Bladder	6
Intestine	5
Mesentery	5
Pancreas	3
Diaphragm	2
Urethra	2
Vascular	2

Jansen JO., et al.: *BMJ*. 2008;336(7650):938-42.

FREQUENCY OF ORGAN INJURY IN PENETRATING ABDOMINAL TRAUMA

Organ	Injury frequency (%)
Liver	37
Small bowel	26
Stomach	19
Colon	17
Vascular	13
Retroperitoneal	10
Mesentery and omentum	10
Spleen	7
Diaphragm	5
Kidney	4
Pancreas	4
Duodenum	2
Other	1

Feliciano DV., et al.: *Adv Sur*. 1995;28:1-39.

FREQUENCY OF ORGAN INJURY IN ABDOMINAL GUNSHOT WOUNDS

Organ	Injury frequency (%)
Small bowel	50
Colon	40
Liver	30
Abdominal vascular structures	25

Feliciano DV., et al.: *Adv Sur*. 1995;28:1-39.

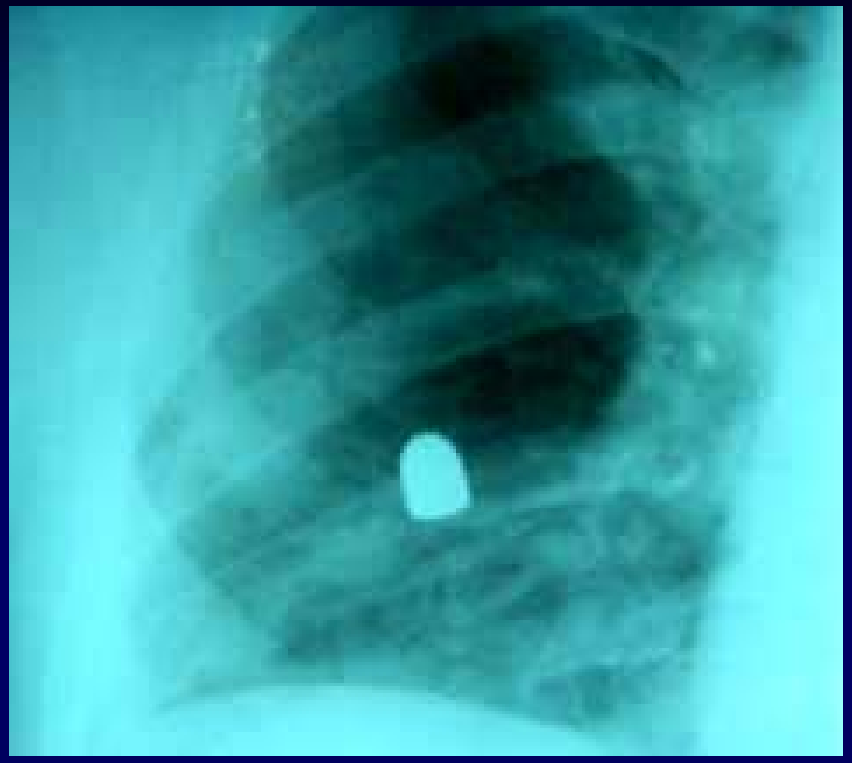
DIAGNOSIS

- 25% of all trauma patients require ex lap.
- Physical exam can be unreliable
  - Compensated hemoperitoneum, retroperitoneal, pelvic injuries
- Diagnostic tools:
  - Simple thoraco-abdominal x-ray
  - Diagnostic peritoneal lavage (DPL)
  - Ultrasound (FAST)
  - CT
  - Laparoscopy

DIAGNOSIS

- Test of choice dependent on **patient's hemodynamic stability** and severity of associated injuries.
- Stable blunt trauma → FAST or CT
- Unstable blunt trauma → FAST or DPL
- Stab wounds without peritoneal signs, evisceration, or hypotension → wound exploration or DPL.
- Gun shot wounds → surgical exploration.

DIAGNOSIS EXAMINATION



Wound severity (degree of skin injury)

I – Ø > 25 cm (laparotomy just in case of positive peritoneal signs)

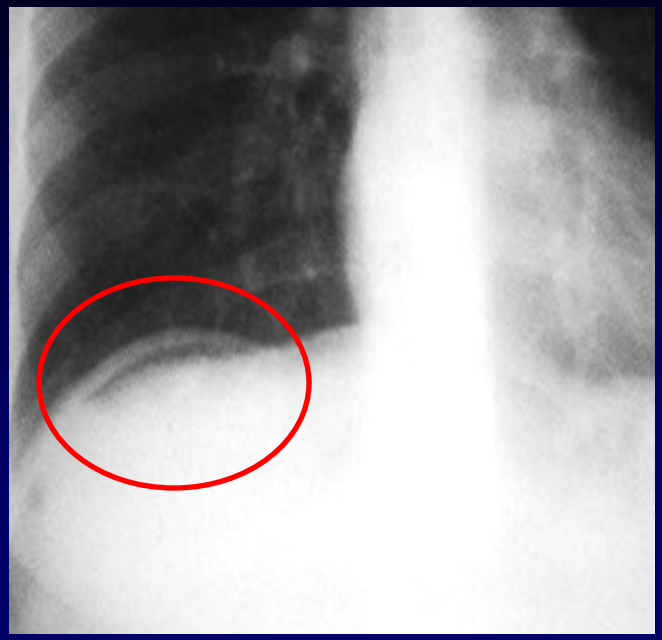
II – 10-25 cm (almost all patients need exploratory laparotomy)

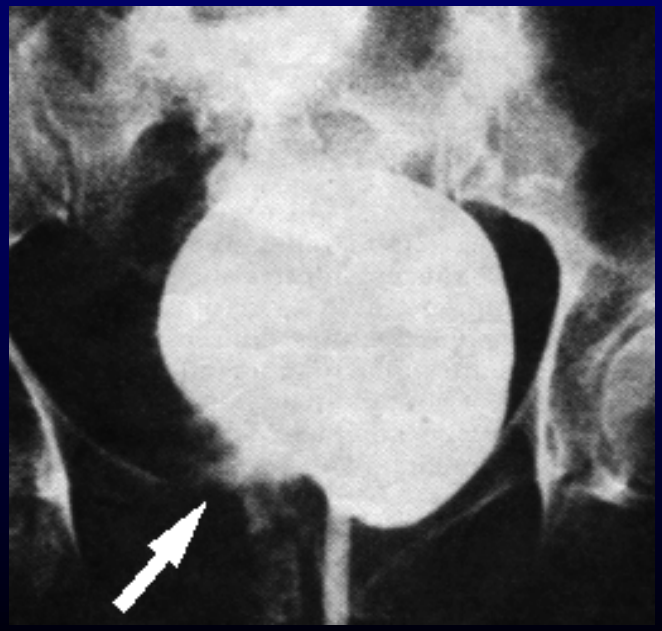
III – Ø < 10 cm (immediate surgery – 100%)

Glezer JA et al., Am Surg.1993;59(2):129-32.

DIAGNOSIS

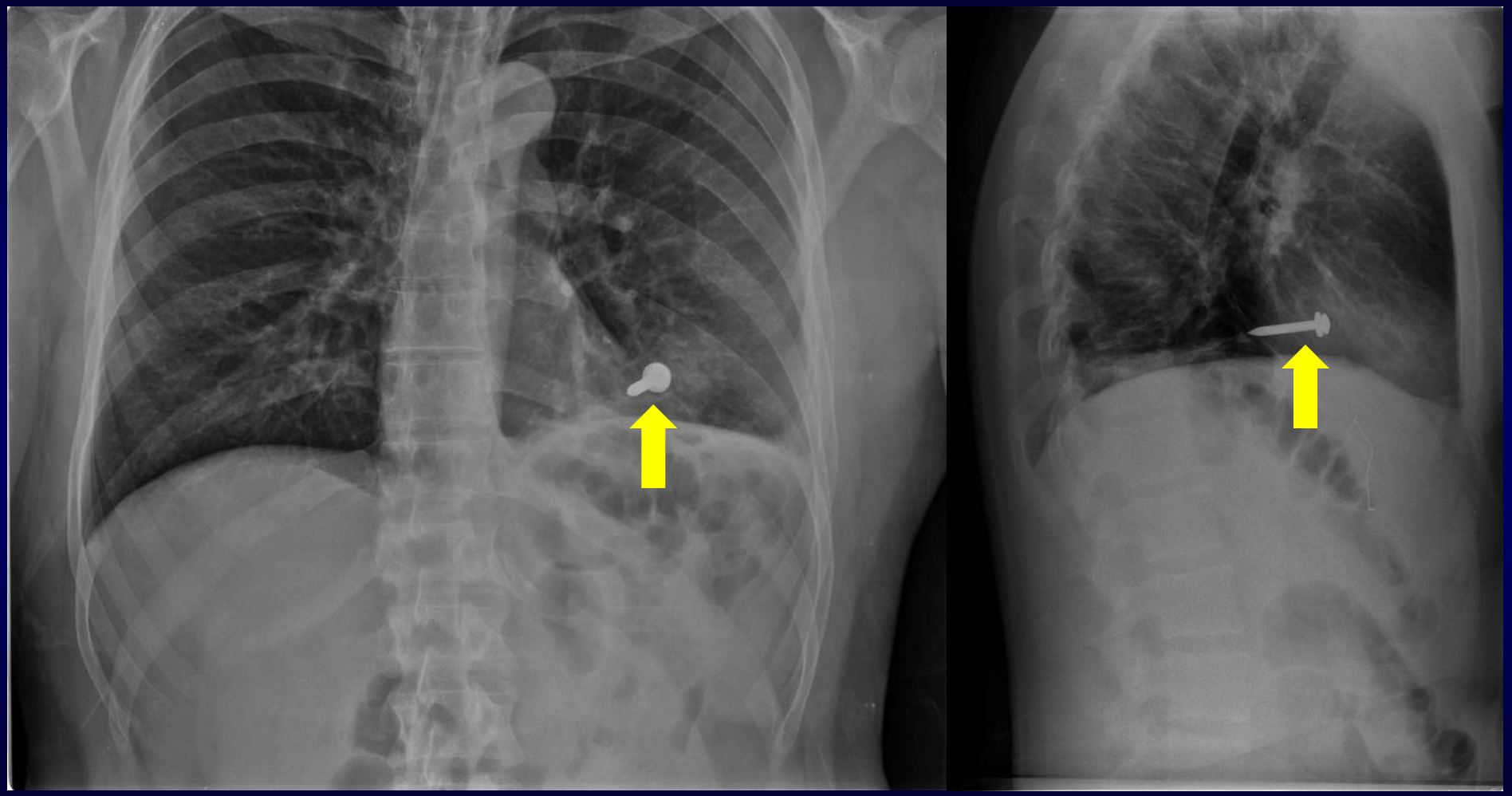
- Abdominal plain films
- Retrograde urethrography and cystography, excretory urography
- Ziuldovich procedure
- Ultrasonography





Cystography demonstrating retroperitoneal bladder rupture (arrow).

DIAGNOSIS

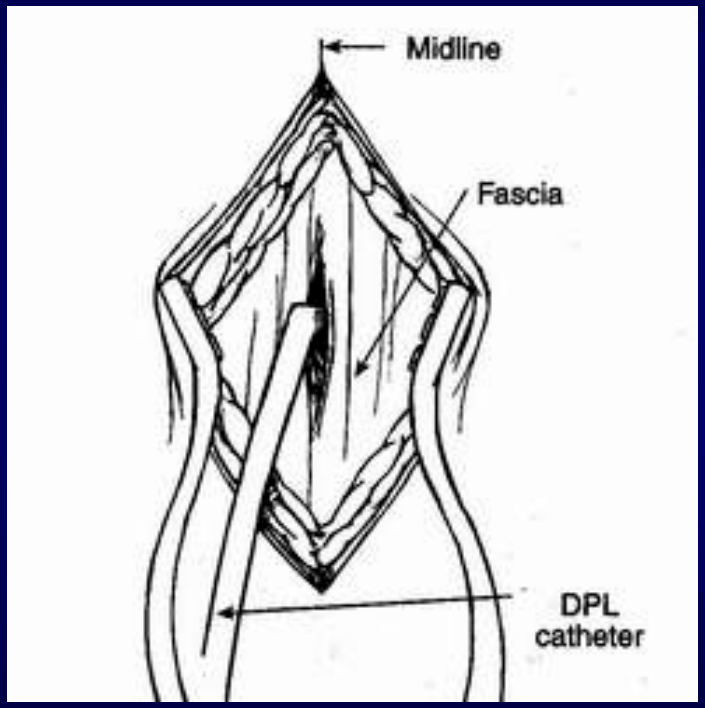


Foreign body in the left thorax – nail (arrow)

DPL

Indications

- Unconscious patient with question of potential abdominal injury.
- Patient with multiple injuries and unexplained shock.
- Patient with thoracoabdominal injuries with fractures of the inferior ribs.
- Patient with spinal cord injury.
- Intoxicated patient in whom abdominal injury is suspected.



DPL


Product No. AK-09000
Peritoneal Lavage Kit
ARROW
Product No. AK-09000 8" 24 .035
Peritoneal Lavage Kit
ARROW
Product No. AK-09000 8" 24 .035
Peritoneal Lavage Kit

DPL

Criteria for positive DPL (surgery – exploratory laparotomy is indicated if):

- **RBC > 100.000 per milliliter**
- **WBC > 500 per milliliter**
- **Ht > 1-2%**
- **Amylase > 175 IU/dL**
- **Bile, bacteria, or food**

DPL

- Contraindications
  - Clear indication for ex lap
  - Prior abdominal surgery
  - Pregnancy
  - Obesity

DPL

- Highly sensitive to intraperitoneal blood, but low specificity → nontherapeutic explorations.
- Supraumbilical if pelvic fracture present
- Significant injuries may be missed
  - Diaphragm
  - Retroperitoneal hematomas
  - Renal, pancreatic, duodenal
  - Minor intestinal
  - Extraperitoneal bladder injuries

Focused Assessment with Sonography for Trauma (FAST)

Perihepatic

Perisplenic

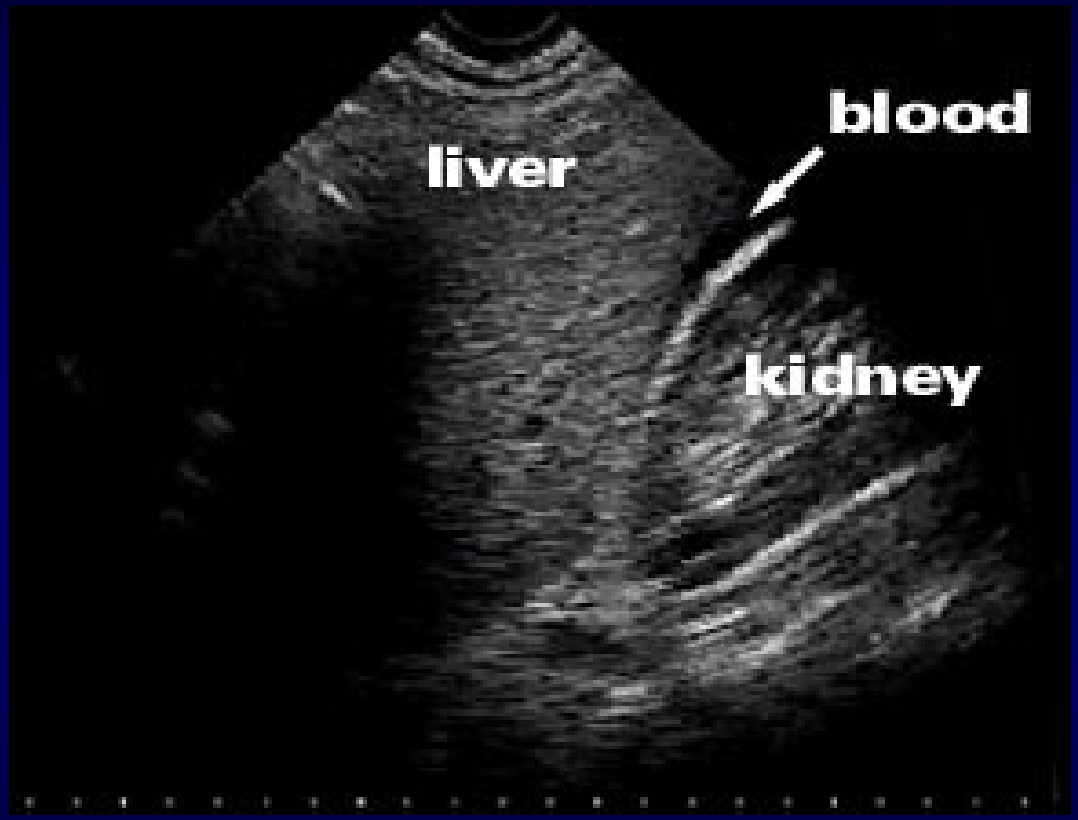
Pelvis

Pericardium

Focused Assessment with Sonography for Trauma (FAST)

Focused Assessment with Sonography for Trauma (FAST)

- Pros
  - Noninvasive
  - Fast
  - Low cost



- Cons
  - User dependent
  - Obesity, gas interposition
  - Misses retroperitoneal/hollow viscus injury
  - May not detect free fluid <50-80 cc

CT Scan

- Hemodynamically stable patient
- Pros
  - Retroperitoneal assessment
  - Nonoperative management of solid organ injury
  - High specificity
- Cons
  - Hardware, cost, radiation
  - Hollow viscus injuries, diaphragm injury

Laparoscopy

- Role still being defined
- Good for diaphragm injury evaluation
- Cons
  - Invasive
  - Expensive
  - Missed small bowel, splenic, retroperitoneal injuries

MECHANISM OF TRAUMA

BALLISTICS
Wounding capacity of bullets:
Kinetic energy transferred bullet → body

$$KE=\frac{(MxV^2)}{2}$$

Thus the bullet's velocity is important, but not it's mass!

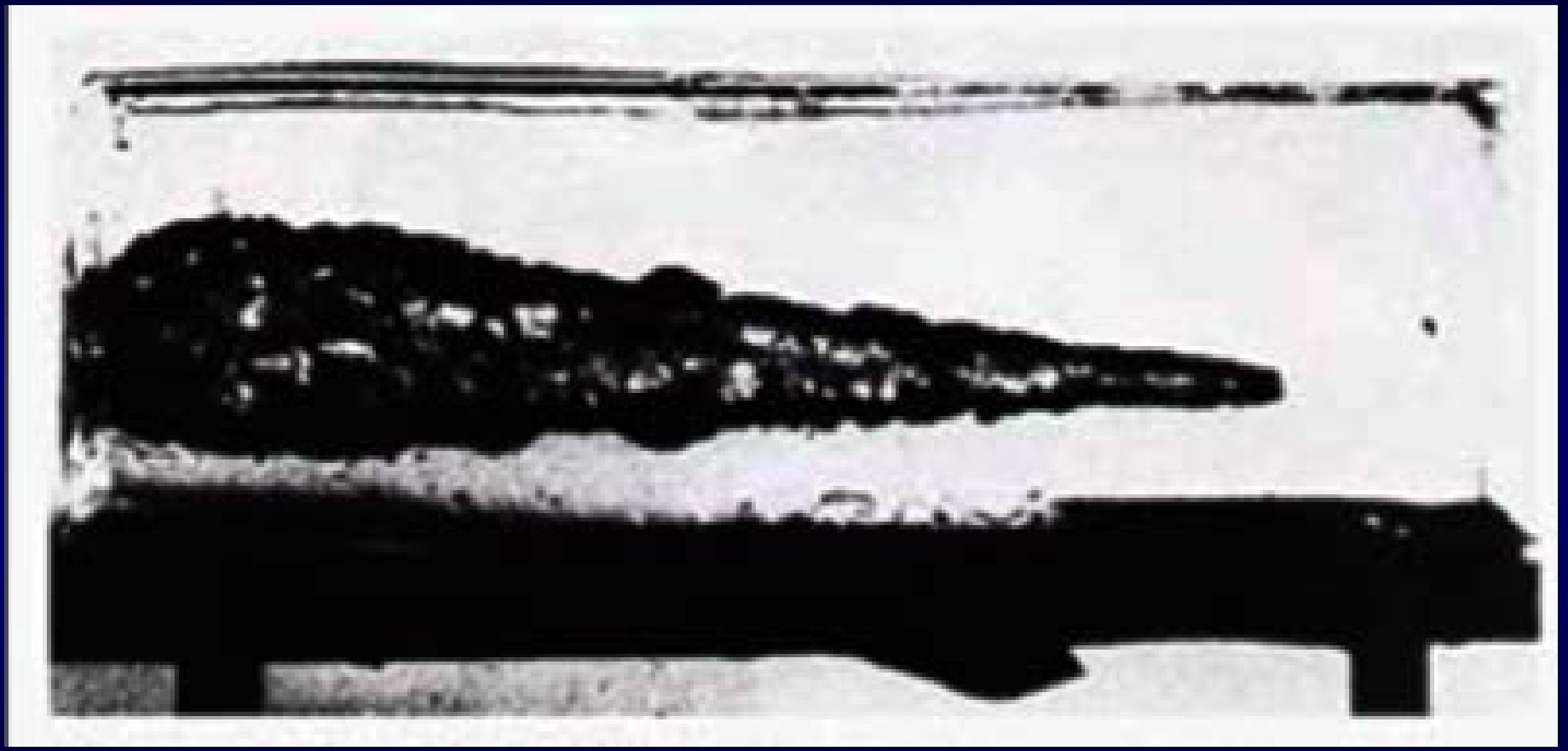
Low velocity ammunition (LV)

Civil trauma, hand guns
Small tissue cavity formation
Minimal collateral damage

High velocity ammunition (HV)

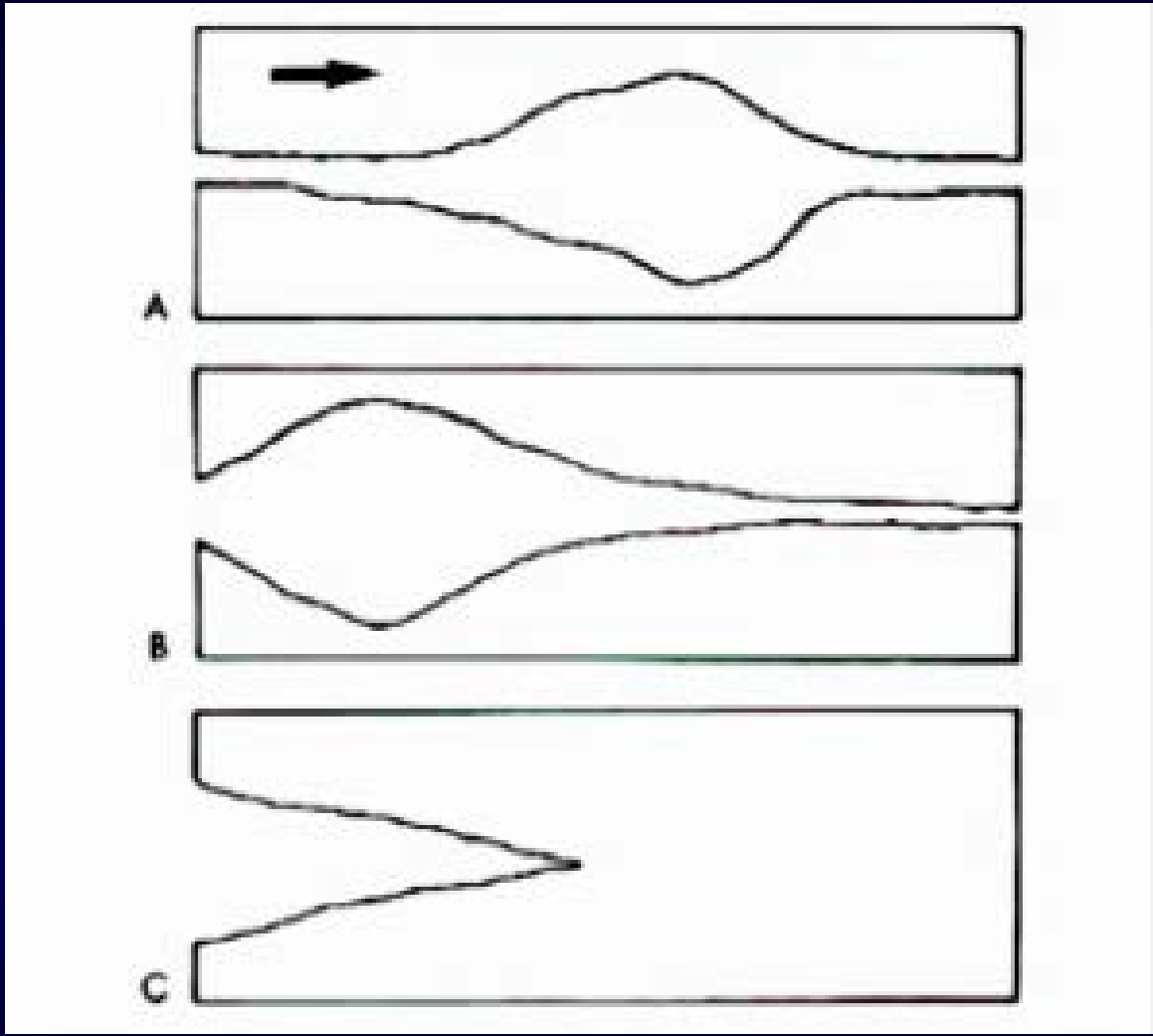
Civil and combat trauma, rifles
Extensive tissue cavity formation (temporary cavitation 4-5 times larger than the bullet's diameter)
Maximal collateral damage
Cavitation: cavity enlarges → collapses
Suction of external debris into wound
Fluid shock wave blasts colon, bladder

MECHANISM OF TRAUMA



Temporary cavity produced in gelatin block by a 110 g semijacketed hollow point 38 special bullet

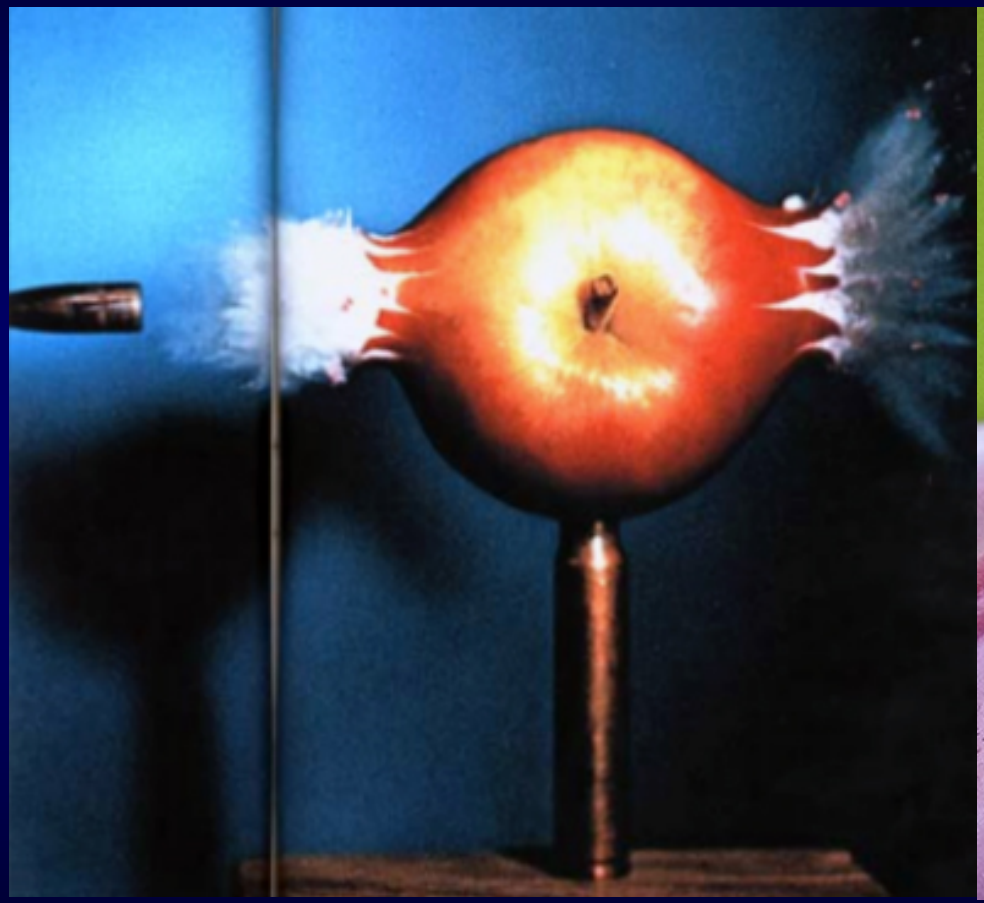
MECHANISM OF TRAUMA



Temporary cavities in gelatin blocs (A) full metal jacketed rifle bullet, (B) hunting rifle bullet, (C) handgun bullet

MECHANISM OF TRAUMA

Effect of high velocity bullet on parenchyma-like object



Blast of the whole object due to pulsating high frequency shock-wave transmitted by high velocity energy to the object

Effect of high velocity bullet on parenchyma

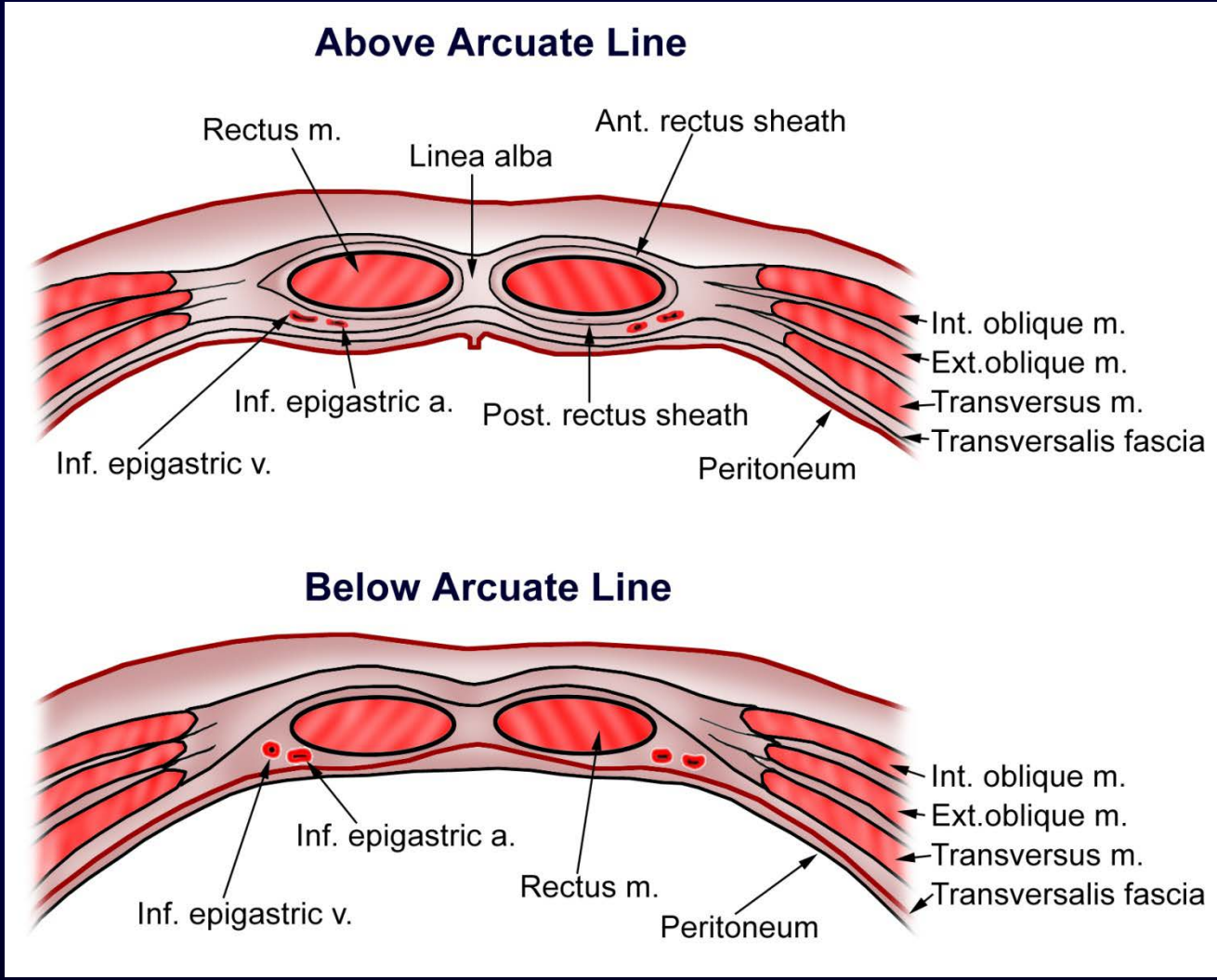
AK-47 right lower limb injury

RUPTURED ABDOMINAL MUSCLES - RECTUS SHEATH HEMATOMA

Rectus sheath hematoma (RSH) is an uncommon and often clinically misdiagnosed cause of abdominal pain. It is the result of bleeding into the rectus sheath from damage to the superior or inferior epigastric arteries or their branches or from a direct tear of the rectus muscle.

RSH is an ancient disorder first being accurately described by Hippocrates and mentioned by Galen.

RUPTURED ABDOMINAL MUSCLES - RECTUS SHEATH HEMATOMA



Anatomy of the rectus sheath.

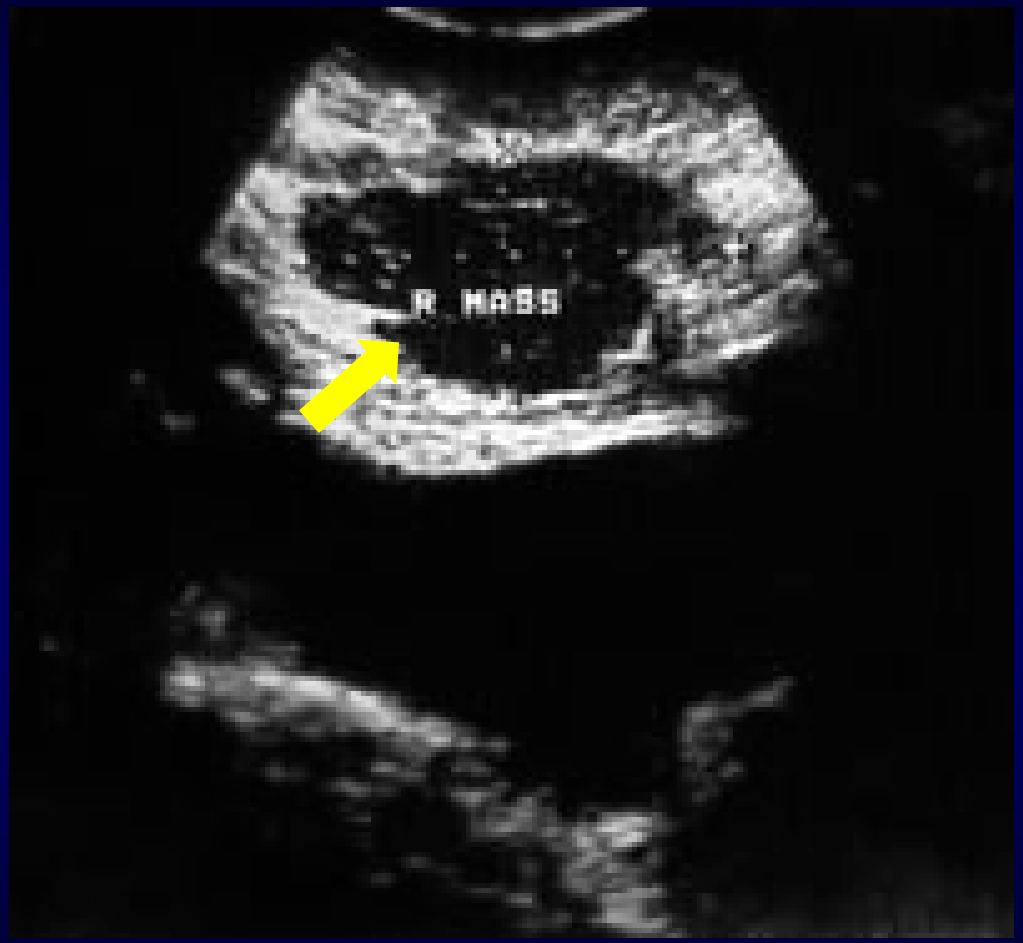
RUPTURED ABDOMINAL MUSCLES - RECTUS SHEATH HEMATOMA

RSHs are generally caused either by rupture of one of the epigastric arteries or by a muscular tear with shearing of a small vessel. The immediate cause of the rupture may be external trauma to the abdominal wall, iatrogenic trauma from surgery, or excessively vigorous contractions of the rectus muscle.

Etiology: Valsalva maneuver, severe coughing, vomiting, or straining at the stool. Because the arteries supply the recti posteriorly, most hematomas are posterior to the muscle, making diagnosis by means of palpation more difficult.

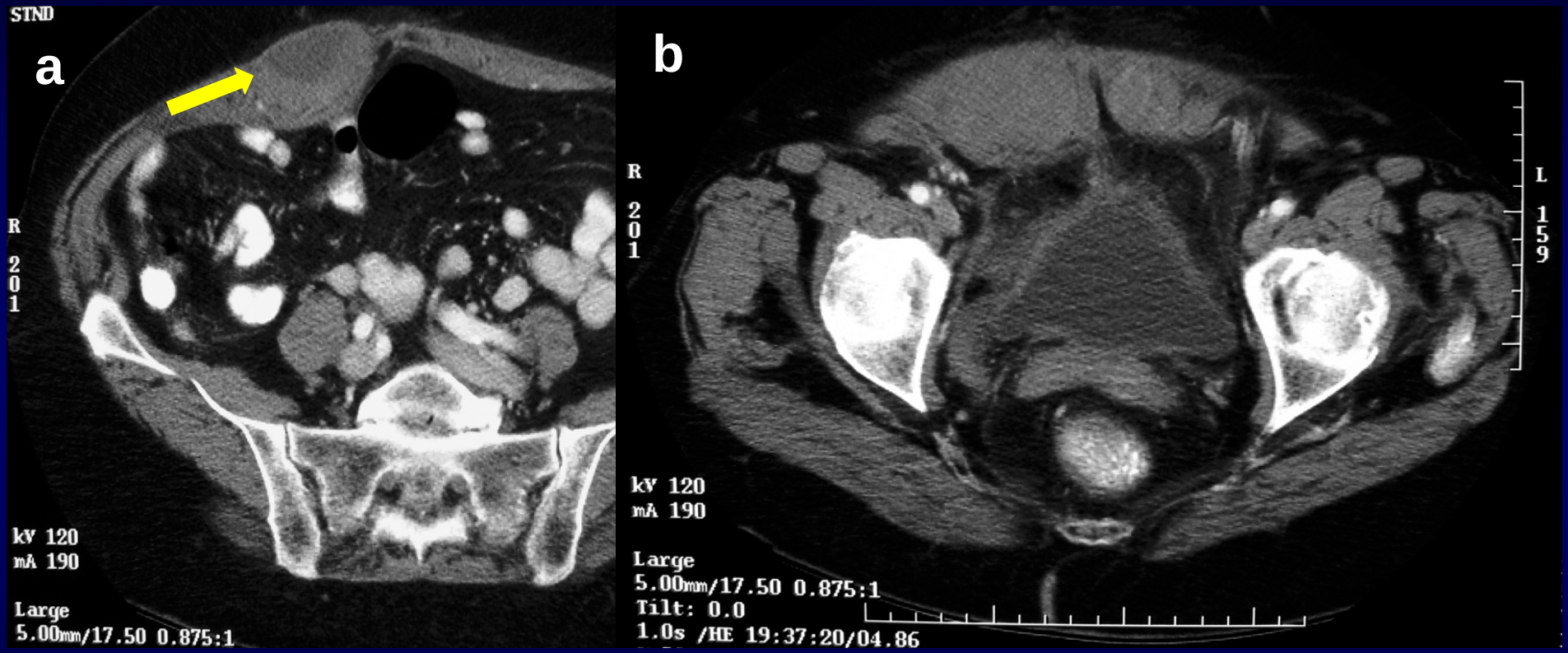
The Cullen sign, periumbilical ecchymosis, in a patient with a rectus sheath hematoma.

RUPTURED ABDOMINAL MUSCLES - RECTUS SHEATH HEMATOMA



Ultrasound image of a rectus sheath hematoma presenting as a tender, unilateral abdominal mass (arrow).

RUPTURED ABDOMINAL MUSCLES - RECTUS SHEATH HEMATOMA



Rectus sheath hematoma of the right rectus muscle CT image (a) (arrow), rectus sheath hematoma becomes bilobar as it dissects inferiorly (b).

RUPTURED ABDOMINAL MUSCLES - RECTUS SHEATH HEMATOMA

Teske's 1946 case series of 100 patients with rectus sheath hematoma showed **60% to be on the right side** and more than **80% to be in the lower quadrants**.

Teske JM. *Am J Surg*. 1946;71:689-95.

Right-sided hematomas are presumably more common because more people are right handed and, thus, are more prone to right-sided strain of the rectus muscle during significant activity.

The lower quadrants are more frequently involved because of the long vascular branches that are present and because muscle excursion during contraction is greater.

RUPTURED ABDOMINAL MUSCLES - RECTUS SHEATH HEMATOMA

In 1996, Berna et al used the appearance of RSH on CT scans to differentiate 3 levels of severity with disposition and therapeutic implications.

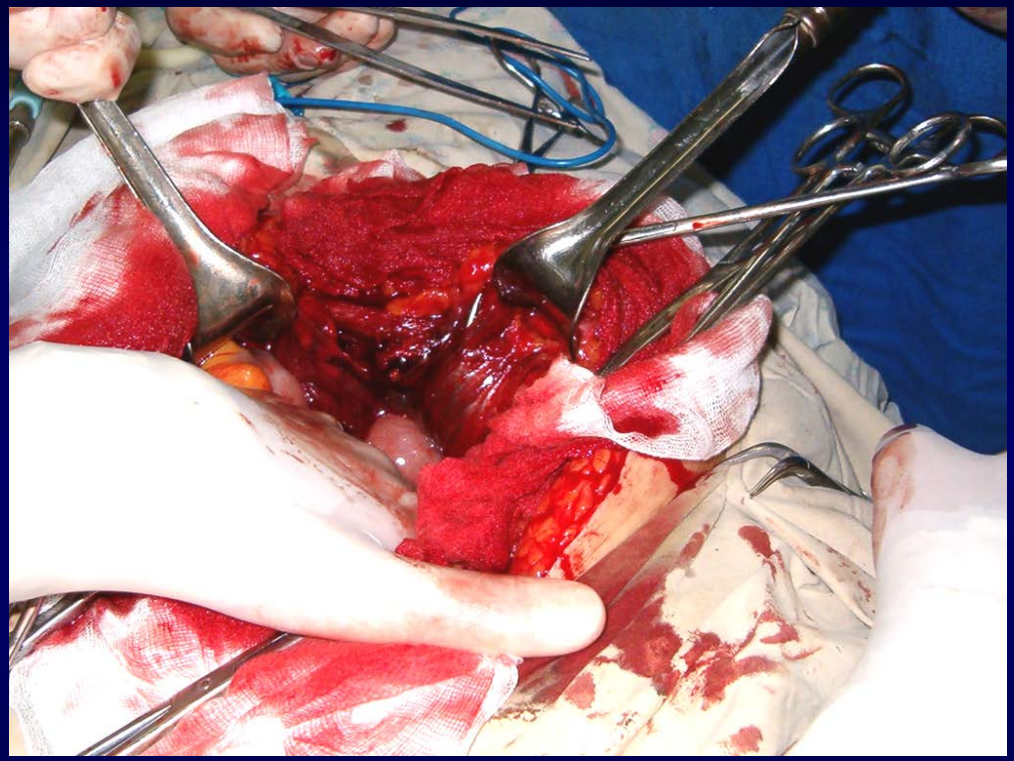
Berna JD., et al.: *Abdom Imaging*. 1996;21(1):62-4.

Type I: The hematoma is intramuscular, and an increase in the size of the muscle is observed, with an ovoid or fusiform aspect and hyperdense foci or a diffusely increased density. **The hematoma is unilateral** and does not dissect along the fascial planes. The patient presents with mild-to-moderate abdominal pain and typically does not require hospitalization. Type I hematomas resolve by themselves within 1 month.

Type II: The hematoma is intramuscular (mimicking type I) but with blood between the muscle and the transversalis fascia. It **may be unilateral but is usually bilateral**, and no blood is observed occupying the prevesical space. A fall in hematocrit may be observed. A patient may require hospitalization for close observation, but most do not require transfusions, and most are discharged within 3 days. Type II hematomas usually resolve within 2-4 months.

RUPTURED ABDOMINAL MUSCLES - RECTUS SHEATH HEMATOMA

Type III: The hematoma may or may not affect the muscle, and blood is observed between the transversalis fascia and the muscle, in the peritoneum, and in the prevesical space. A hematocrit effect can be observed, and, on occasion, hemoperitoneum is produced. These patients are often taking anticoagulation medications and require hospitalization. They often require transfusion and are discharged after 1 week. Only rarely will they develop hemodynamic instability that cannot be controlled with fresh frozen plasma and fluid resuscitation. These unstable patients may require surgical intervention. Type III hematomas usually require more than 3 months to resolve.



Intraoperative view – DO NOT OPEARTE!
(unless hemodynamic instable or complications occur)

Diaphragmatic Ruptures

Introduction

The first description of a diaphragmatic injury with the herniation of intraperitoneal organs is attributed to **Sennertus** in **1541.**

In 1579, Ambroise Paré described a traumatic diaphragmatic rupture (TDR) in a French artillery captain, who was shot eight months previously, the death being induced by TDR complications. **Ambroise Paré** described the autopsy results of the corpses with TDR after blunt and penetrating trauma.

The first communication regarding a TDR diagnosed *in vivo* was done by **Bowditch** in **1853.**

The first successful surgical procedure for TDR repair is attributed to **Riolfi** in **1886**, and in **1900 Walker** reports the first successful TDR repair in a patient with blunt abdominal trauma.

Ambroise Paré (ca. 1510-1590)

Goh BK, Wong AS, Tay KH, Hoe MN. CJEM. 2004 ;6(4):277-80.
Rashid F, Chakrabarty MM, Singh R, Iftikhar SY. World J Emerg Surg. 2009;4:32.

Acute traumatic diaphragmatic rupture (TDR) is relatively rare and results from physical trauma. Traumatic diaphragmatic ruptures occur in from 1% to 7% of major blunt trauma victims and in 10%–15% of patients with trauma penetrating the lower chest.

Reber PU., et al.: J Trauma. 1998;44(1):183-8.

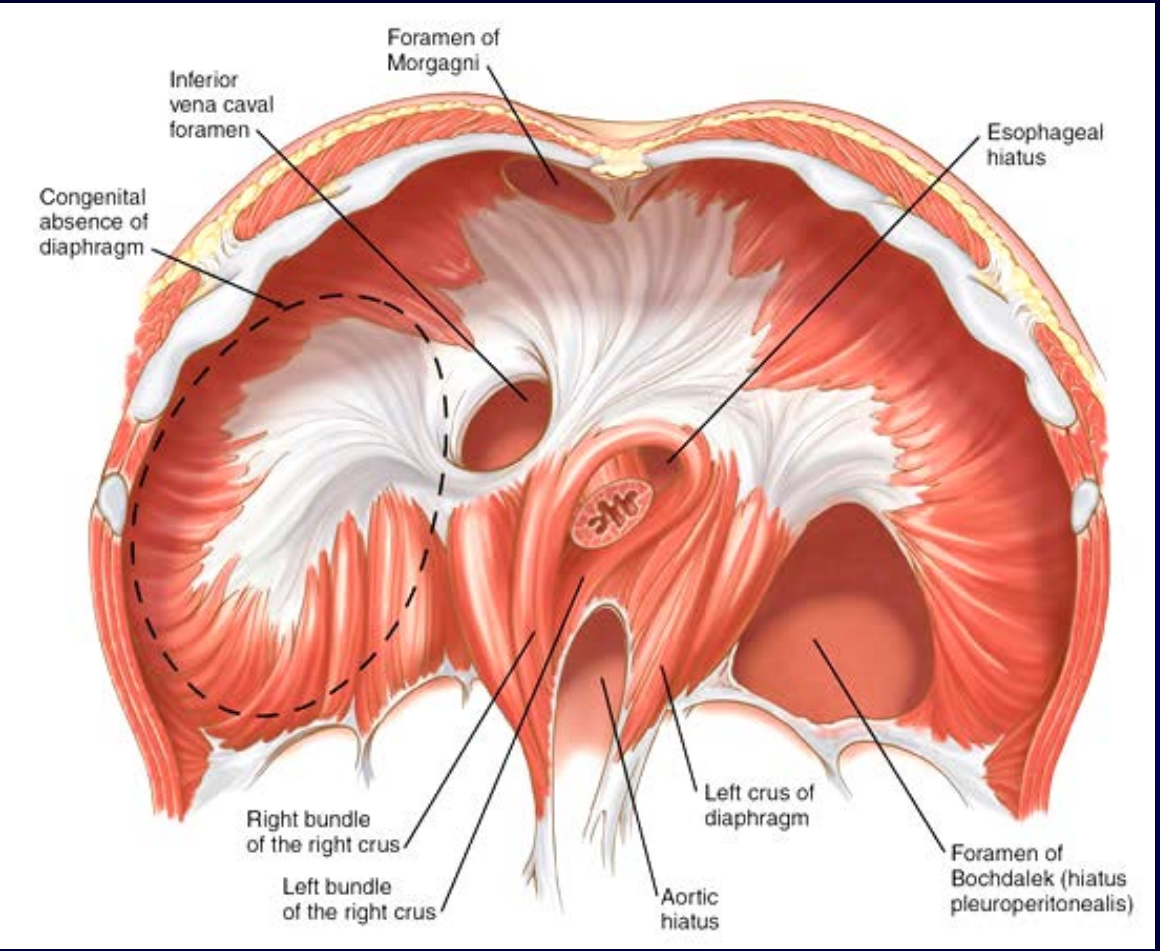
Diaphragmatic rupture at an acute phase is rarely life threatening; however, the injuries associated with diaphragmatic rupture are commonly life threatening.

Amin M., et al.: Pak Armed Forces Med J 1994;44:169–72.

The delayed diagnosis of TDR is associated with increased morbidity and mortality because of herniation and strangulation of the intra-abdominal organs through the ruptured diaphragm into the thorax. **All TDRs must be repaired**. All penetrating injuries involving the lower chest below the nipple line, abdomen, and back have a risk of diaphragmatic injury.

Miller Let al.: J Trauma. 1984;24(5):403-9.

ANATOMY



- Diaphragm consists of a central tendon, with right and left leaflets composed of striated muscles.
- Three large openings disrupt the continuity of the diaphragm: **the aortic, esophageal, and inferior vena cava apertures.**
- The diaphragm is covered by parietal pleura and peritoneum except for the bare area of the liver.
- Anatomically, the diaphragm is composed of two parts: **the lumbar diaphragm and costal diaphragm.**

Duane TM, Ivatury RR, Aboutanos MB, Malhotra AK. Injury to the diaphragm. In Flint L, Meredith JW, Schwab CW, Trunkey DD, Rue LW, Taheri PA (Eds). Trauma: Contemporary principles and therapy. Lippincott Williams & Wilkins, USA, 2007 Chapter 37.

Injury mechanisms

Diaphragm ruptures are frequently trauma induced (high kinetic energy) both in blunt or penetrating abdominal, thoracic or thoracoabdominal trauma.

Goh BK, Wong AS, Tay KH, Hoe MN. CJEM. 2004;6(4):277-80.
Morgan BS, Watcyn-Jones T, Garner JP. J R Army Med Corps. 2010;156(3):139-44.

These patients often have multiple injuries due to the significant energy necessary to induce diaphragmatic injury.

Morgan BS, Watcyn-Jones T, Garner JP. J R Army Med Corps. 2010;156(3):139-44.
Meyers BF, McCabe CJ. Ann Surg. 1993;218(6):783-90.

According to Shah R et al. 75% of all TDR are the result of blunt abdominal trauma while 25% are due to penetrating lesions, still the real TDR incidence is enigmatic due to misdiagnosed cases.

Shah R, Sabanathan S, Mearns AJ, Choudhury AK. Ann Thorac Surg. 1995;60(5):1444-9.

According to a recent study published by Dirican A et al. the frequency of TDR in patients with penetrating thoracic and abdominal injuries is 1.3%, the main etiology being penetrating wounds.

Dirican A, Yilmaz M, Unal B, Piskin T, Ersan V, Yilmaz S. Surg Today. 2011;41(10):1352-6.

Injury mechanisms

Traditionally is considered that the left part of the diaphragm is more frequently affected, the ratio being 25:1.

Vilallonga R, Pastor V, Alvarez L, Charco R, Armengol M, Navarro S. World J Emerg Surg. 2011;6:3.

On the other hand the autopsy results proved that both parts of the diaphragm are equally injured, the recent series showing a 35% ratio for right diaphragm injuries of all TDR.

Goh BK, Wong AS, Tay KH, Hoe MN. CJEM. 2004;6(4):277-80.

These data could be explained by the protective mechanism of the liver, some authors consider that right-sided diaphragmatic injuries are associated with a signifficant mortality rate thus are not diagnosed, this is why the pathology reports are similar for left and right TDR.

Chughtai T, Ali S, Sharkey P, Lins M, Rizoli S. Can J Surg. 2009;52(3):177-81.

According to Grimes OF., 3 evolutive phases of TDR are distinguished: 1) **acute phase**, at the moment of injury; 2) **latent phase** accompanied by transitory visceral herniation and is characterized by nonspecific signs; 3) **obstructive phase** characterized by long-time herniation or strangulation.

Grimes OF. Am J Surg 1974;128(2):175–81.

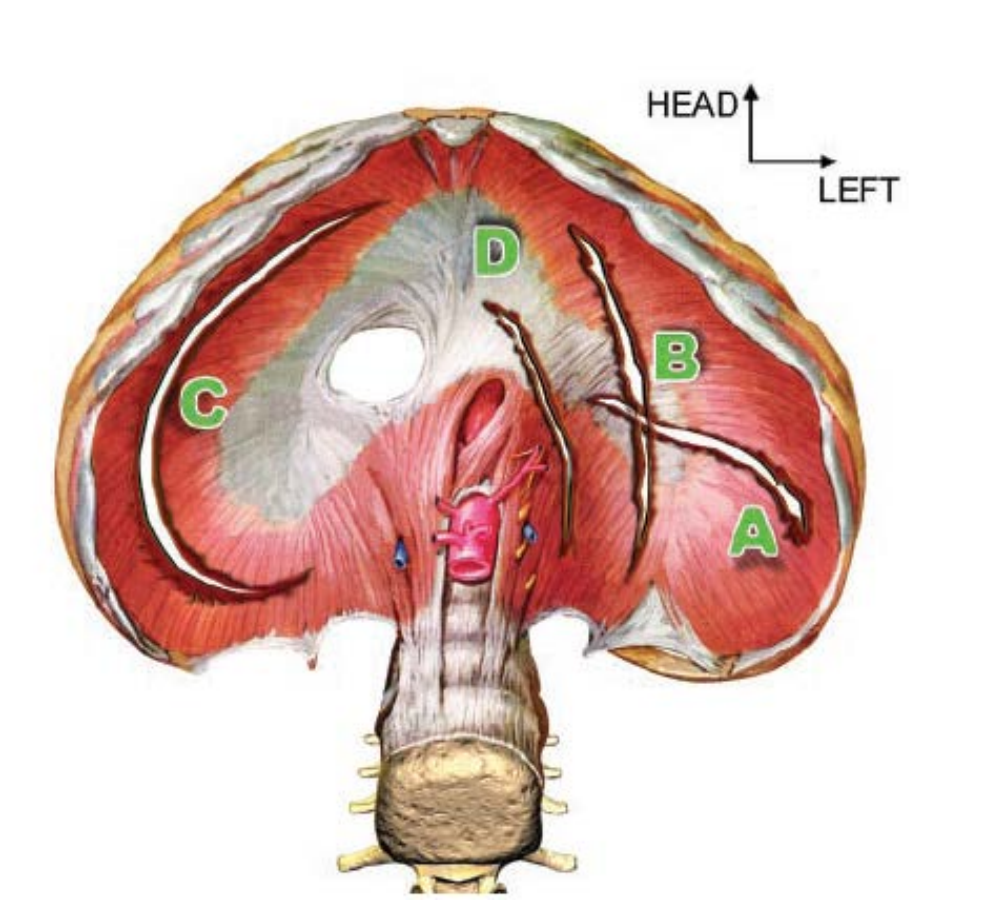
Table 1. Causes and types of trauma, herniation, and location of traumatic diaphragm rupture sustained in 48 patients

Cause of trauma	Side of diaphragm rupture			Total, *n*	*P* value
	Bilateral, *n* (%)	Right side, *n* (%)	Left side, *n* (%)		
Iatrogenic	0	0	1 (100)	1	NS
Gunshot	2 (13)	4 (27)	9 (60)	15	
Stab wound	0	6 (35)	11 (65)	17	
TA	0	0	9 (100)	9	
Fall	1 (17)	0	5 (83)	6	
Type of trauma					
Blunt	1 (7)	0	14 (93)	15	<0.05
Penetrating	2 (6)	10 (30)	21 (64)	33	
Herniation (+, −)					
Herniation (+)	1[a] (6)	0	15 (94)	16	<0.05
Herniation (−)	2 (6)	10 (31)	20 (63)	32	

TA, traffic accident; NS, not significant
[a]Left side herniation

Dirican A., et al.: Surg Today. 2011;41(10):1352-6.

Injury sites



Sites of injuries. Drawing shows
Radial (A)
Transverse (B)
Central (C)
Peripheral detachment (D).

Radial tears appear to be the most frequently found injury at surgery, whereas peripheral detachments are the least frequent.

Most ruptures are longer than 10 cm and occur at the posterolateral aspect of the hemidiaphragm between the lumbar and intercostal attachments and spread in a radial direction

Iochum S, Ludig T, Walter F, Sebbag H, Grosdidier G, Blum AG. Radiographics. 2002;22 Spec No:S103-18.

Surg Today (2011) 41:1352–1356
DOI 10.1007/s00595-010-4518-3

SURGERY TODAY

Original Article

Acute Traumatic Diaphragmatic Ruptures: A Retrospective Study of 48 Cases

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Department of General Surgery, Inonu University School of Medicine, Turgut Ozal Medical Center, 44315 Malatya, Turkey

The most common symptoms were dyspnea in 30 patients (65%) and upper abdominal pain in 25 patients (52%). Hemorrhagic shock occurred in 22 (46%) patients when they were admitted to the hospital.

Forty patients' (83%) TDR diagnoses and treatments were established less than 24 h after the trauma occurred.

In the remaining 8 patients, the diagnostic and treatment delay ranged from 1 to 10 days.

Clinical Features

Three distinct phases of presentation of TDI*

Acute Phase: This is from the initial insult to apparent recovery from injury

- Abdominal Pain
- Other injuries (Chest/abdominal wall, pelvis, head, extremities, haemopneumothorax, abdominal viscera)
- Haemodynamic instability or lability
- Respiratory Distress
- Decreased air entry on affected side
- Auscultation of bowel sounds in chest (pathognomic)!
- Chest x-ray abnormality
- Defect identified at emergency surgery (traditionaly laparotomy)

* Grimes OF. Am J Surg 1974;128(2):175–81.

Clinical Features

***Latent Phase*: This occurs as intra-abdominal content traverses the defect into the thorax and may occur from hours to weeks after injury. It decreases the functional capacity of the thorax**

- **Upper gastrointestinal complaints**
- **Dyspnoea/cyanosis**
- **Tachycardia**
- **Substernal pain/referred shoulder tip pain**
- **Restlessness**
- **Dyspnoea exacerbated by lying flat**
- **Dull percussion note / decreased breath sounds on affected side**
- **Auscultation of bowel sounds in chest**
- **Abnormal chest x-ray findings**

*** Grimes OF. Am J Surg 1974;128(2):175–81.**

Clinical Features

Obstructive phase: It occurs months to years after injury as the herniated viscera obstruct or strangulate. 85% of strangulations occur within three years of initial injury.

- Nausea/vomiting
- Symptoms of intestinal obstruction/ischaemia/haemorrhage
- Chronic respiratory difficulty secondary to atelectasis and resultant pneumonitis
- Mediastinal shift
- ***Borchardts triad*** (upper abdominal pain and distension, vomiting and inability to pass a NG tube)
- Auscultation of bowel sounds in chest

* Grimes OF. Am J Surg 1974;128(2):175–81.

Diagnosis

Up to date several modalities are available for TDR diagnosis:

- **Thoracic x-Ray**
- **CT**
- **USG**
- **MRI**
- **Contrasted GI studies**
- **Fluoroscopic evaluation of the diaphragm motility**
- **Laparoscopy**
- **Video-Assisted Thoracoscopy**

Chest X Ray is the most accessible and frequently used method for TDR diagnosis.

Mihos P, Potaris K, Gakidis J, Paraskevopoulos J, Varvatsoulis P, Gougoutas B, Papadakis G, Lapidakis E. Injury. 2003;34(3):169-72.
Morgan BS, Watcyn-Jones T, Garner JP. J R Army Med 2010;156(3):139-44.

Diagnosis

Up to 50% of Chest X Rays studies in patients with TDR, that are confirmed further, are described as “normal” or misinterpreted .

Mihos P, Potaris K, Gakidis J, Paraskevopoulos J, Varvatsoulis P, Gougoutas B, Papadakis G, Lapidakis E. Injury. 2003;34(3):169-72.
Murray JG, Caoili E, Gruden JF, Evans SJ, Halvorsen RA Jr, Mackersie RC. AJR Am J Roentgenol. 1996;166(5):1035-9.
Rosati C. Chest Surg Clin N Am. 1998;8(2):371-9.

Initial Chest X Ray (no TDR is visualized)

Air-fluid level in the left thorax – herniated stomach

Diagnosis

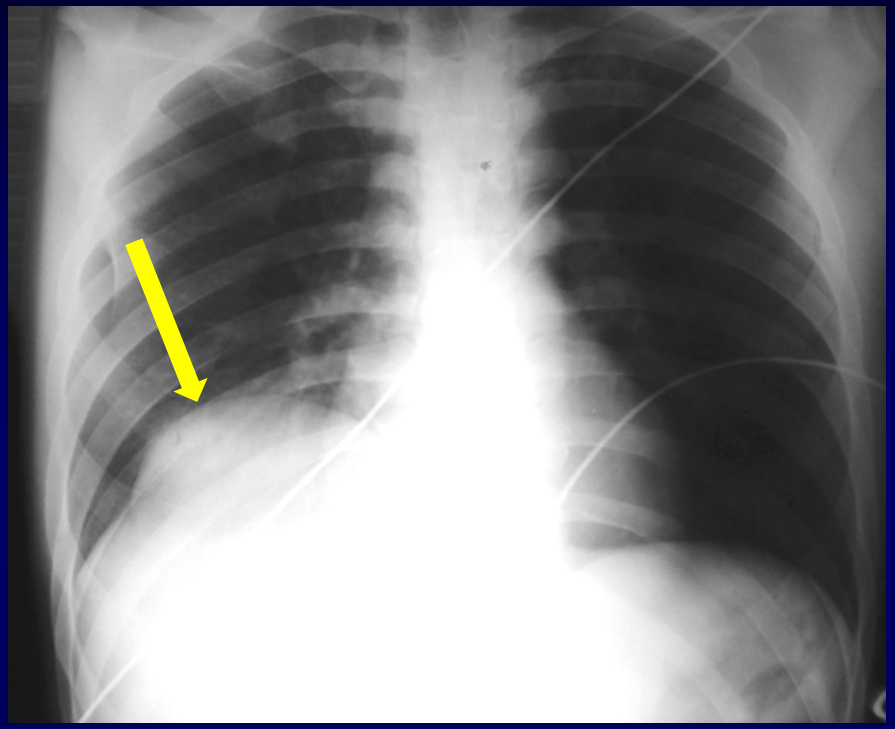
Diagnostic accuracy of simple chest X Ray is 4 times higher for left sided TDR *vs.* rite-sided lesions (62% *vs.* 17%) respectively.

Mihos P, Potaris K, Gakidis J, Paraskevopoulos J, Varvatsoulis P, Gougoutas B, Papadakis G, Lapidakis E. Injury. 2003;34(3):169-72.

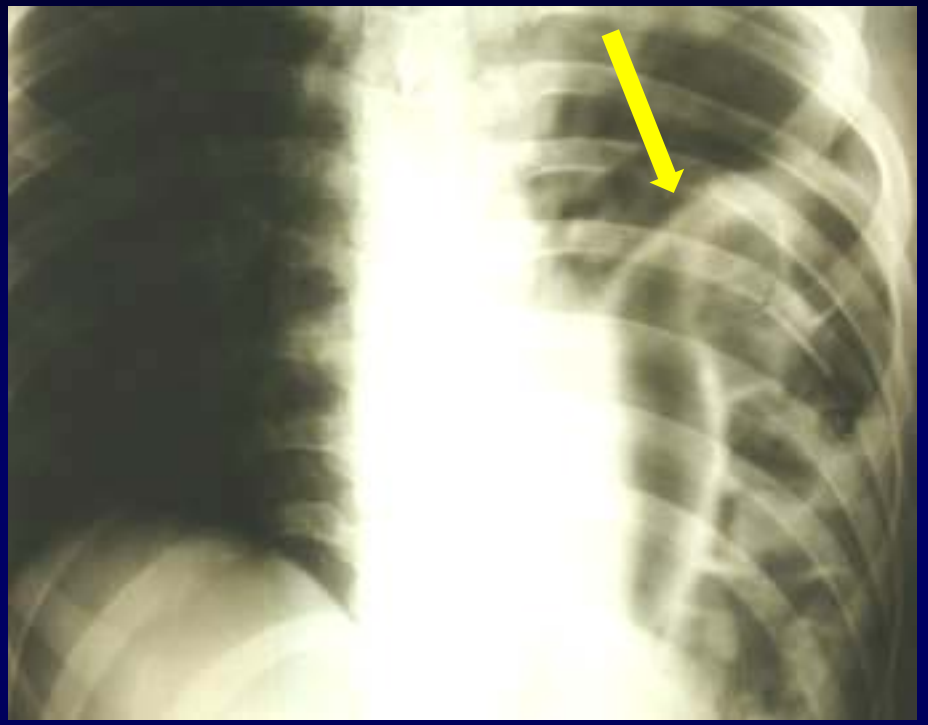
Specific signs	Suggestive signs
Nasogastric tube above the hemidiaphragm on the left side	Elevation of the hemidiaphragm
Intrathoracic herniation of a hollow viscus (stomach, colon, small bowel)	Distortion or obliteration of the outline of the hemidiaphragm
Focal constriction of the viscus at the site of the tear (collar sign)	Contralateral shift of the mediastinum

Gwely NN. Asian Cardiovasc Thorac Ann. 2010;18(3):240-3.

Diagnosis



Chest radiograph showing a rupture of the right hemidiaphragm (arrow)

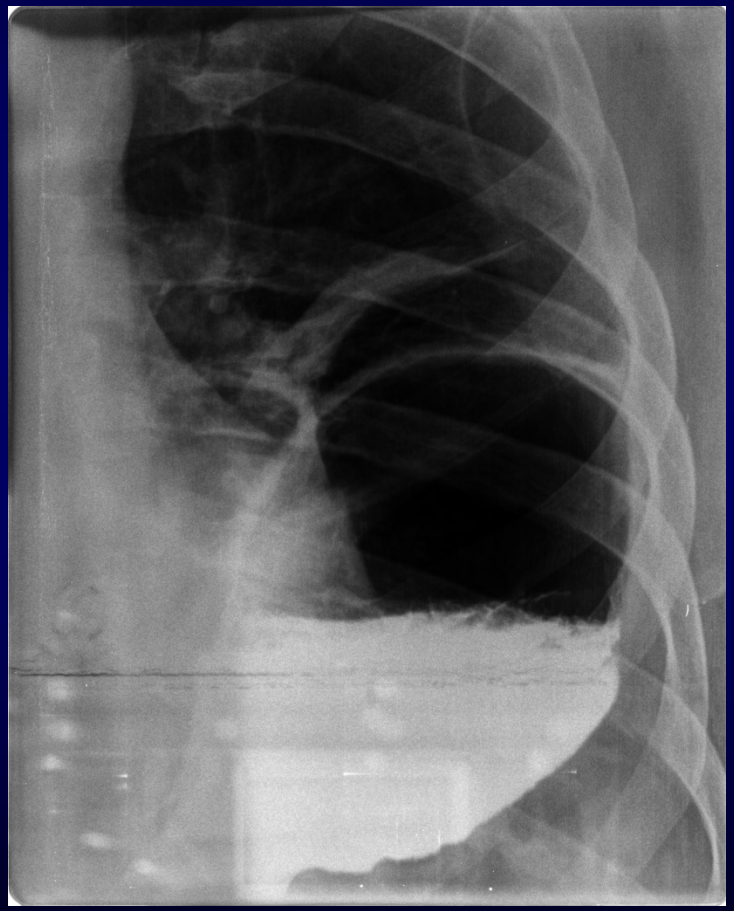


Chest radiograph showing a rupture of the left hemidiaphragm (arrow)

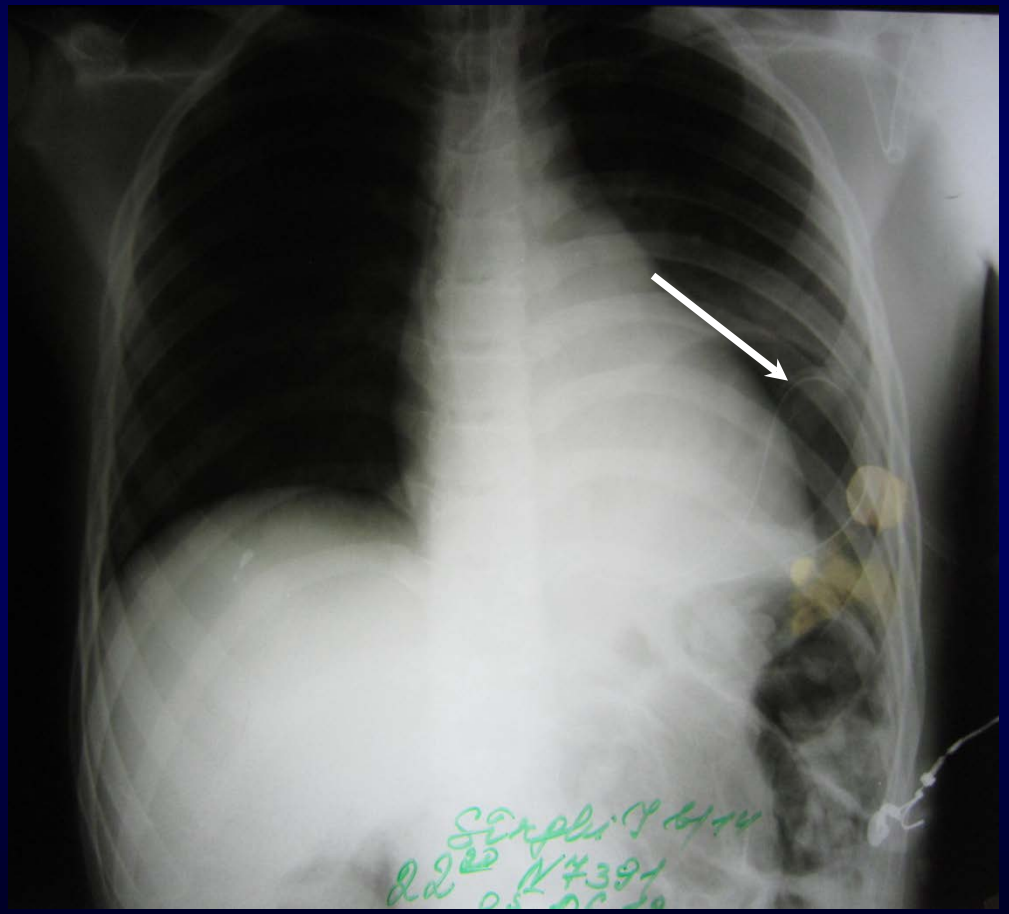
Diagnosis

Diagnostic accuracy of simple chest X Ray can be improved by oral administration of contrast media or by placing a NG tube.

Mihos P, Potaris K, Gakidis J, Paraskevopoulos J, Varvatsoulis P, Gougoutas B, Papadakis G, Lapidakis E. Injury. 2003;34(3):169-72.



Gastrography – herniated stomach into the left thorax

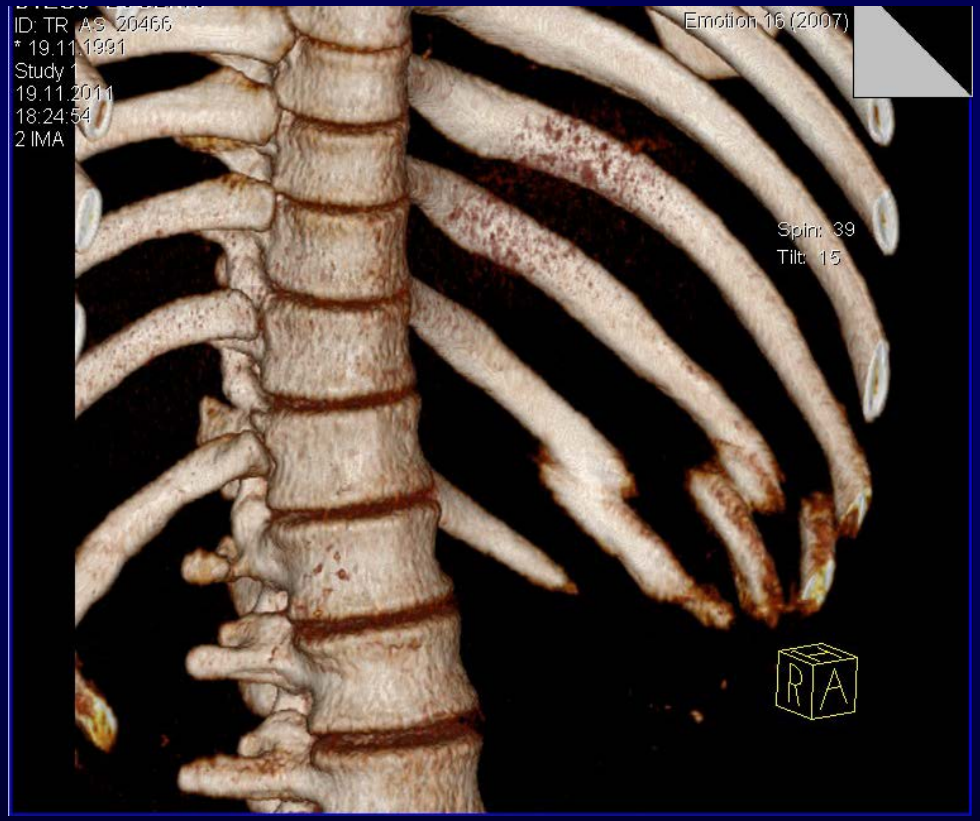


NG tube in the left thorax (→)

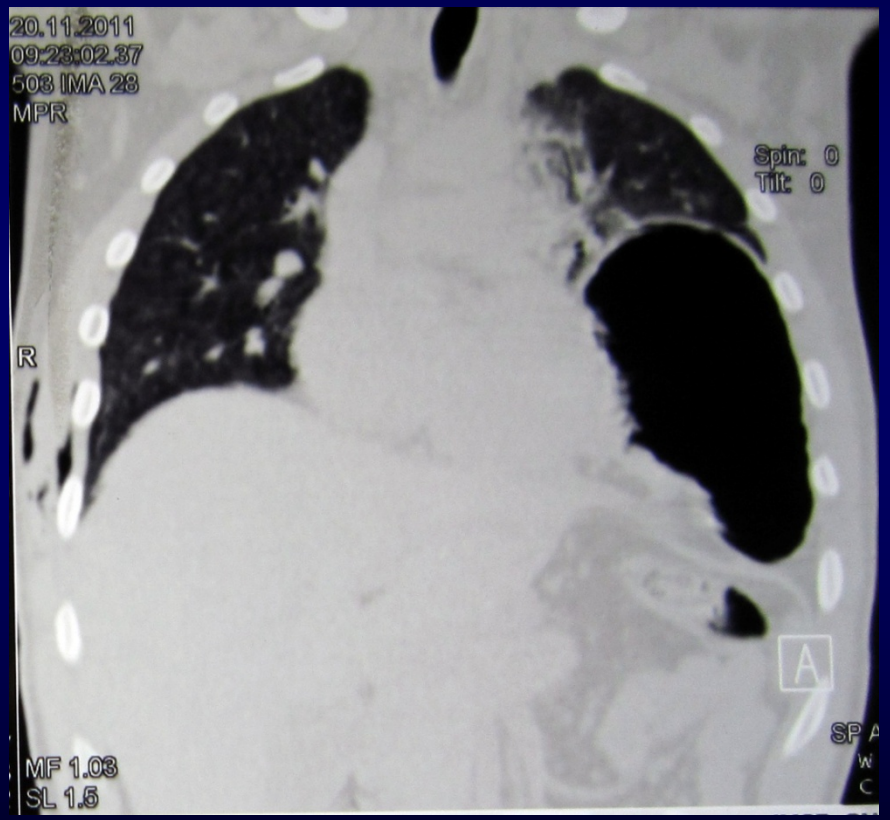
Diagnosis

Chest X Ray is considered a screening test for potential diagnosis of a TDR, up to date this could be replaced with MDCT "multi-detector computed tomography".

Mirvis SE, Shanmuganagthan K. Eur Radiol. 2007;17(6):1411-21.



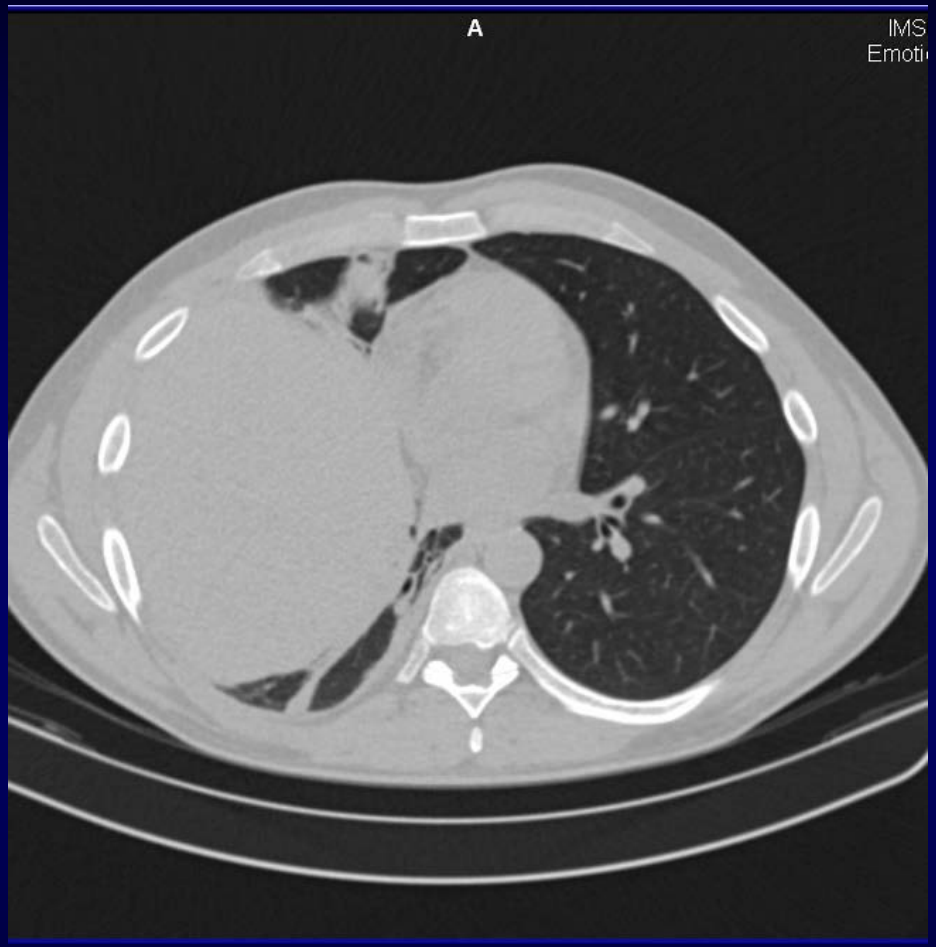
CT – multiple left-sided rib fractures



CT – herniated stomach into the left thorax

Diagnosis

CT – herniated liver into the pleural cavity (A-P view)



CT – herniated liver into the pleural cavity

Traumatic diaphragmatic rupture was preoperatively diagnosed in 12 (25%) patients and perioperatively diagnosed in 36 (75%) patients.

Dirican A., et al.: Surg Today. 2011;41(10):1352-6.

The diagnostic methods included: a chest X-ray, computed tomography (CT), ultrasonography (USG), and oral contrast studies.

Dirican A., et al.: Surg Today. 2011;41(10):1352-6.

Treatment

The management of TDR is surgical. Up to date several approaches for TDR treatment are available:

- Open
- Minimal invasive
- Via peritoneal cavity
- Via pleural cavity
- Combined (thoraco-abdominal)

The surgical approach depends upon the experience, technical equipment and profile of the department.

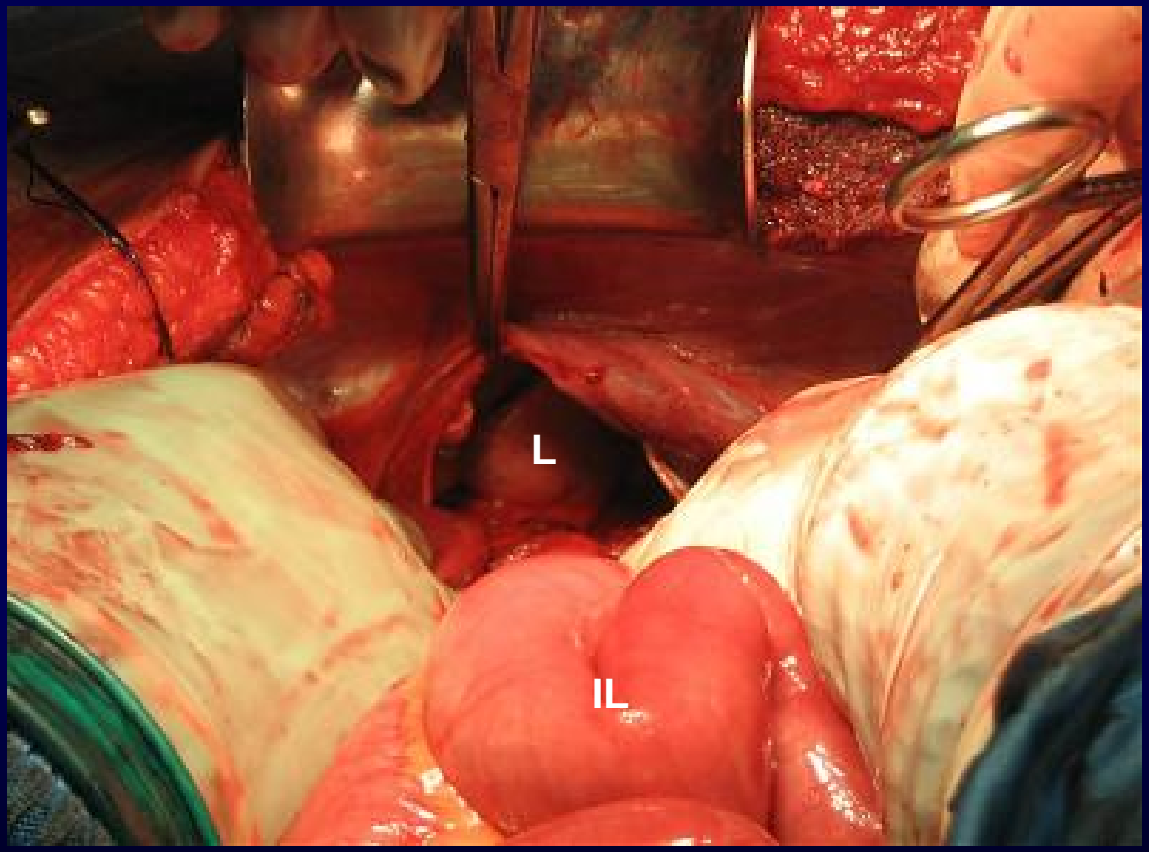
Author	Nr. of cases	Type of trauma Blunt/Penetrating	Site Left/Right/Bilateral	Surgical approach Abdomen/Thorax/ Combined	Mortality %
Lewis JD., et al. (2009)	254	99/155	129/78/9	165/8/21	22*
Athanassiadi K., et al. (1999)	41	41	24/15/2	22/10/4	6
Gwely NN., et al. (2010)	44	44	30/12/2	4/37/3	13
Matsevych OY. (2008)	12	12	9/2/1	11/0/1	25
Chandra A., et al. (2007)	15	12/3	12/3/0	0/11/4	6.7
Dirican A., et al. (2011)	48	15/33	35/10/3	46/2/0	14.8

*54/254 did not survive to be operated, mortality is presented in the operated group

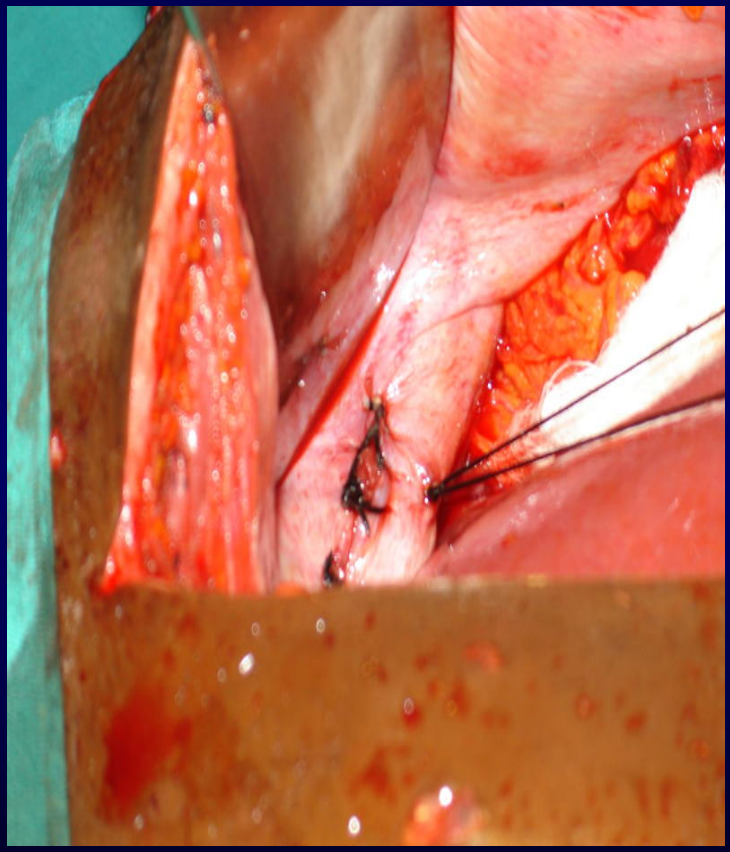
Treatment

The aim of the surgical management is “hernia” reposition, suturing of the TDR and associated injuries treatment. All TDR must be repaired either with absorbable or non-absorbable sutures.

Grillo IA, Jastaniah SA, Bayoumi AH, Karami F, al-Naami MY, Malatani TS, al-Ghamdi B, Eltahir MI, al-Shehri MY. Indian J Chest Dis Allied Sci. 2000;42(1):9-14.

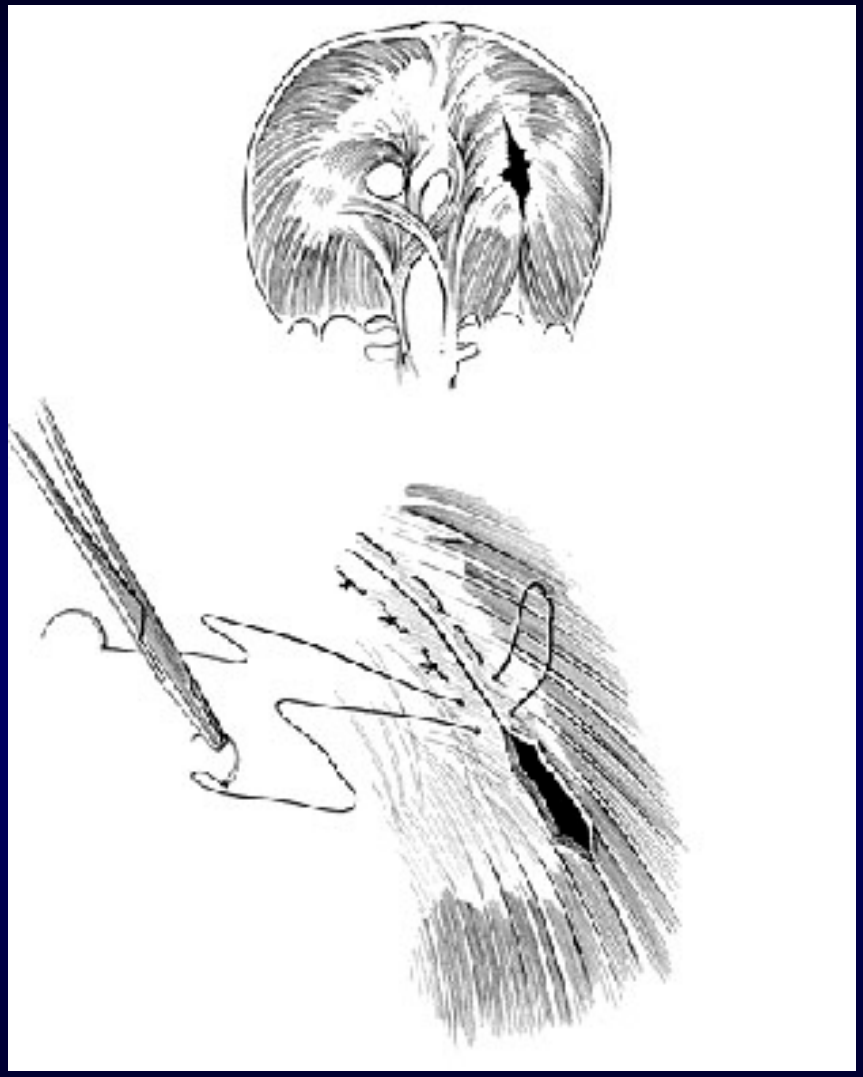


Left-sided diaphragm injury, peritoneal approach (IL – intestinal loop, L – lung)

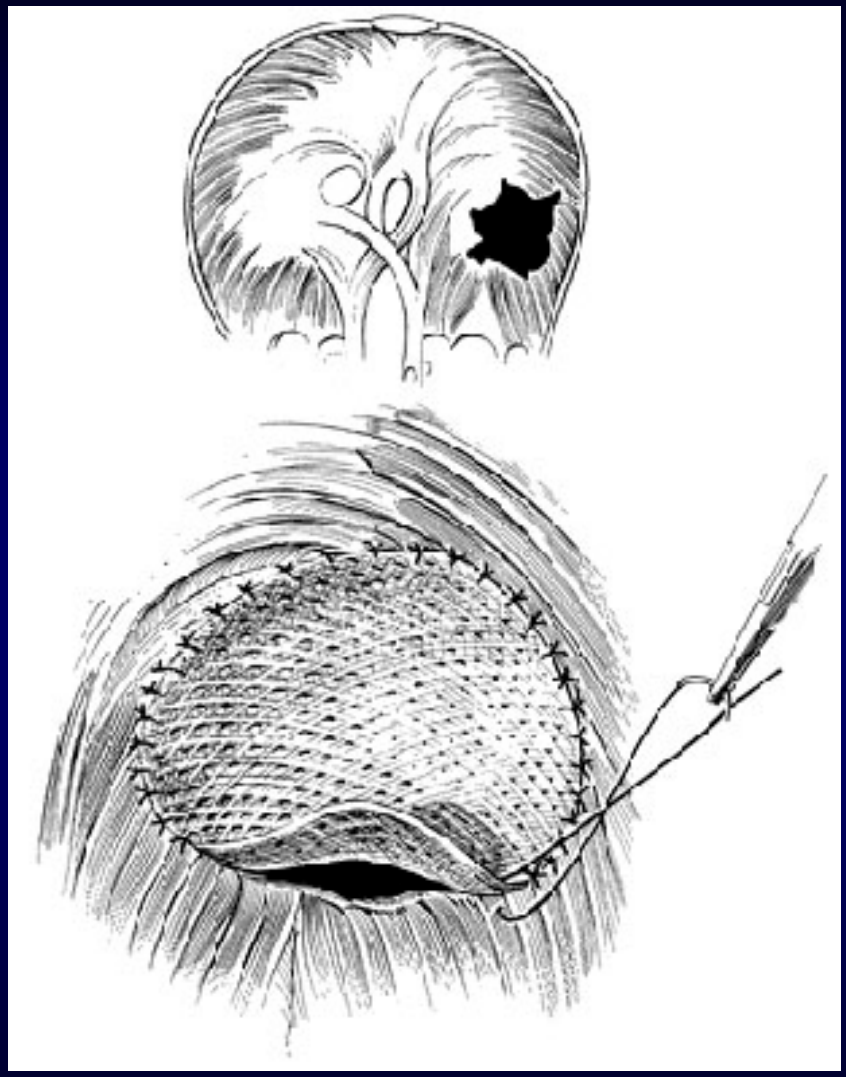


Diaphragm injury sutured through abdominal approach

In case of significant sized injuries the “tension free” principle, by implanting of prosthesis in an option.

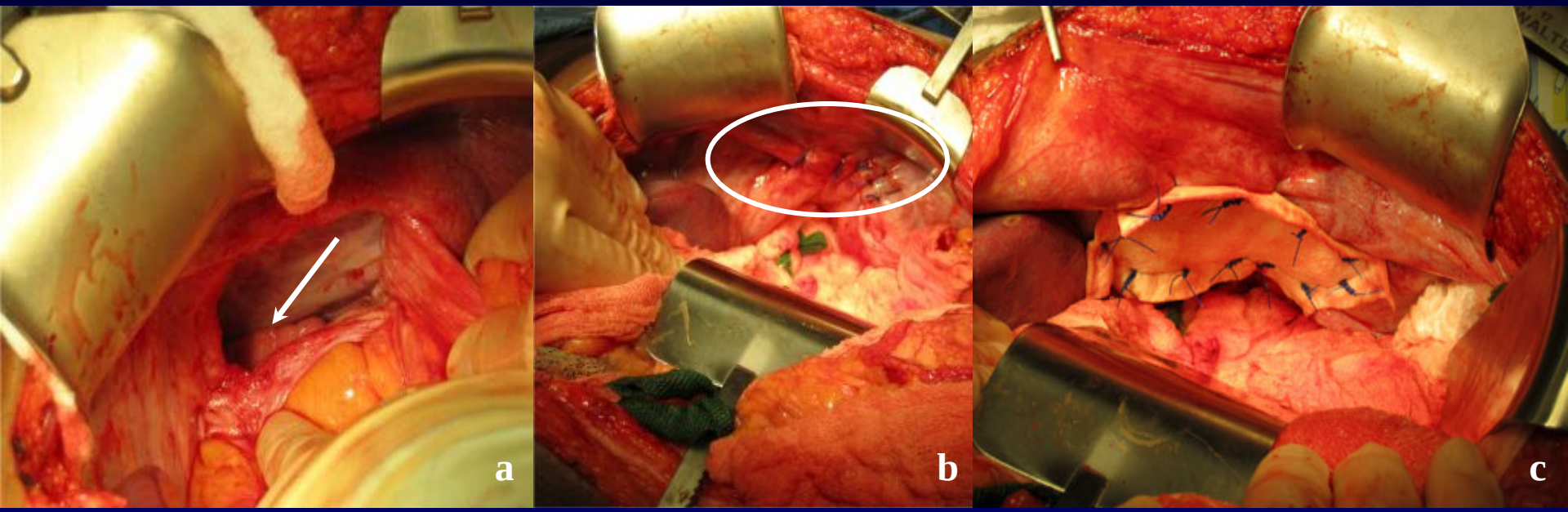


Diaphragmatic repair using interrupted sutures



Closure of a large defect with marlex mesh using interrupted sutures

Treatment

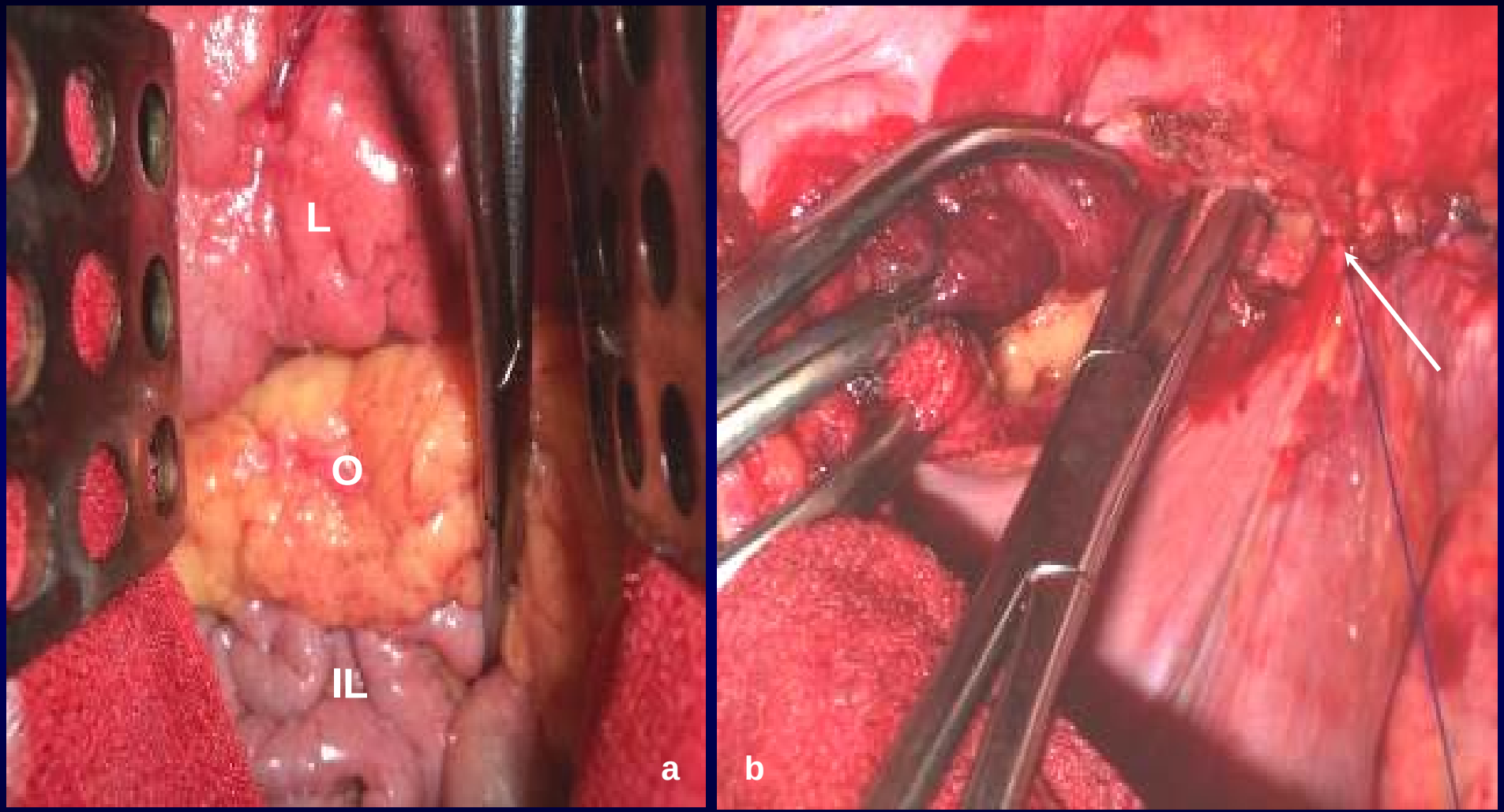


(a) The diaphragm with a defect approximately 10 x 12 cm extending from the central tendon laterally. The inferior left lung lobe can be seen in the background (→).

(b) The diaphragm edges are mobilized from the surrounding adhesions. The defect is closed under minimal tension.

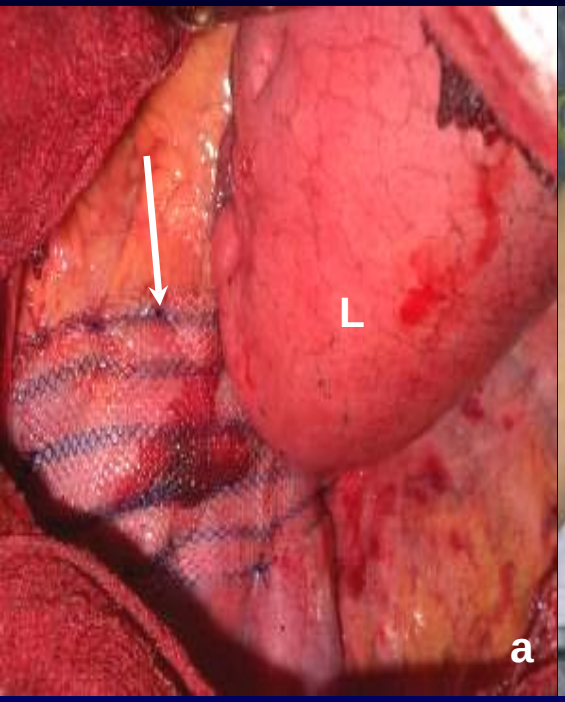
(c) Due to the size of the defect, it was reinforced with Alloderm 8cm x 15cm circumferentially in interrupted fashion.

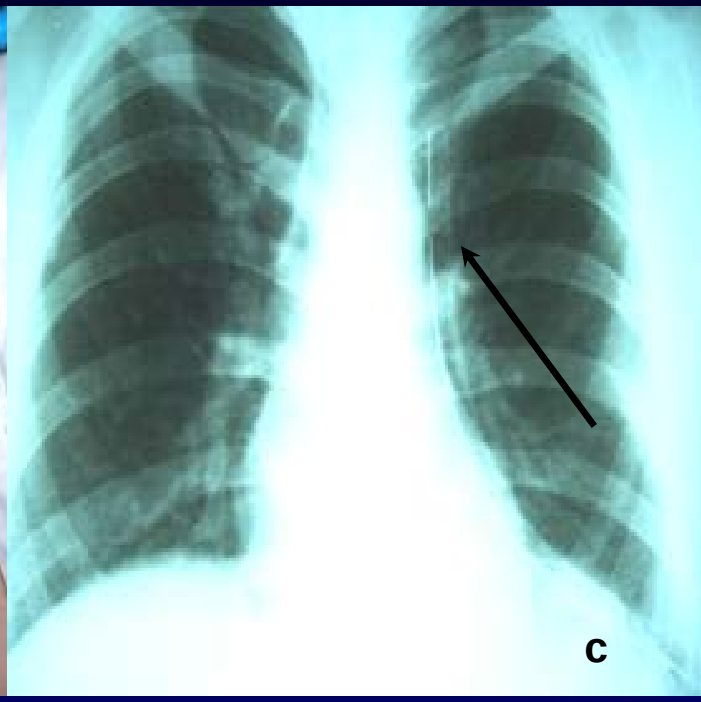
Treatment



a) Thoracotomy – intestinal loops (IL) in the left thorax; lung (L); omentum (O)
b) TDR repair with non-absorbable running suture (→)

Treatment



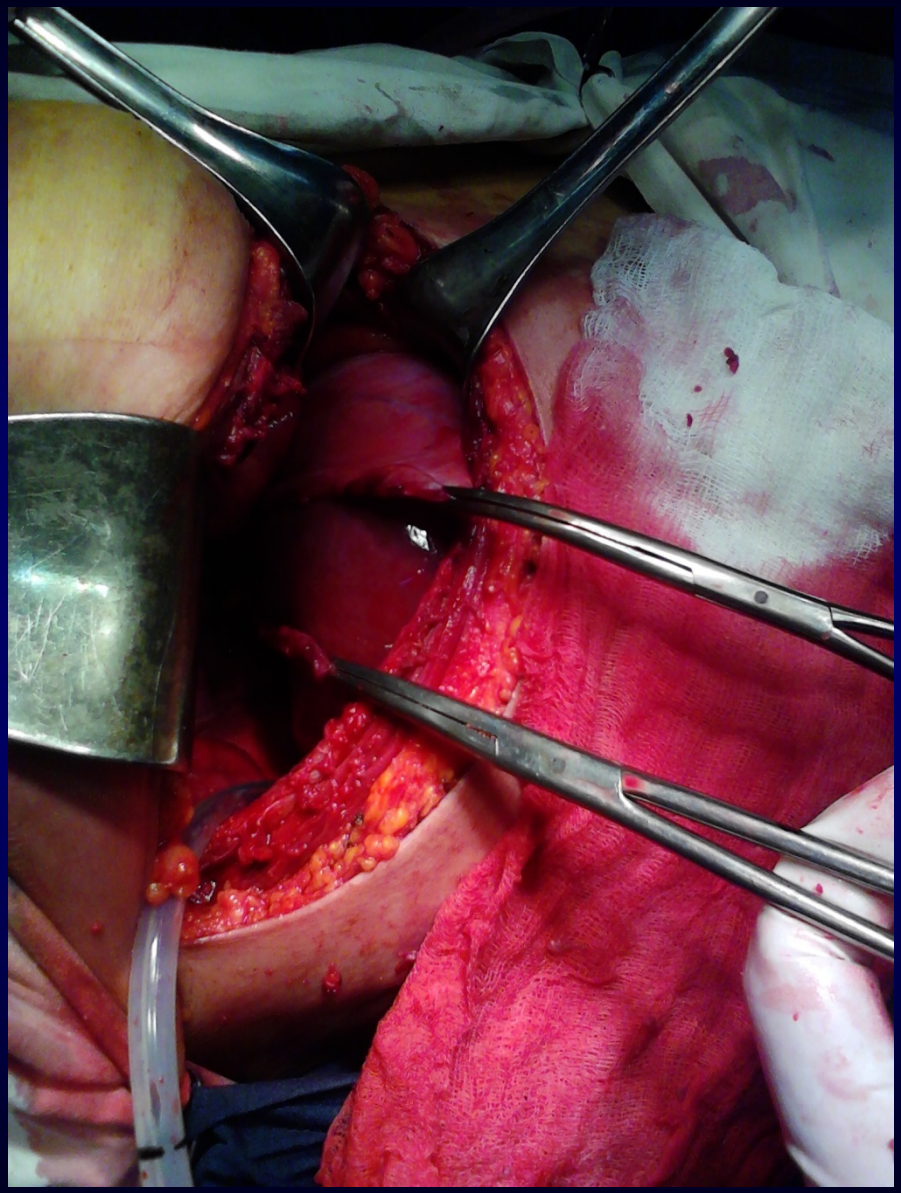


a) The suture line was secured with a mesh (→); lung (L)

b) Final view, drainage in the left pleural cavity (→)

c) Postoperative Chest X Ray expanded lung, drainage *in situ* (→)

Treatment



Treatment

Up to date there are no evidence to prove the superiority of any (Laparotomy vs Thoracotomy) in a hemodynamically stable patient.

Laparotomy is indicated in case of abdominal organs injury – cases that are difficult to deal via a Thoracotomy.

It is accepted that right-sided TDR in the acute phase, as well as the chronic hernias must be approached via a right-sided thoracotomy, while left-sided TDRs – via a laparotomy.

According to Peer SM. et al., thoracotomy is indicated in late diagnosed cases or in acute cases, when concomitant abdominal trauma was ruled out.

Morgan BS, Watcyn-Jones T, Garner JP. J R Army Med Corps. 2010;156(3):139-44.
Haciibrahimoglu G, Solak O, Olcmen A, Bedirhan MA, Solmazer N, Gurses A. Surg Today. 2004;34(2):111-4.
Peer SM, Devaraddeppa PM, Buggi S. Int J Surg. 2009;7(6):547-9.

Treatment

In a hemodynamically unstable patient the primary optimal surgical approach is questionable.

In case of laparotomy, 53% had to be stopped compared to 36% of initial thoracotomy.

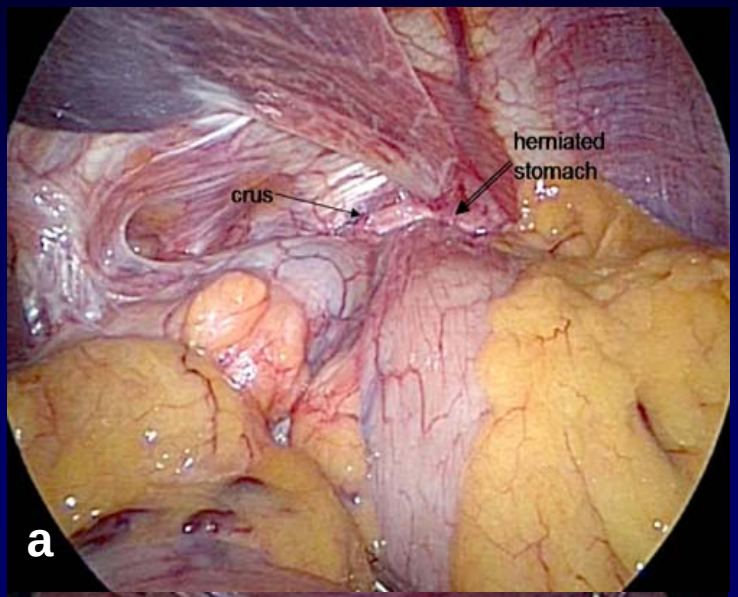
The most common indication for the exploration of another cavity was the patient's hemodynamic instability, that could not be explained by the injuries of the first cavity, or significant drainage discharge though a chest-tube thoracostomy.

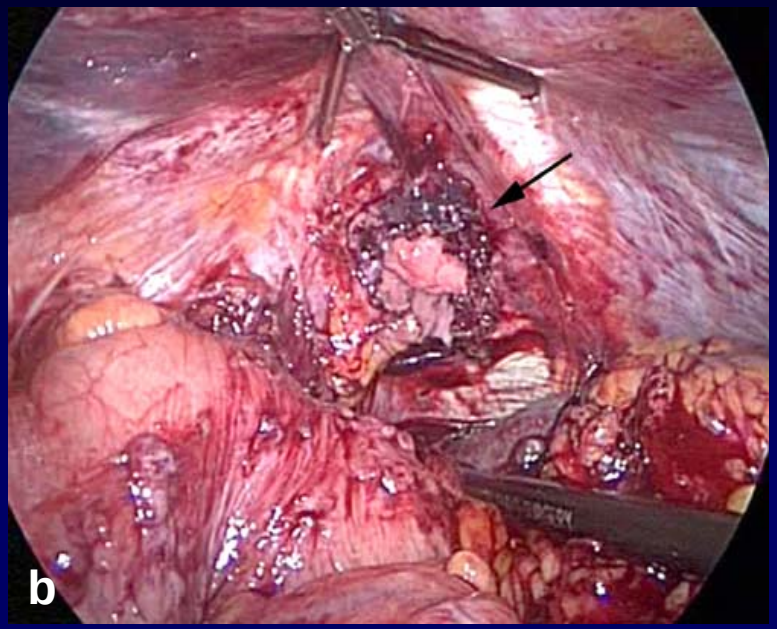
Generally about 50% of the thoraco-abdominal procedures are chronologically incorrect and the mortality in case of both cavity approach is double compared to the patients that had only one cavity exposed (31% *vs.* 59%).

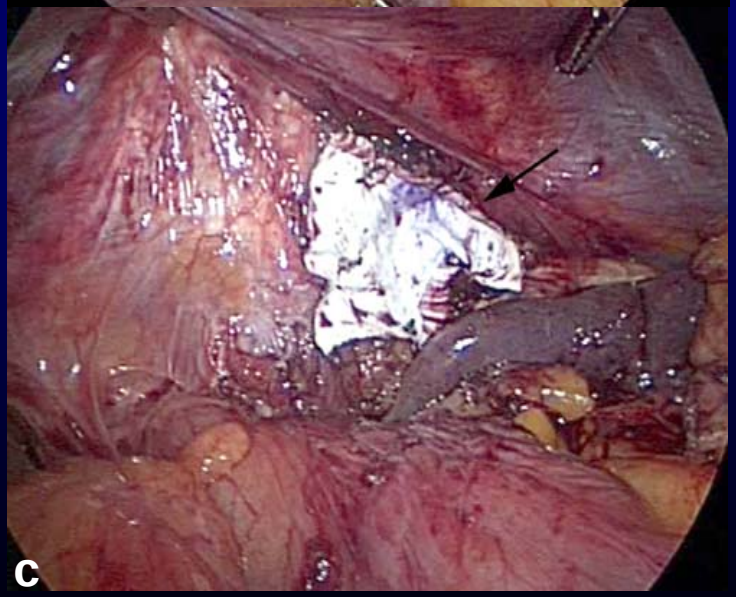
Asensio JA, Arroyo H Jr, Veloz W, Forno W, Gambaro E, Roldan GA, Murray J, Velmahos G, Demetriades D. World J Surg. 2002;26(5):539-43.

Laparoscopic approach for a diaphragmatic hernia

The minimally-invasive procedures are use either as diagnostic or treatment modalities, with similar results to laparotomy or thoracotomy approach.







(a) Intraoperative view – herniated stomach through the defect in the left diaphragm.

(b) Intraoperative view – the left diaphragm defect (→) after gastric reposition.

(c) Intraoperative view – the left diaphragm defect closed by PTFE (→) prosthesis.

TDR Patient's characteristic treated in the Chishinau Emergency Hospital 2012

Nr	Age/sex	Trauma mechanism	Injury site	Injury size (cm)	Diagnosis (h)	Surgical approach
1	34/M	Wound	Right	0.5	<12	Laparoscopic
2	46/M	Blunt	Left	20	60	LM
3	14/M	Blunt	Left	6	120	LM
4	31/M/†	Wound	Right	3	<12	TT+LM
5	45/M	Wound	Left	4	<12	LM
6	27/M	Wound	Right	3	<12	LM
7	32/F	Wound	Right	3	<12	LM

LM – laparotomy; TT+LM – thoracotomy and laparotomy; † - death

The mean age was 32.71±4.12 (14-46) years, 71.42% were assaulted.

The injury site (right *vs.* left) was in a ratio of 1.33:1.

The best majority of cases (71.4%) were diagnosed within the first 12 hours.

The mean injury size was 5.64±2.47 (0.5-20) cm.

In al the cases TDR was repaired using a simple suture.

Postoperative mortality was 14.28%.

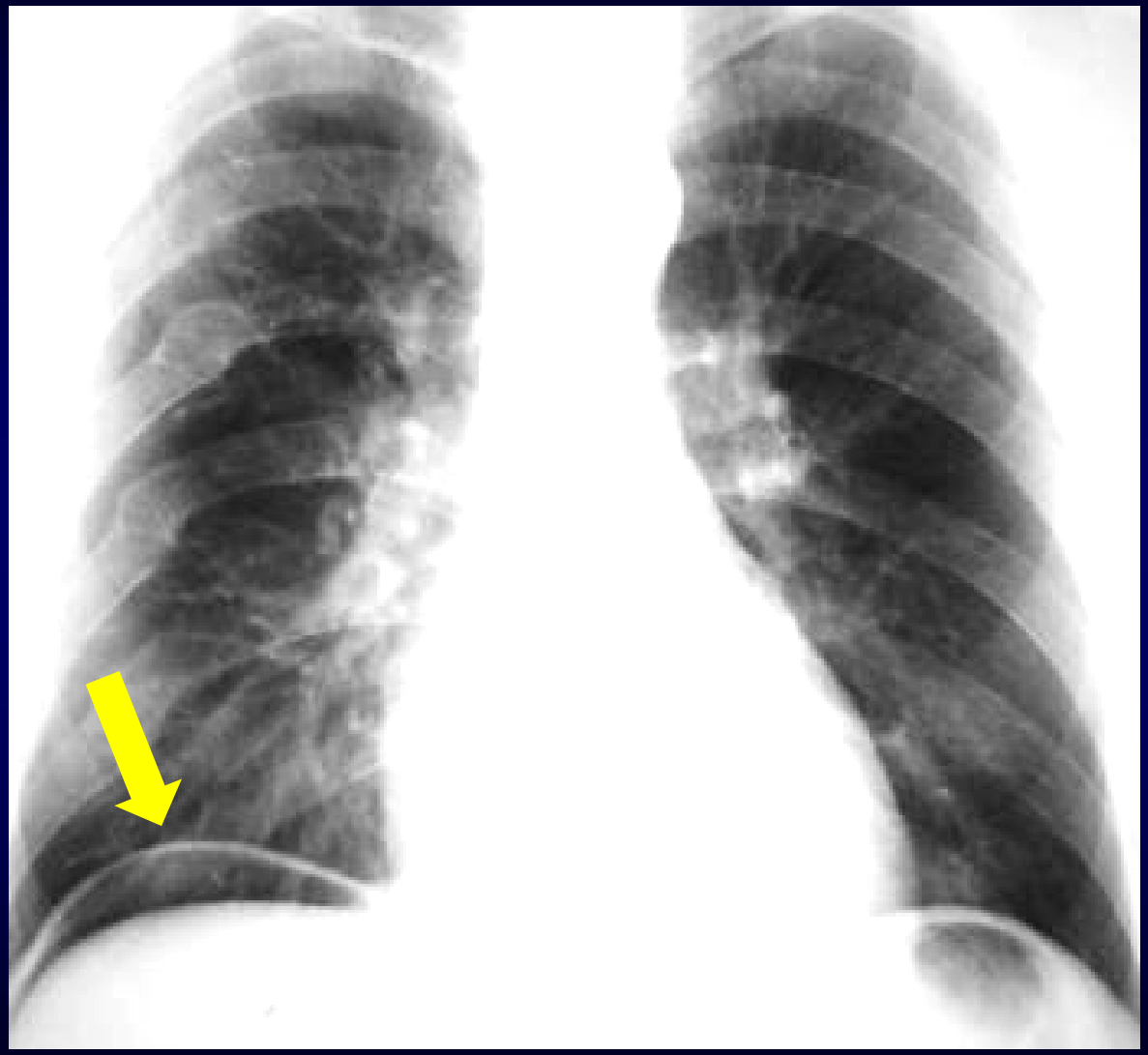
Gastric injuries

STOMACH

Injury severity classification

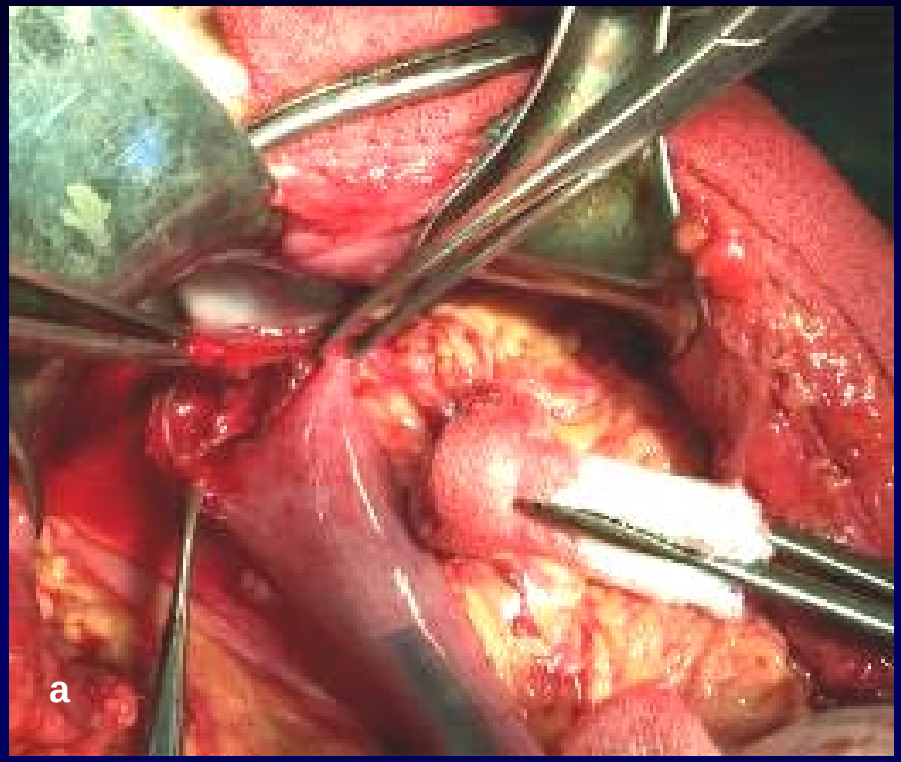
Grade	Injury characteristics
I	Contusion/haematoma; Partial injury without perforation
II	Injury < 2 cm in the GEJ or pyloric area
	Injury < 5 cm in 1/3 proximal part of the stomach
	Injury < 10 cm in 2/3 distal part of the stomach
III	Injury > 2 cm in the GEJ or pyloric region
	Injury > 5 cm in 1/3 proximal part of the stomach
	Injury >10 cm in 2/3 distal part of the stomach
IV	Tissue defect or devascularisation <2/3 of the stomach
V	Tissue defect or devascularisation >2/3 of the stomach

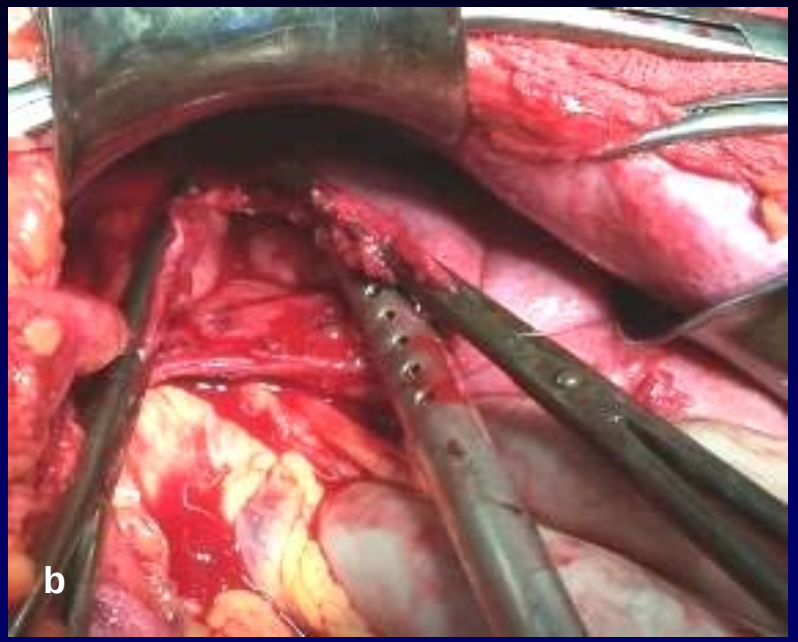
STOMACH

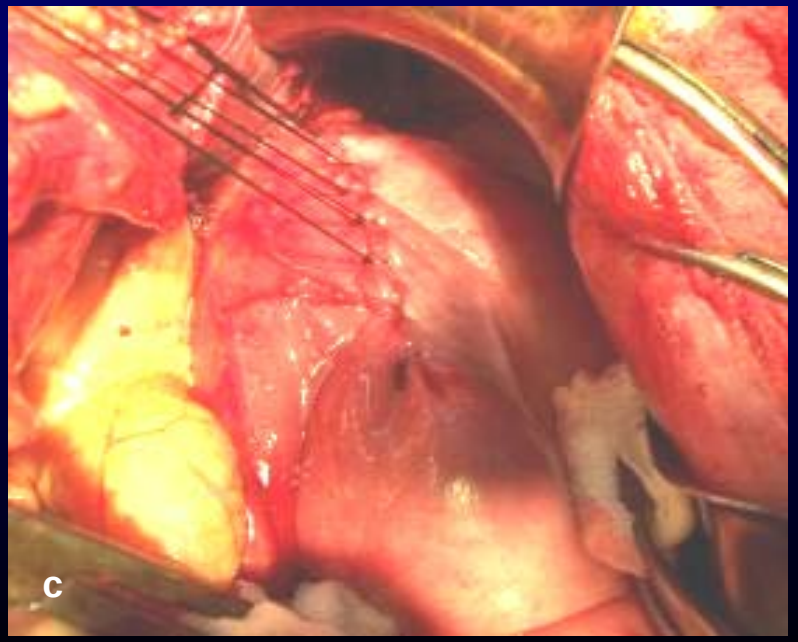


Simple abdominal x-ray - pneumoperitoneum

STOMACH

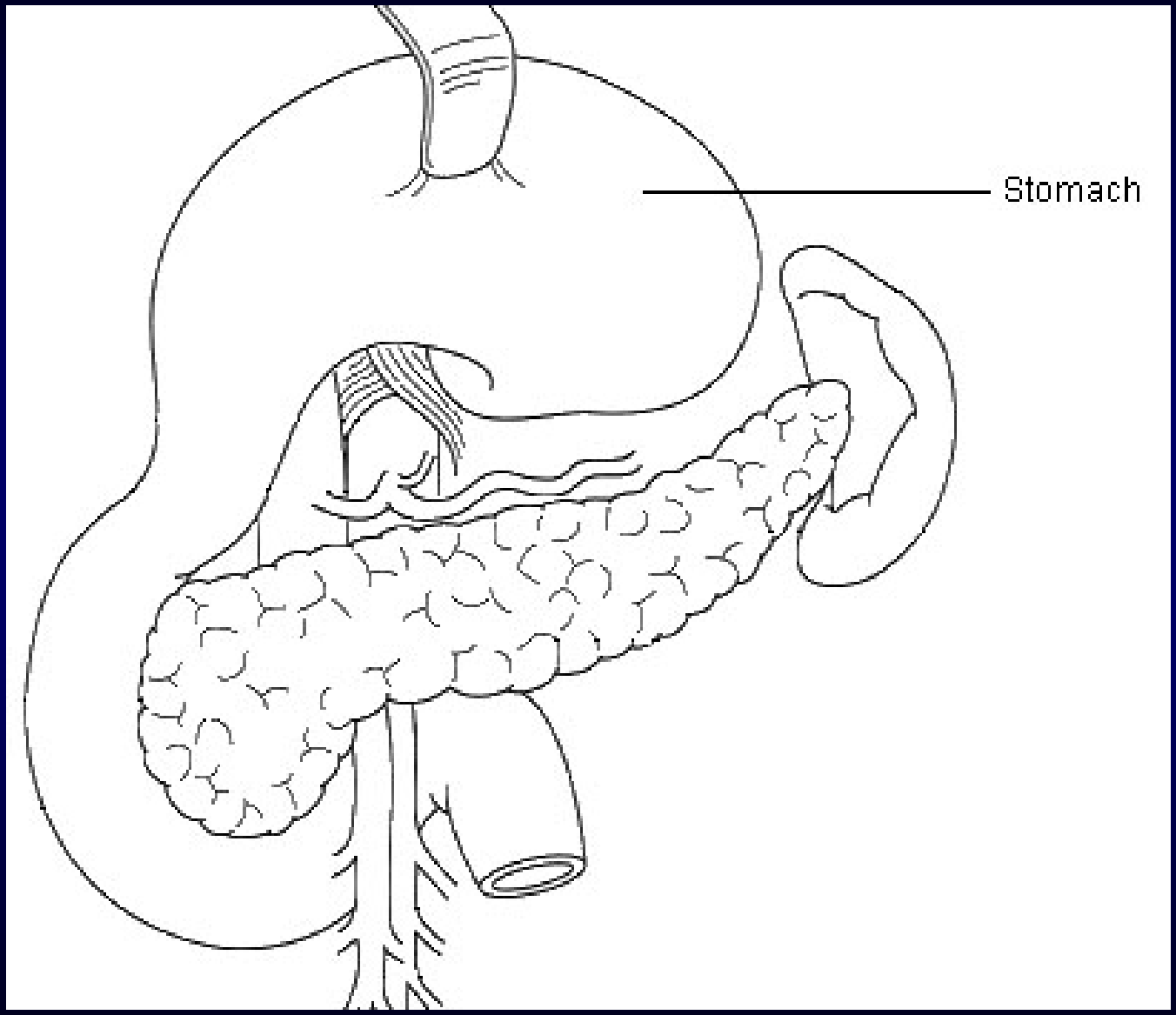






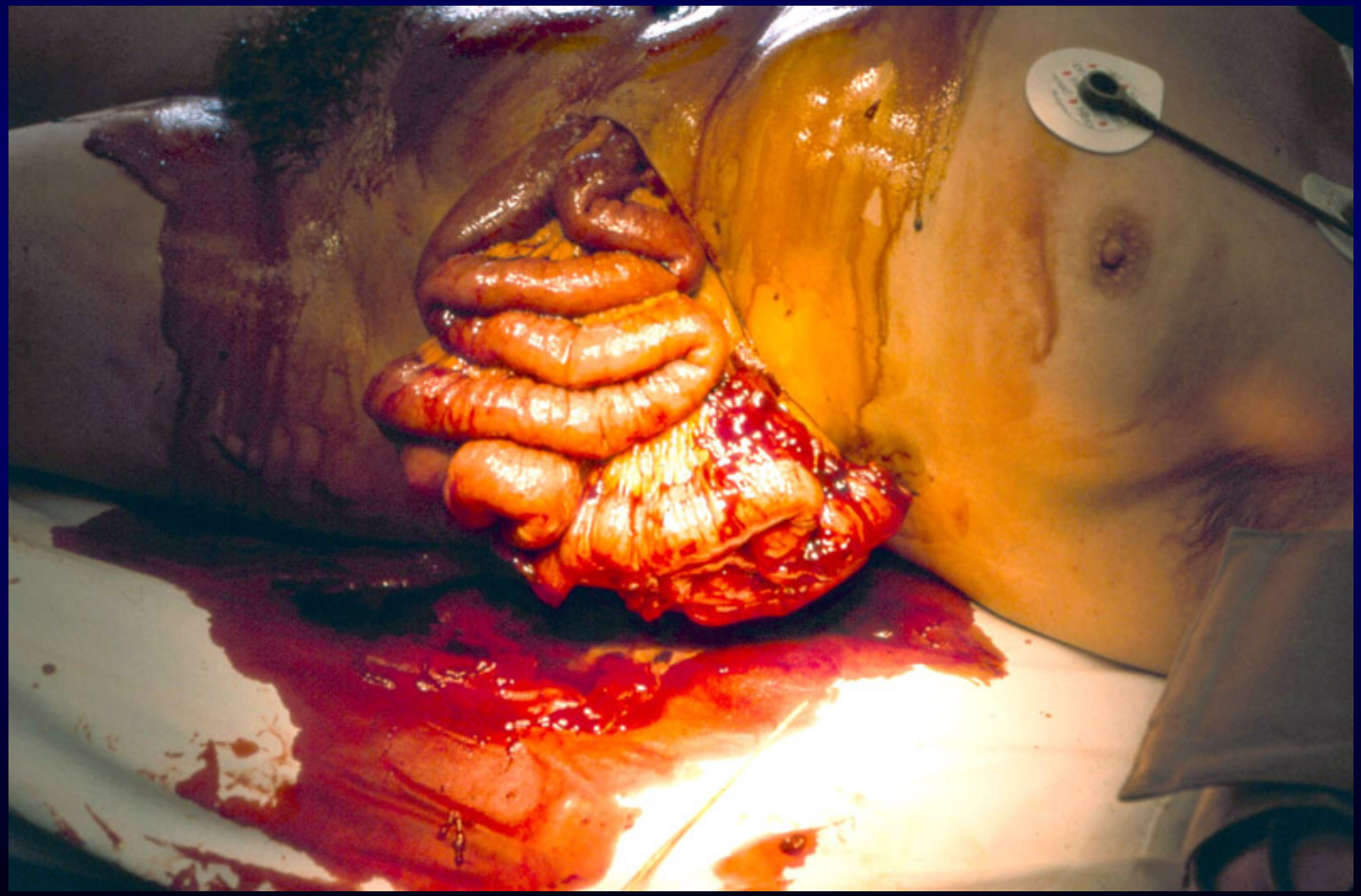
a – stomach wound (proximal stomach)
b – wound debridement (excision)
c – gastroplasty (final view)

STOMACH



Posterior stomach exposure

Small bowel and colon



SMALL BOWELL AND COLON

Grade	Injury characteristics
I	Contusion or haematoma without serosal devascularisation/Non perforating injury
II	Injury < 50% from intestinal diameter
III	Injury ≥ 50% from the intestinal diameter but no total
IV	Transversal intestinal injury
V	Transversal intestinal injury with complete rupture of an intestinal segment, avascular intestinal segment

SMALL BOWELL AND COLON

Factors that influence the outcomes in patients with hollow viscus trauma:

Extent of bacterial colonization		Anatomic blood supply	
Stomach	±	Stomach	++++
Duodenum	±	Duodenum	++++
Gall bladder	±	Gall bladder	++
Intestine	+	Intestine	++++
Colon, right	++	Colon, right	+++++
Colon, left	++++	Colon, left	+
Rectum	++++	Rectum	++++
Urinary bladder	±	Urinary bladder	++++

SMALL BOWELL AND COLON

Plane abdominal x-ray - pneumoperitoneum

SMALL BOWELL AND COLON

- Immediate definite repair
  - Resection of necrotic tissue
  - Lavage of the abdominal cavity
  - On table lavage of the injured colon
  - Resection of perforated part of hollow viscus
  - Direct suture of clean and fresh perforations
  - Diverting ostomy (?) left for:
- High risk patients
- Left colon injuries

Key factors in patient selection

- Conditions
  - After initial resuscitation: stable hemodynamic condition
  - No coagulopathy, hypotermia, shock or SIRS
- Complexes
  - Abdominal cavity injury only
  - No exanguinisation
  - No combination of vascular and multiple visceral lesions
  - No competing priorities (failing heart, CNS, spine injury)
- Critical factors
  - pH > 7.3; T > 35˚C; no MASS transfusion

SMALL BOWELL AND COLON

Colon injuries at urban trauma center
N= 2.964
Primary repair (suture, stapling) leak rate: 1.4%
Resection and anastomosis leak rate: 5.5%

Curran TJ, Am J Surg. 1999;177(1):42-7.

Morbidity of ostomy reversal (for colon injury)

Thal ER	1980	11%
Crass RA	1987	7%
Williams RA	1987	12%
Livingston DH	1989	25%
Pachter HL	1990	5%
Sola JE	1993	8%

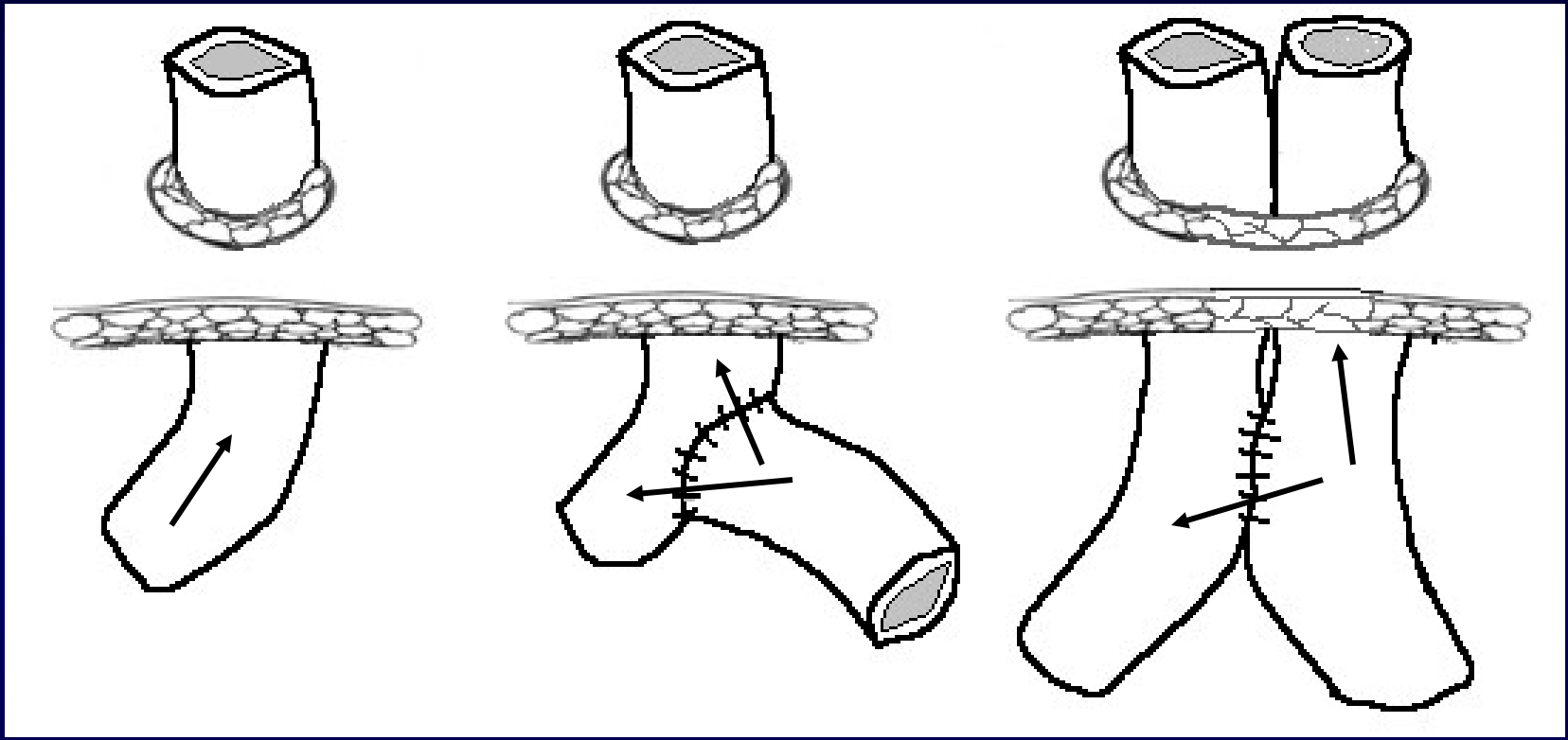
SMALL BOWELL AND COLON

Retrospective analysis
N = 231
Significant comorbid disease
≥ 6 PRBC units pre + intraoperatively
Anastomotic leak 14 %
Death with leakage 33%

Shock and comorbidities → colostomy

Miller PR., et al.: Ann Surg. 2002 Jun;235(6):775-81.

SMALL BOWELL AND COLON

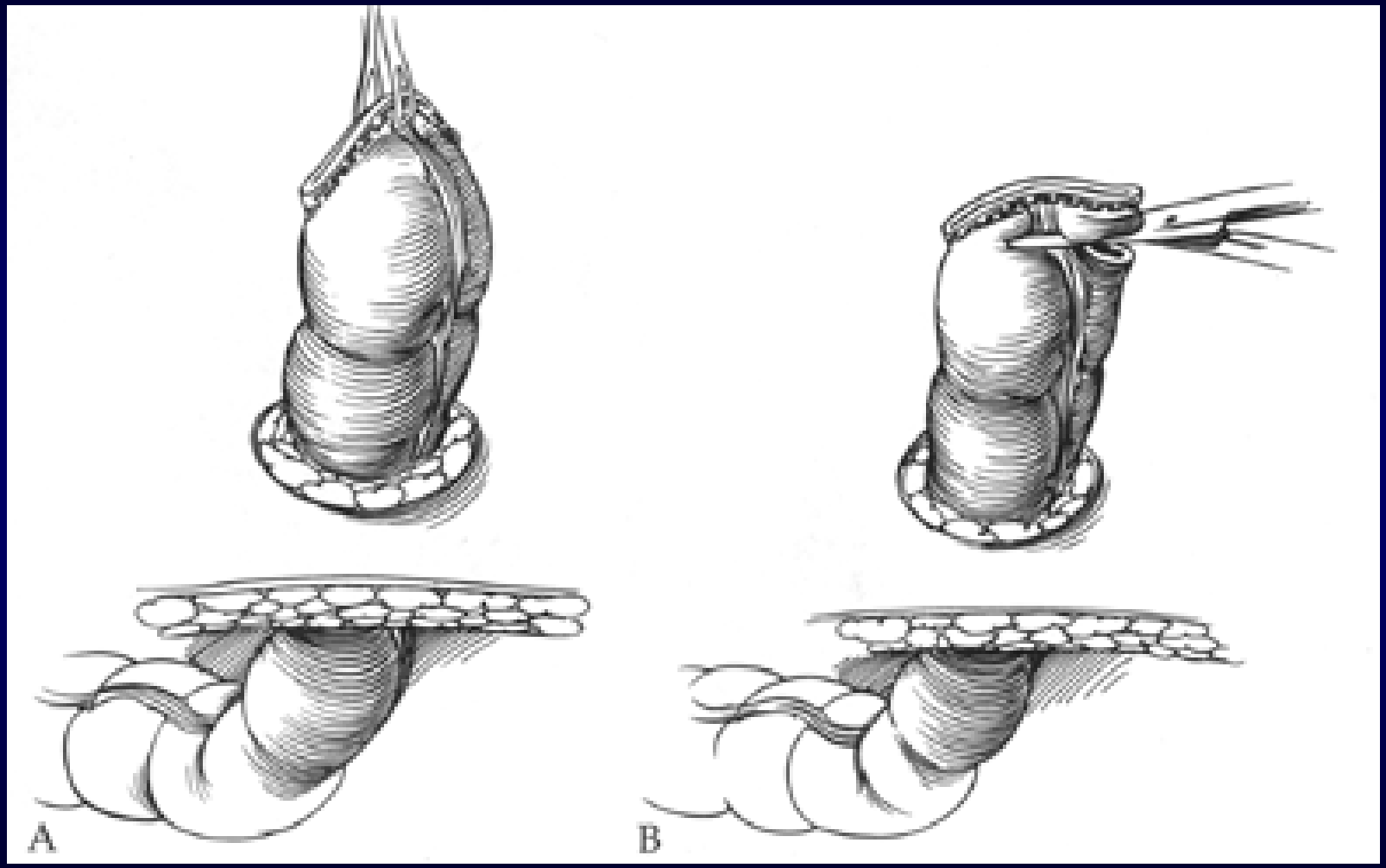


End-ileostomy

Maydl procedure

Mikulicz procedure

SMALL BOWELL AND COLON



Simple colostomy (a) step of surgery, (b) final view

SMALL BOWELL AND COLON

Comorbidities

Shock

Exanguination

Multicavitary injury

Delay > 6 h

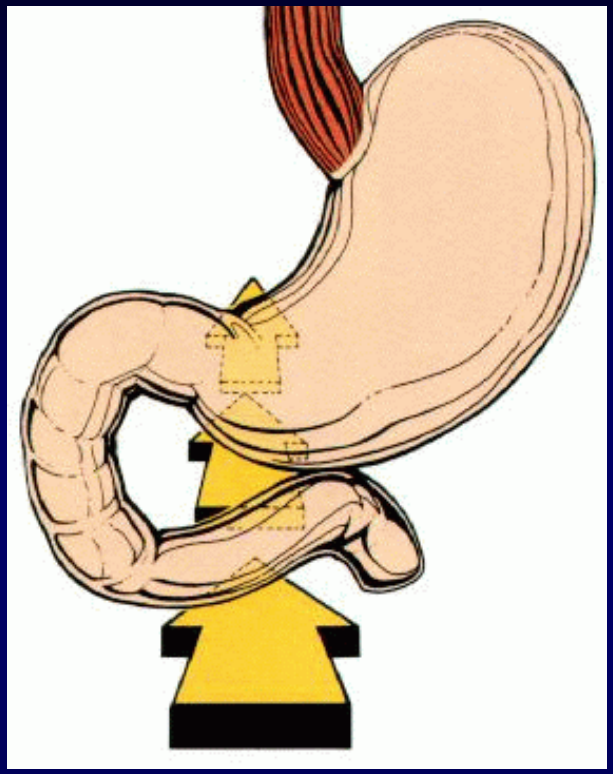
Extensive fecal contamination

present → **Shock and comorbidities ostomy**

absent → **Primary repair, no ostomy**

Duodenal injuries

DUODENUM



Mechanism of duodenal injuries:

Blunt injuries result from compression of the duodenum against the vertebral column after either a direct blow, or rapid deceleration.

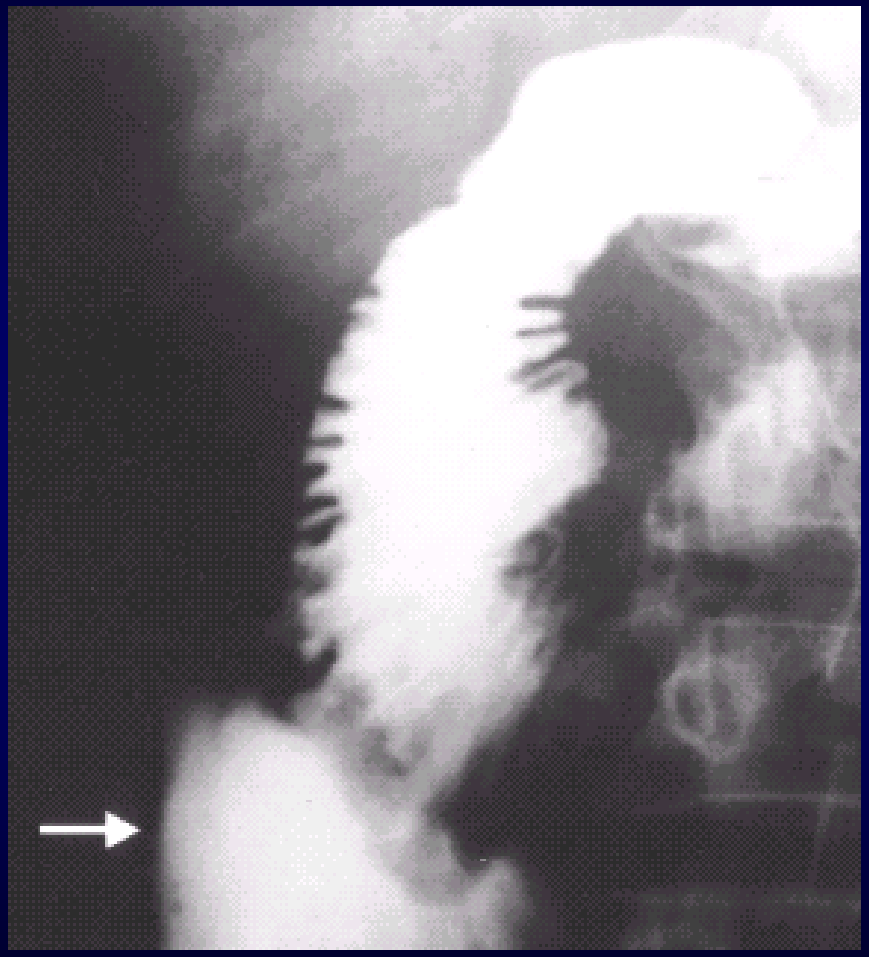
Duodenal injuries are associated with injuries of:

- Pancreas (28%)
- Liver (38%)
- Biliary tract (9%)
- Right kidney (21%)
- Small bowel (29%)
- Large bowel (30%)
- Stomach (24%)
- Vena cava inferior (17%)
- Abdominal aorta (5%)

DUODENUM

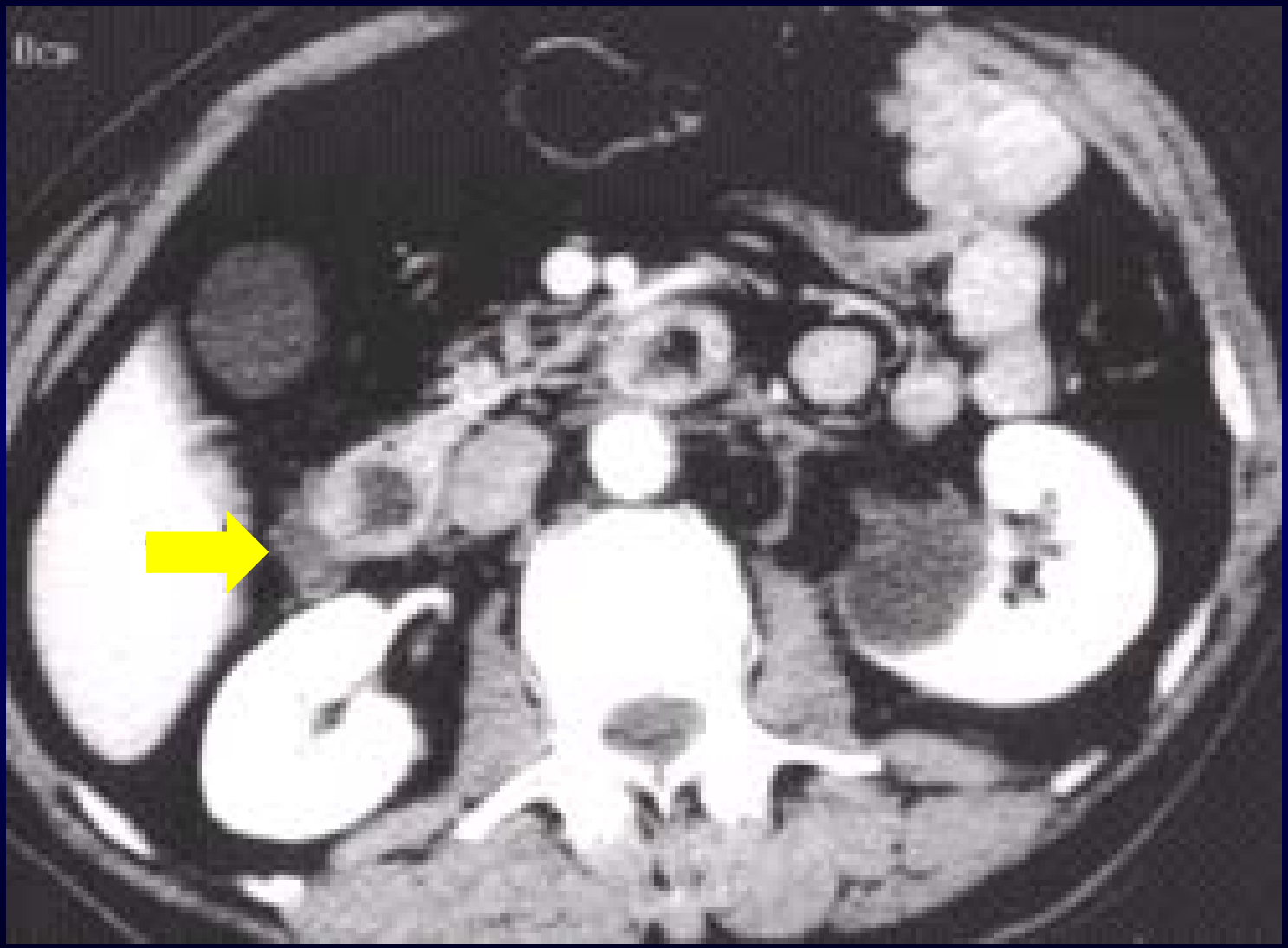
Retropneumoperitoneum

DUODENUM



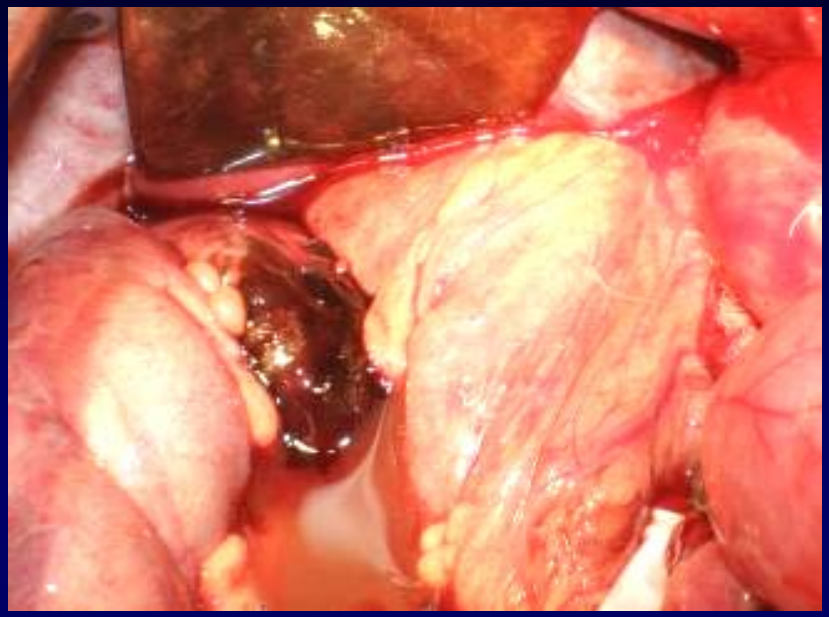
Contrast leakage in duodenal injury (arrow)

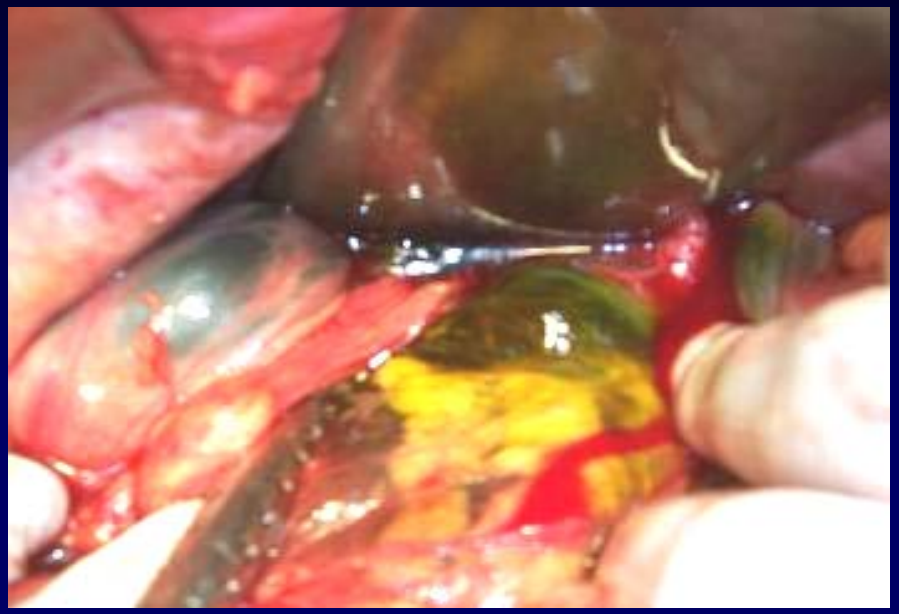
DUODENUM



CT periduodenal fluid (arrow) without duodenal leakage

DUODENUM





Retroperitoneal paraduodenal haematoma – (93,75%)

Retroperitoneal emphysema – (56,25%)

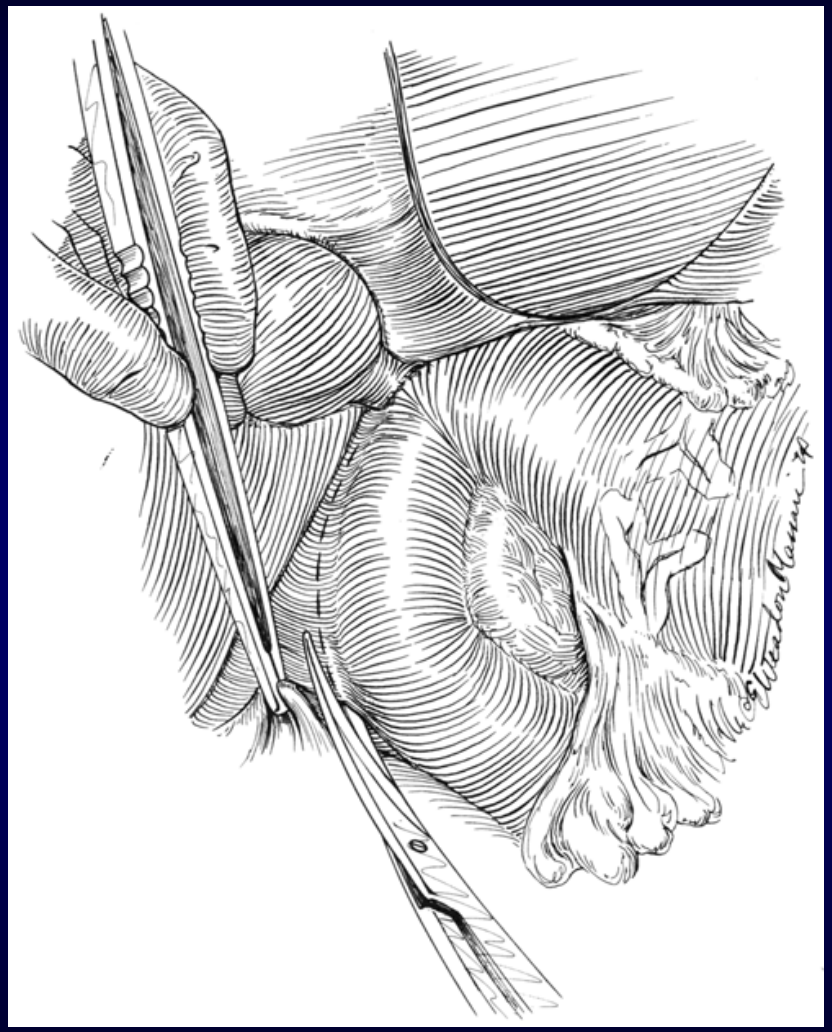
Intraoperatively:

Retroperitoneal bile impregnation – (43,75%)

Retroperitoneal phlegmona – (31,25%)

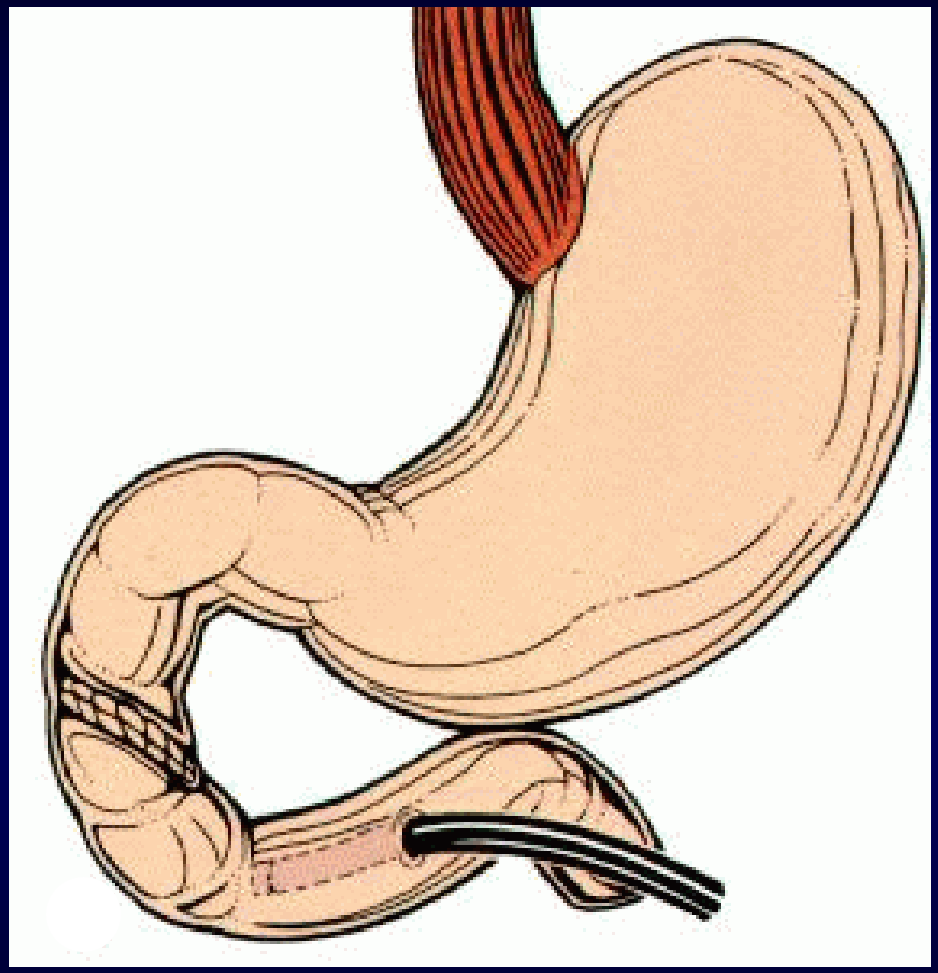
Haemoperitoneum (500 – 2000ml) – (62,5%)

DUODENUM



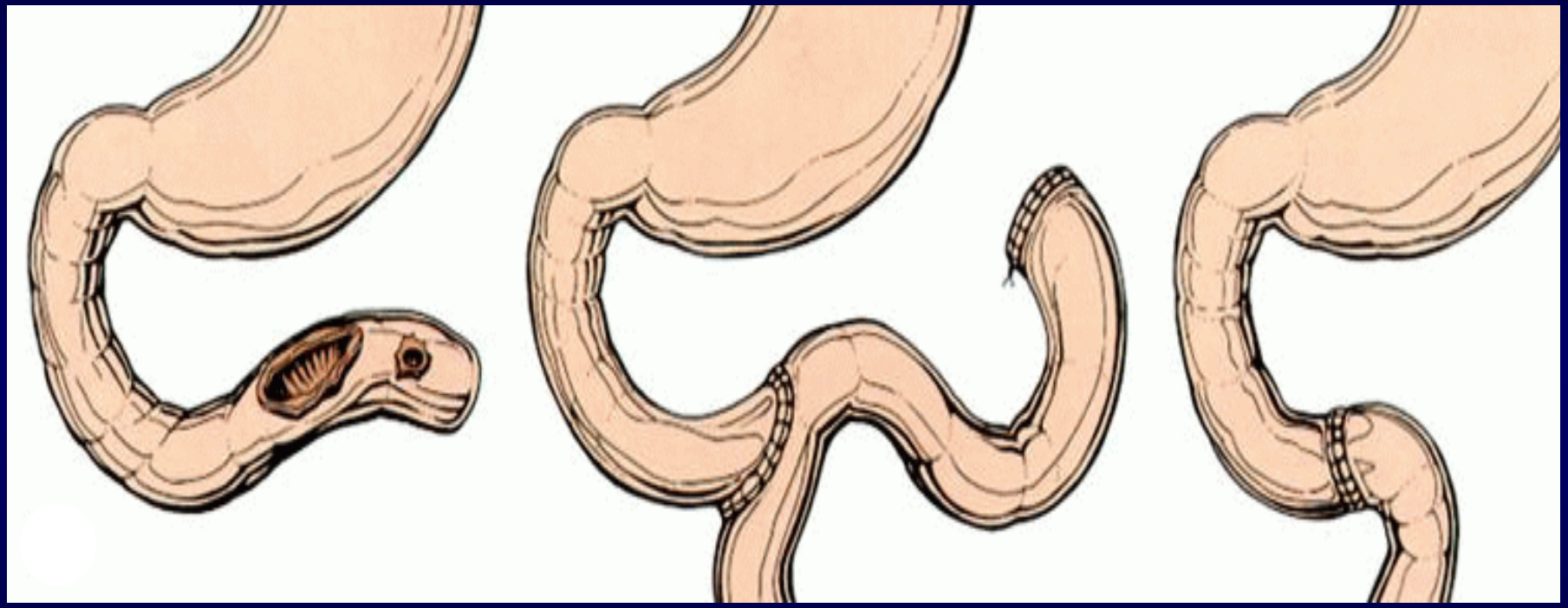
The Kocher maneuver begins by opening the peritoneum lateral to the duodenum

DUODENUM



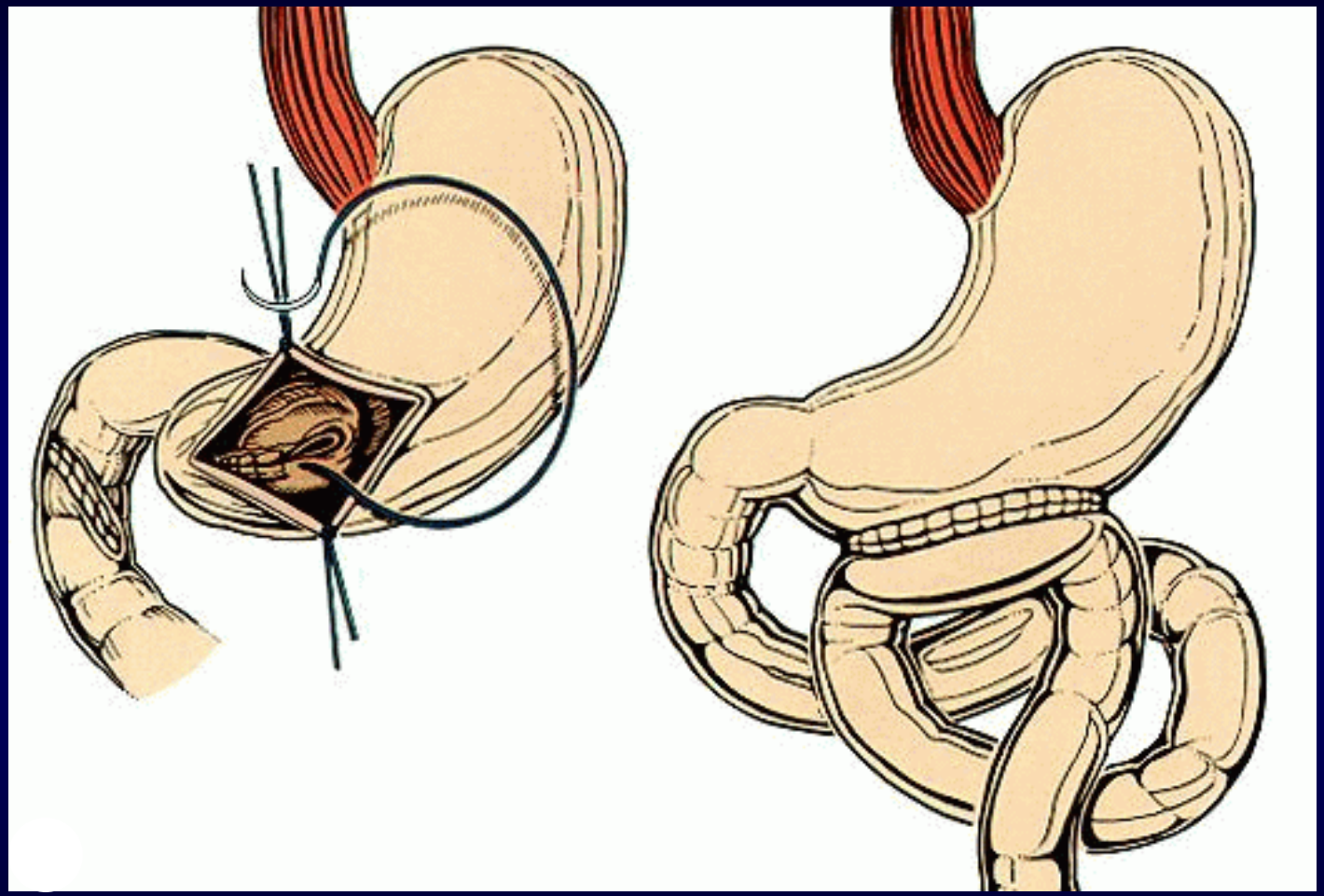
Simple injuries may be repaired primarily, a protective decompressive duodenostomy tube could be required.

DUODENUM



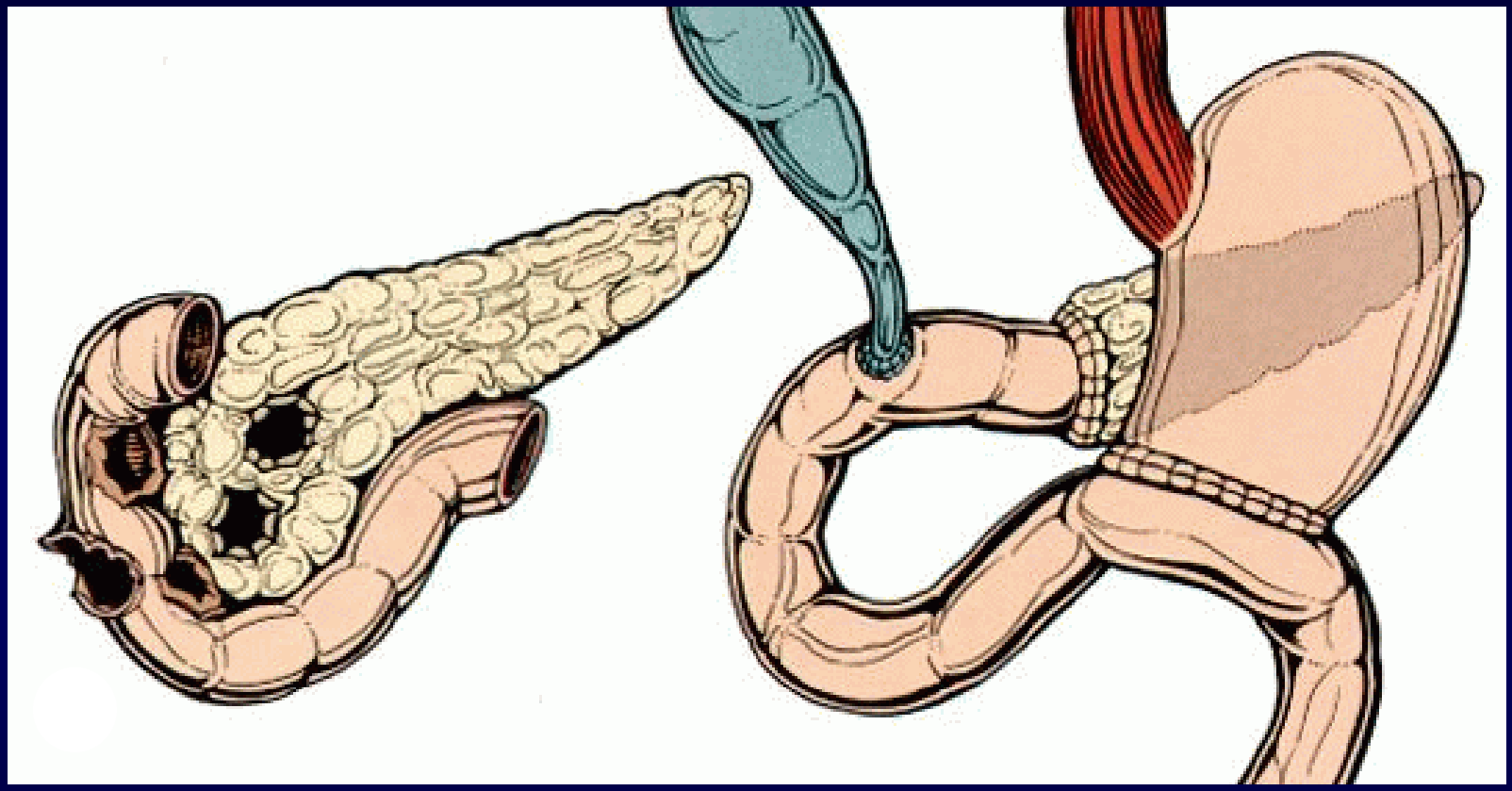
More complex injuries can be addressed by jejunal patch or segmental resection

DUODENUM



Severe injuries, especially those detected after a delay in diagnosis, may be managed by pyloric closure and gastric bypass

DUODENUM



The mortality of pancreato-duodenal injuries may be as high as 60% and may require pancreatoduodenectomy for management

DUODENUM





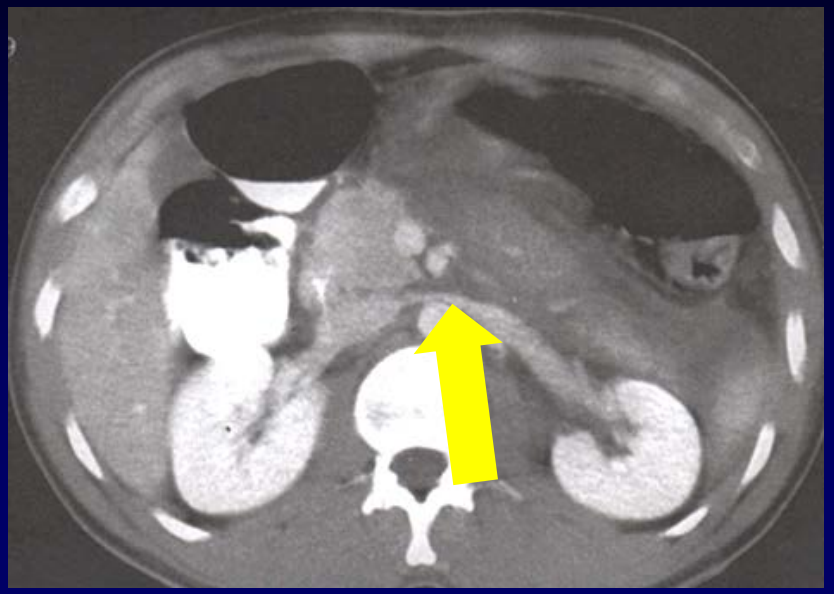

Pancreatic injuries

PANCREAS

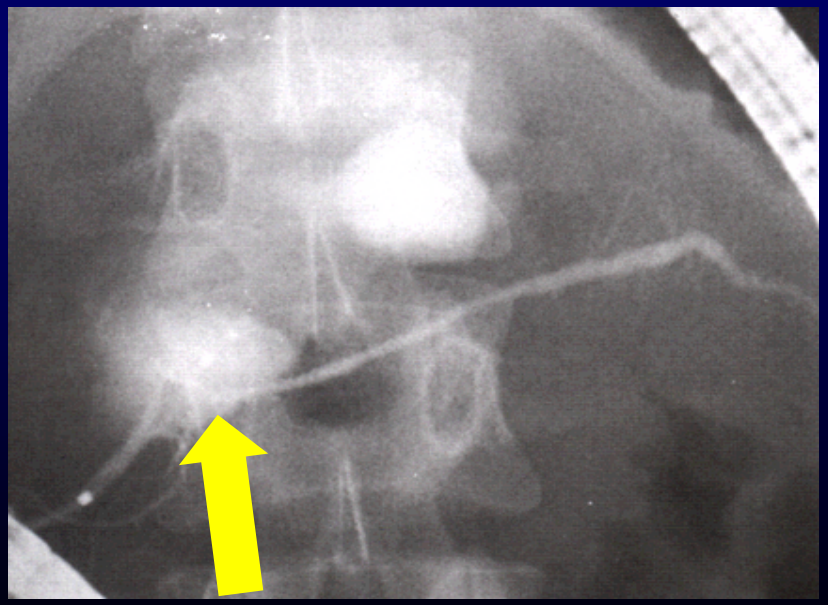
Mechanism of pancreatic injuries

PANCREAS

Abdominal ct scan demonstrating disruption of the pancreas anterior to the spine (arrow)



ERCP demonstrating a pancreatic ductal extravasation (arrow)



PANCREAS

CLASSIFICATION

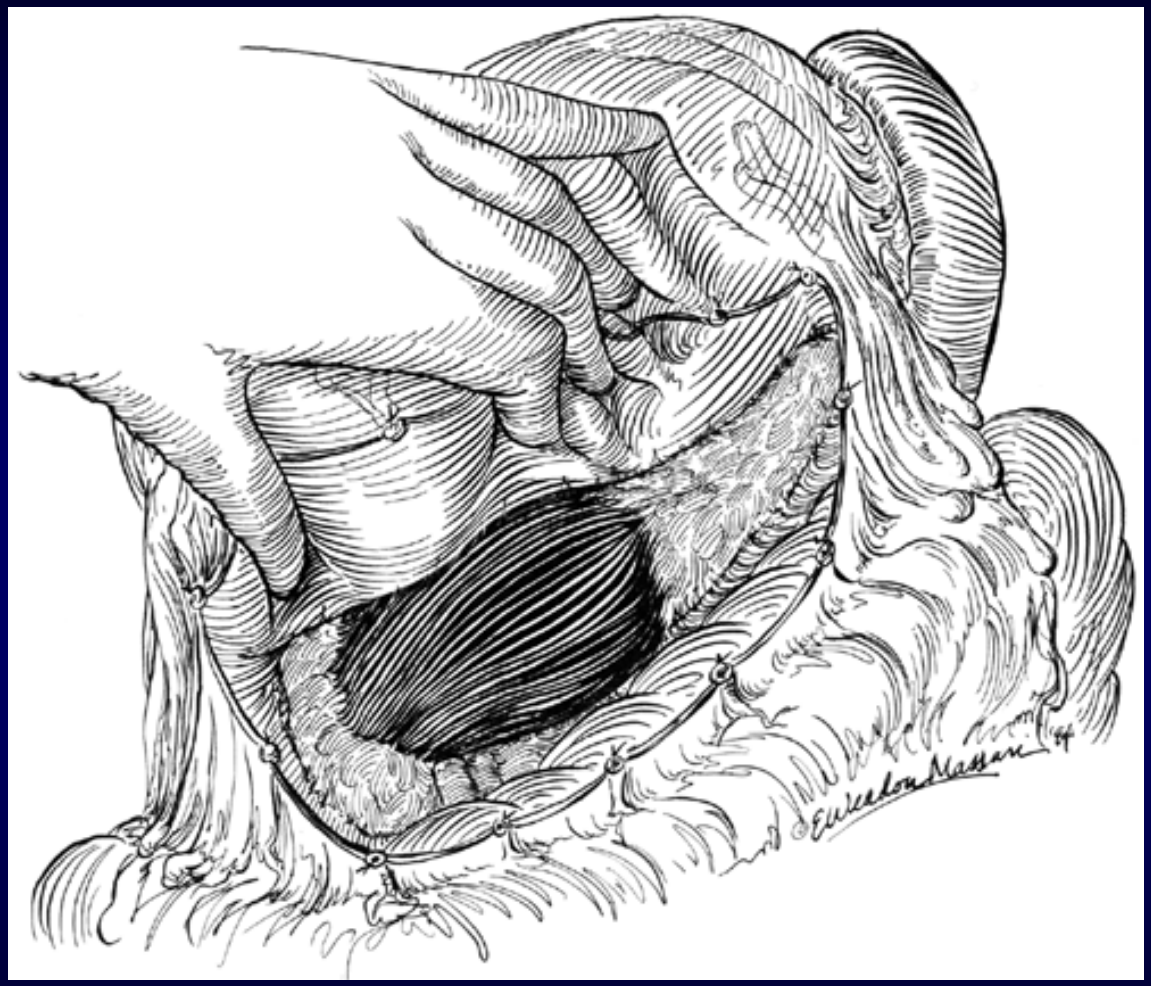
CLASS I INJURIES ARE SIMPLE CONTUSIONS OF THE PANCREAS

CLASS II INJURIES ARE LACERATIONS OF THE PARENCHYMA IN THE BODY OR TAIL OF THE PANCREAS

CLASS III INJURIES ARE THOSE WITH SEVERE DISRUPTION OF THE HEAD OR BODY

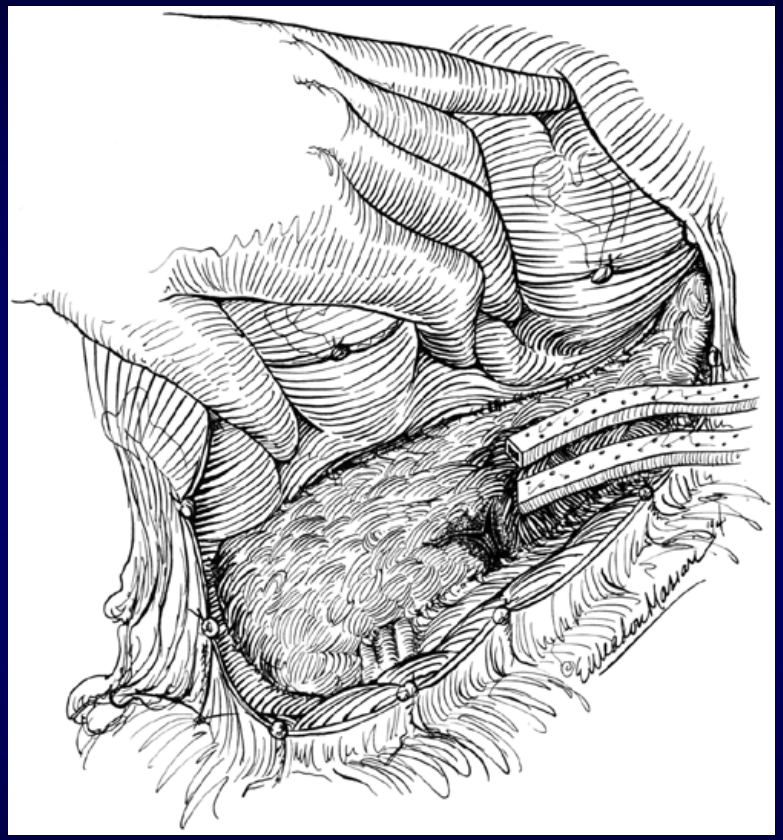
CLASS IV INJURIES ARE THOSE IN WHICH THERE IS AN ASSOCIATED INJURY TO THE DUODENUM

PANCREAS

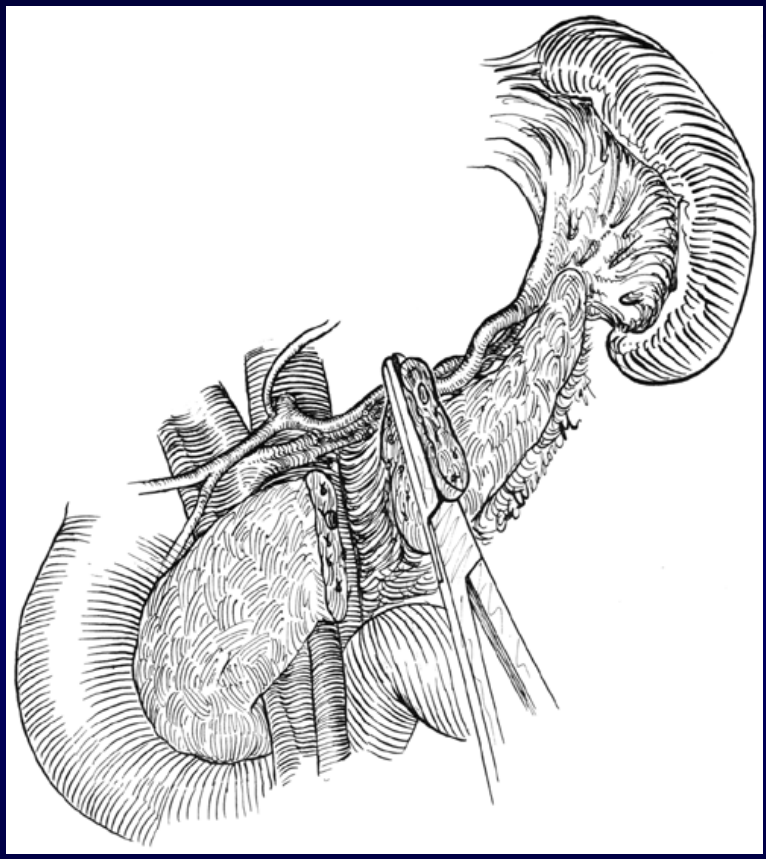


The lesser sac has been exposed through the gastrocolic ligament and reveals the so-called masking hematoma, which may cover a pancreatic fracture

PANCREAS

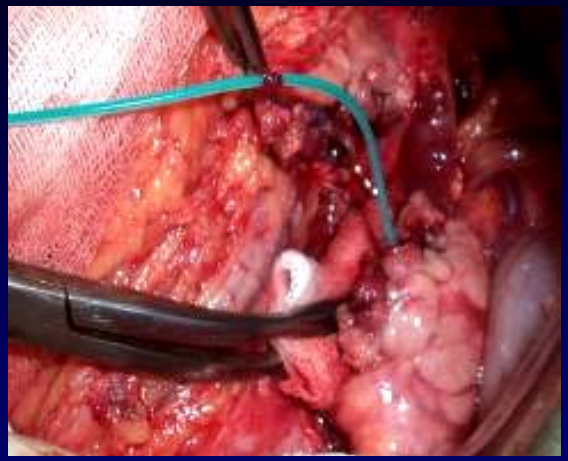


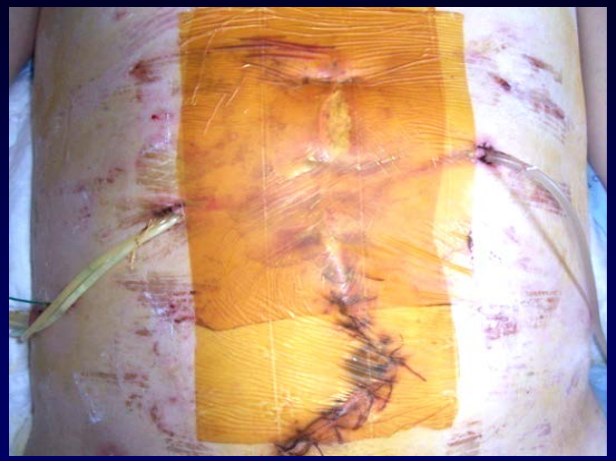
Drainage of a pancreatic wound



Distal pancreatectomy with or without spleen preservation

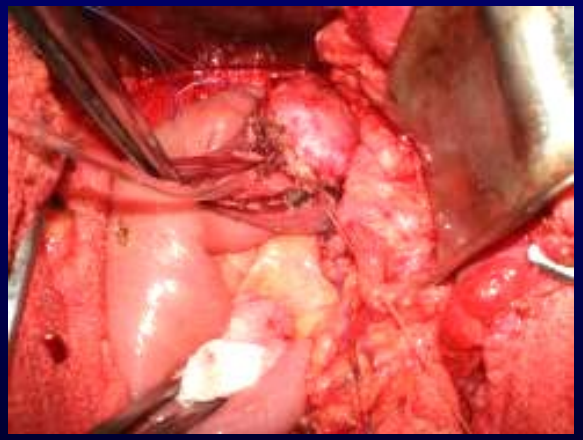
PANCREAS

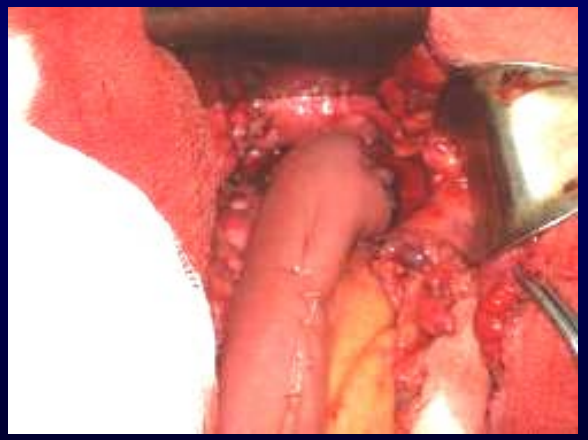




Primary surgery (02.2007): suture of the proximal pancreatic stump, VAC-sealing, external fistula of the Wirsung duct

Fistulofgraphy





Reconstructive surgery (09.2007): End-to-end pancreato-jejunostomy

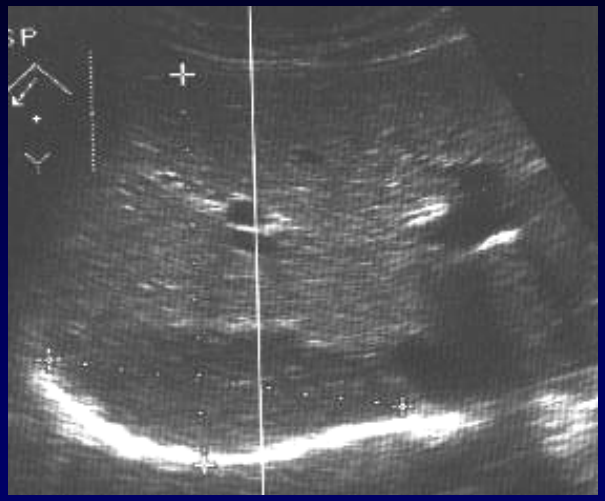
Solid organ injury (liver and spleen)

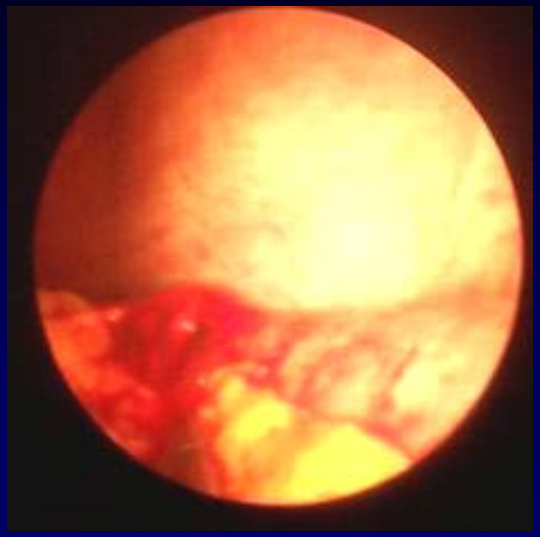
LIVER

Grade	Injury Description	
I	Haematoma	Subcapsular, <10% surface area
	Laceration	Capsular tear, <1cm parenchymal depth
II	Haematoma	Subcapsular, 10-50% surface area
		Intraparenchymal, <10cm diameter
	Laceration	1-3cm parenchymal depth, <10cm length
III	Haematoma	Subcapsular, >50% surface area or expanding. Ruptured subcapsular or parenchymal haematoma
		Intraparencymal haematoma >10cm or expanding
	Laceration	>3cm parenchymal depth
IV	Laceration	Parenchymal disruption involving 25-75% of hepatic lobe or 1-3 Coinaud's segments in a single lobe
V	Laceration	Parenchymal disruption involving >75% of hepatic lobe or >3 Coinaud's segments within a single lobe
	Vascular	Juxtahepatic venous injuries ie. retrohepatic vena cava/central major hepatic veins
VI	Vascular	Hepatic Avulsion

American Association for the Surgery of Trauma (AAST)

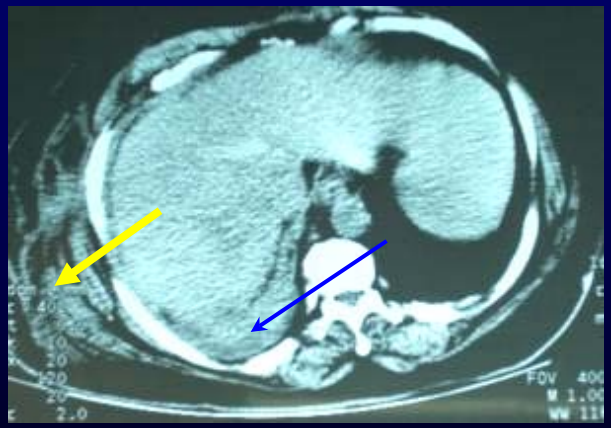
LIVER

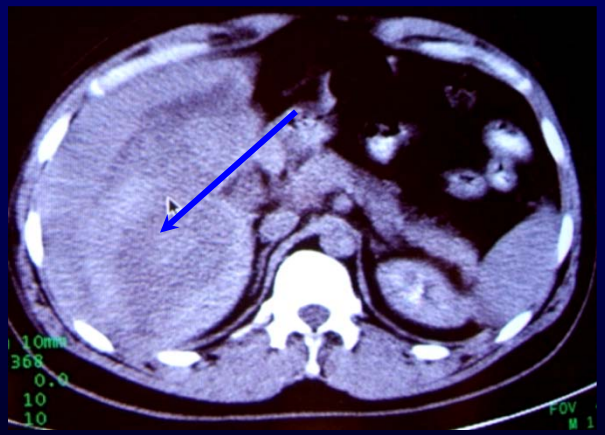




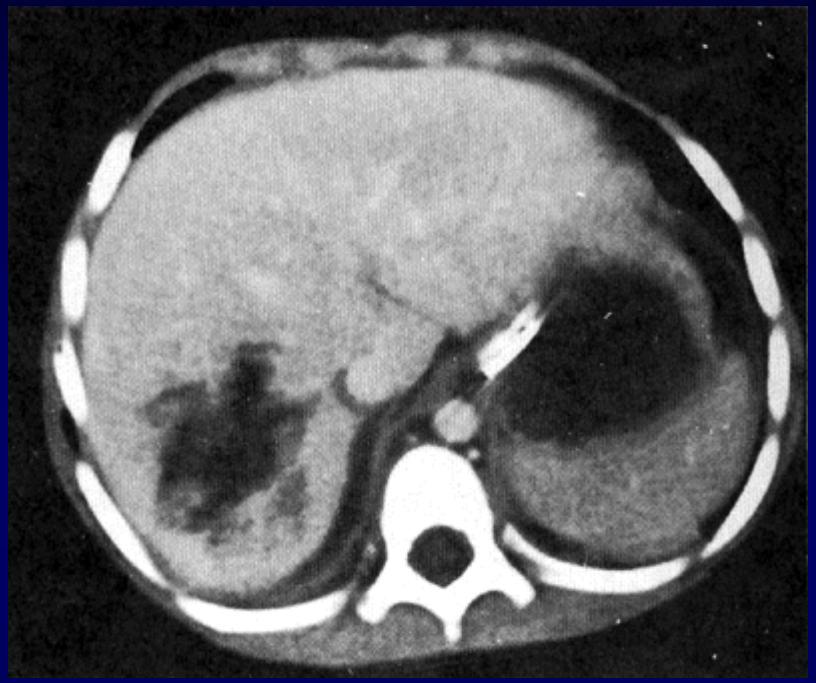
Abdominal US – (84,2%) - free fluid in the peritoneal cavity (60 – 600 ml)

Laparoscopy – blood in the peritoneal cavity

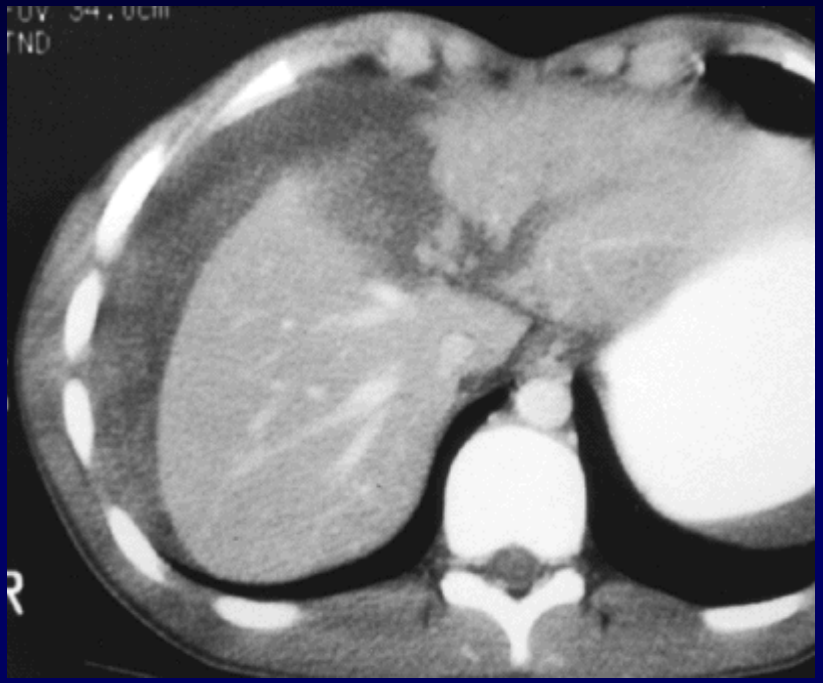




LIVER



Abdominal ct scan demonstrating laceration of the posterior right lobe of the liver

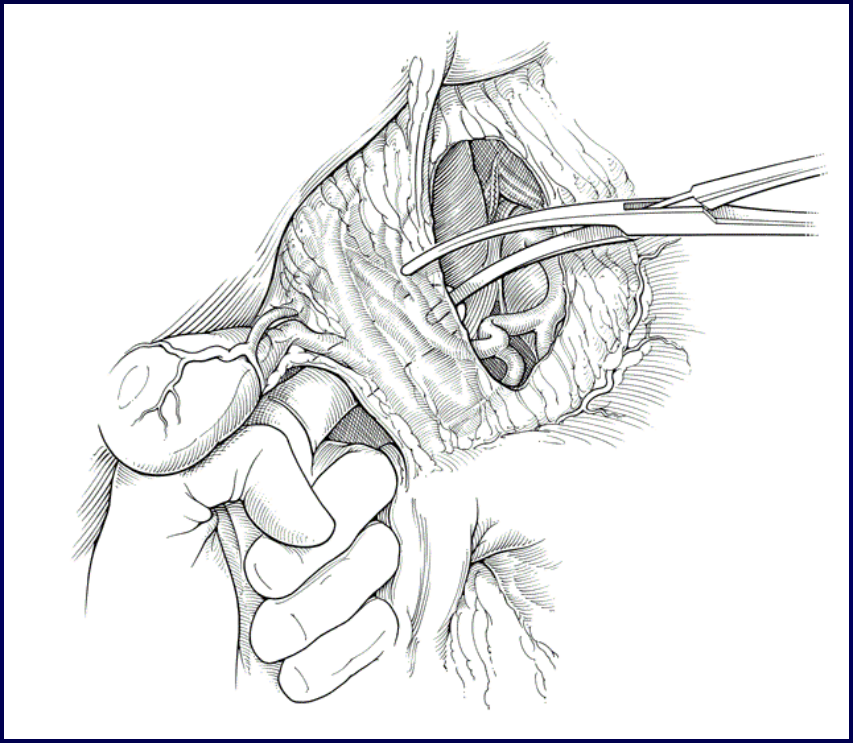


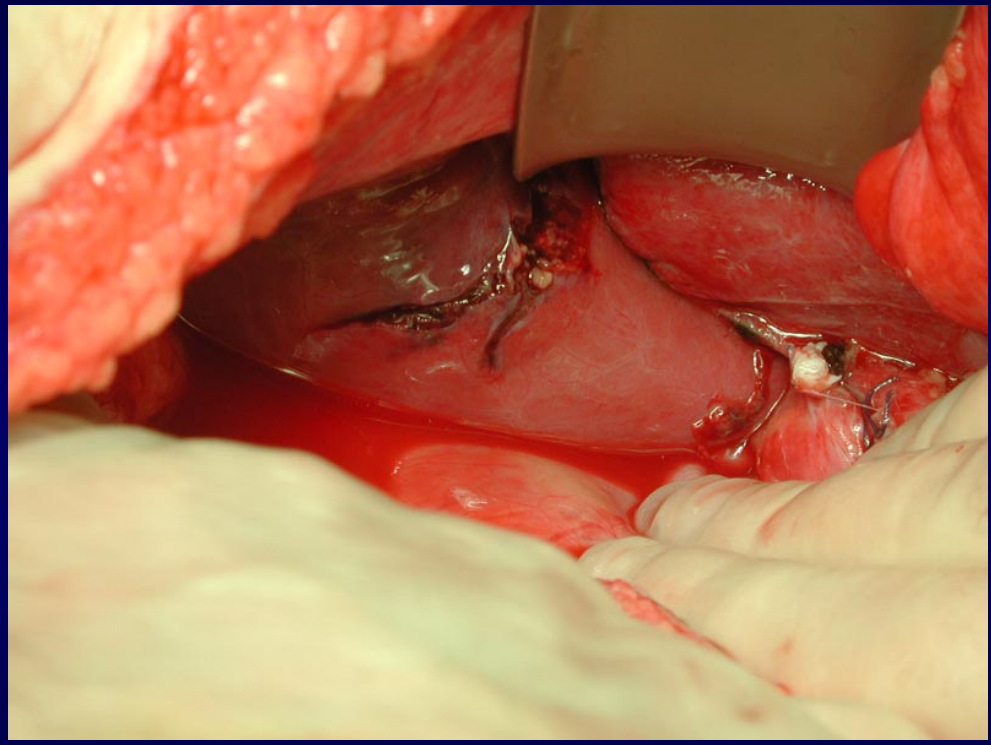
Almost complete transection of the liver in its anatomic plane

LIVER

- Frequently injured in both blunt & penetrating trauma.
- Control of profuse bleeding from deep lacerations a formidable challenge.
  - Simple suture, mattress sutures, packing, debridement, resection, mesh hepatorrhaphy
- Nonoperative treatment (blunt trauma)
  - Stable without peritoneal signs → U/S → CT
  - Low-grade liver lesions (1-3, 95% success)
  - ICU monitoring

LIVER





In the event of continued bleeding a vascular clamp can be placed around porta hepatis Pringle Maneuver

LIVER

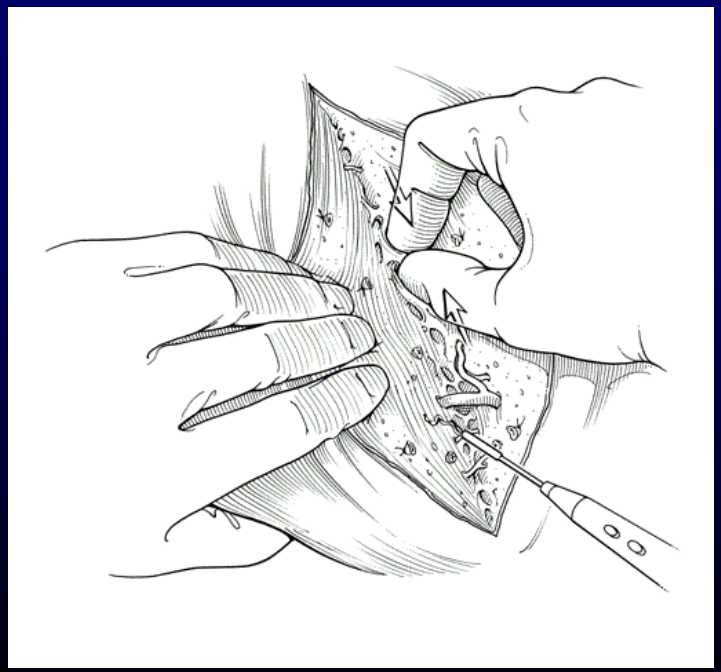
If bleeding continues…

A. It is coming from the portal vein or hepatic artery

OR

B. It is coming from the retrohepatic vena cava or hepatic veins

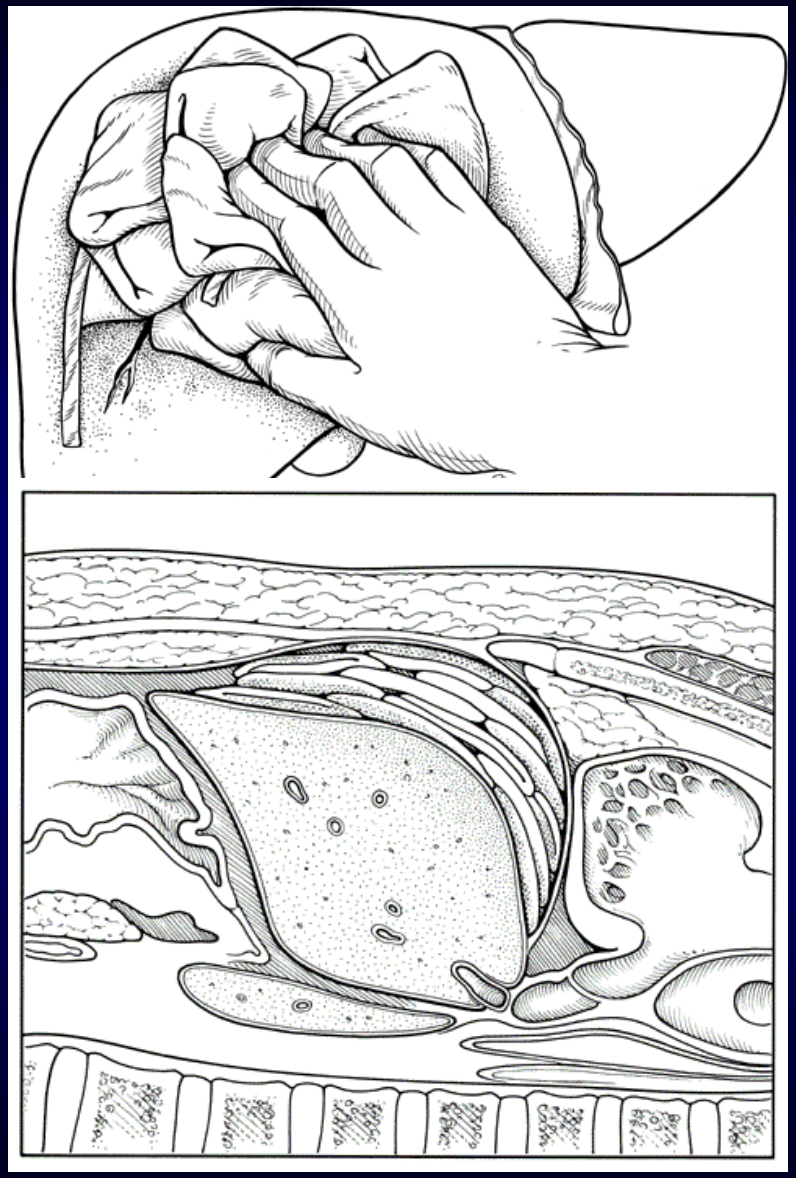
- Alternative approach for deep lacerations
- Extend laceration along non anatomical plains to expose and directly ligate bleeding vessels
- Low mortality 10.7%
- Large defect in liver parenchyma
- Should only be performed by experienced surgeons



Finger Fracture Hepatotomy

LIVER

- Used when other techniques fail to controlling hemorrhage
- Used in patients with hypothermia, acidosis, coagulopathia
- ICU for rewarming
- Re-explore 48-72 hours
- Intra-abd abscesses <15%
- Arteriography/embolization useful adjunct



Hemostasis of liver fracture. Direct pressure with packs is usually sufficient to control the majority of liver parenchymal bleeding

SPLEEN

- Most frequently injured intra-abdominal organ in blunt trauma.
- Splenic preservation when possible
- More than 70% can be treated nonoperatively

SPLEEN

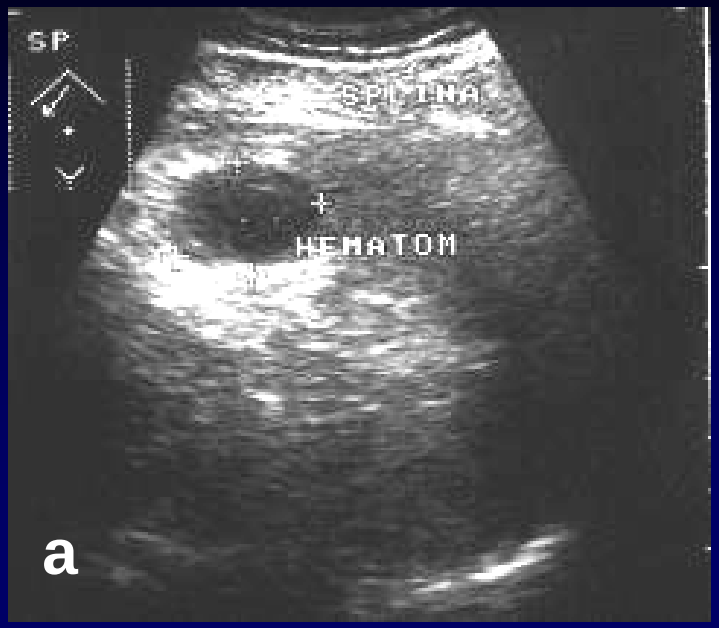
- Nonoperative criteria
  - Hemodynamic stability
  - Negative abdominal examination
  - Absence of contrast extravasation
    - Angiography/embolization an option
  - No other clear indications for ex lap
  - No coagulopathy
  - Low grade injuries (1-3)

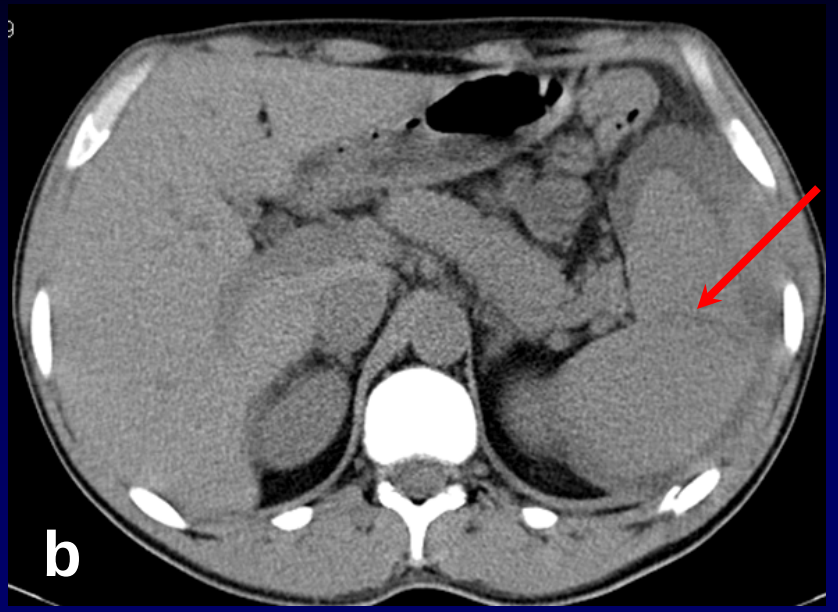
SPLEEN

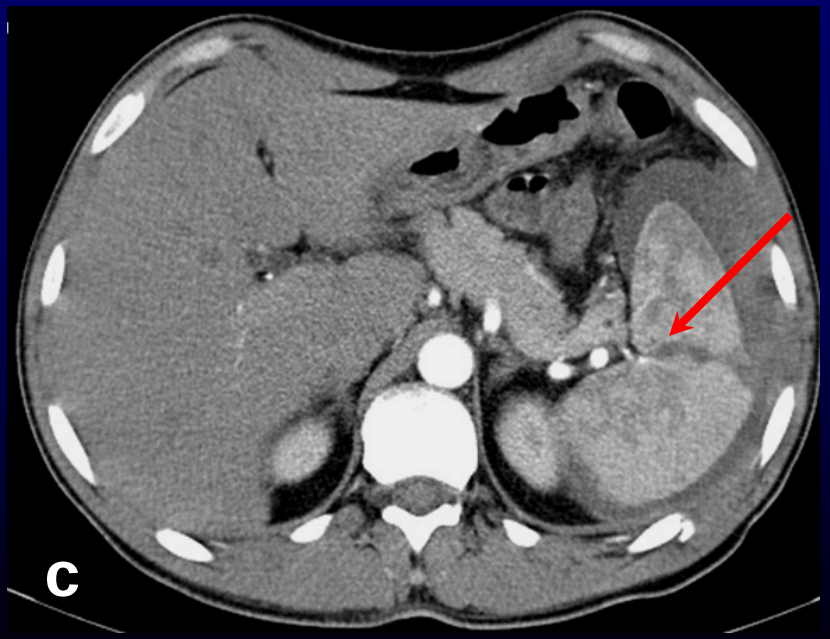
Grade	Injury Description	
I	Haematoma	Subcapsular, <10% surface area
	Laceration	Capsular tear, <1cm parenchymal depth
II	Haematoma	Subcapsular, 10-50% surface area Intraparenchymal, <5cm diameter
	Laceration	1-3cm parenchymal depth not involving a parenchymal vessel
III	Haematoma	Subcapsular, >50% surface area or expanding. Ruptured subcapsular or parenchymal haematoma. Intraparencymal haematoma >5cm
	Laceration	>3cm parenchymal depth or involving trabecular vessels
IV	Laceration	Laceration of segmental or hilar vessels producing major devascularization (>25% of spleen)
V	Laceration	Completely shattered spleen
	Vascular	Hilar vascular injury which devascularized spleen

American Association for the Surgery of Trauma (AAST)

SPLEEN







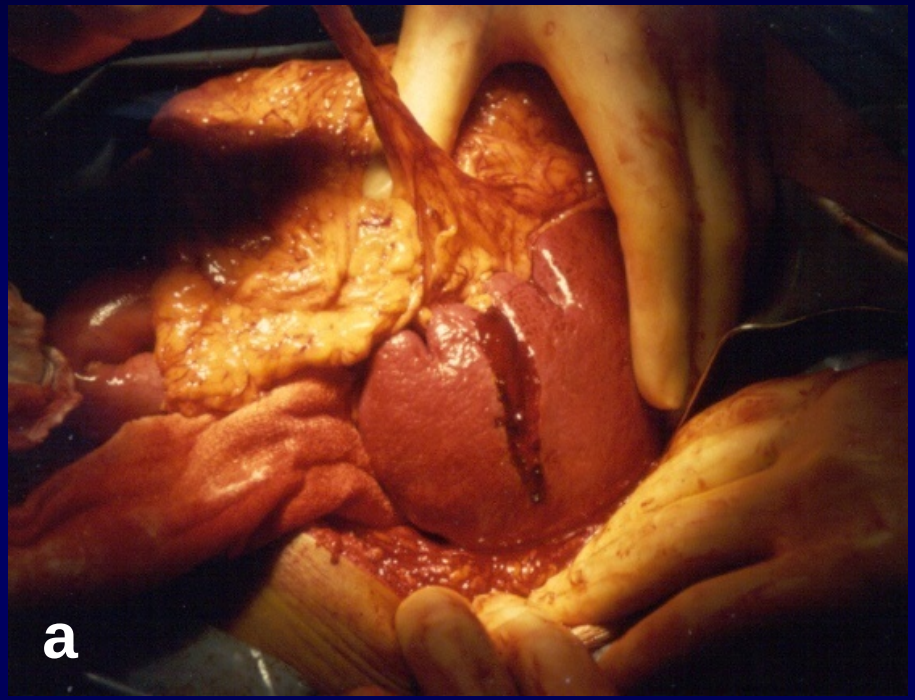
a – USG splenic injury.
b – CT (native) – grade III splenic injury.
c – CT (angio) – grade III splenic injury.

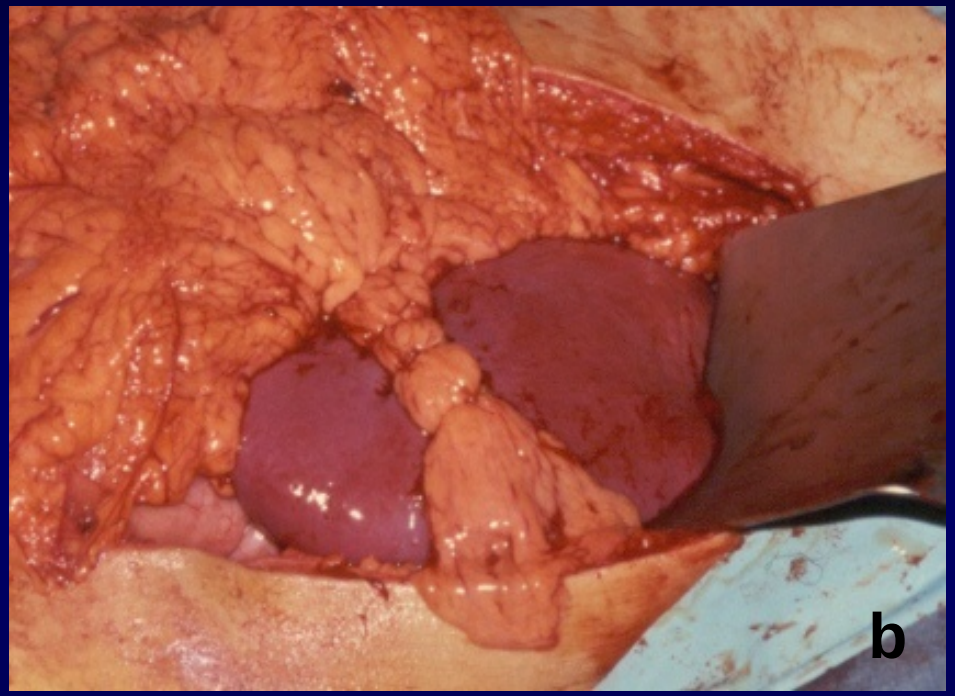
SPLEEN

CT (angio) – grade III splenic injury (upon admission).

CT (angio) – grade III splenic injury (40 days follow-up non-operative management).

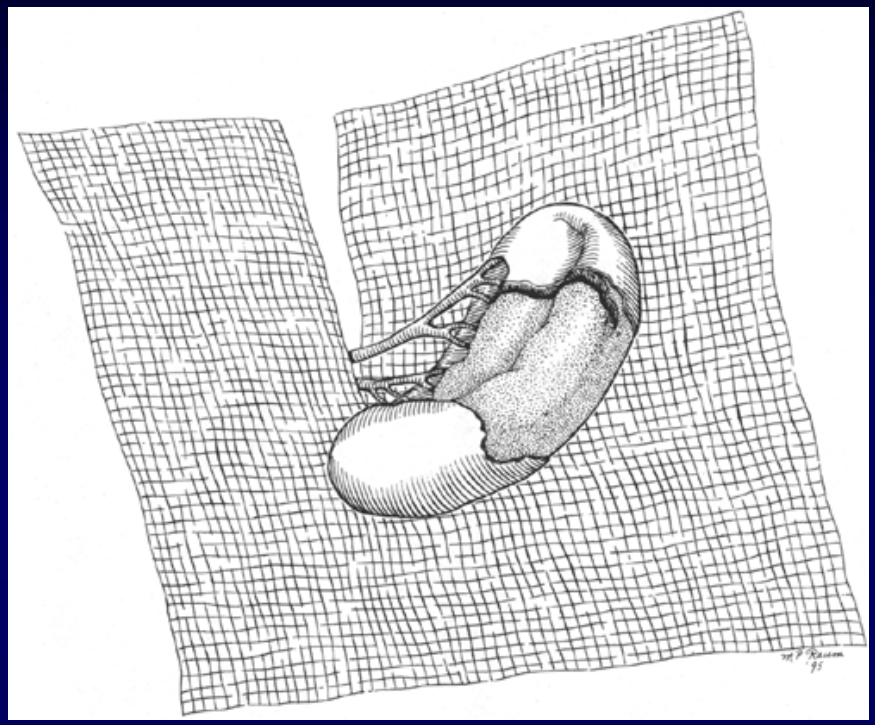
SPLEEN





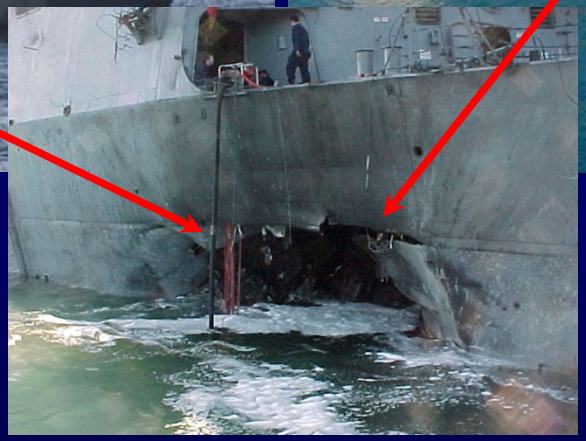
The omentum can be mobilized (a) to provide a hemostasis for deep splenic lacerations (b) – final view

SPLEEN



Mesh can be fashioned to provide a tamponade wrap for a severely lacerated spleen

Damage Control Surgery (DCS)



Aboard a ship, **damage control** parties swing into action after engaging in hostile actions where she takes a hit.

Every man is assigned a specific function in order to maintain the vessel's structural integrity and **save lives**.

Damage Control Surgery (DCS)

Initial abbreviated laparotomy
ICU resuscitation
Reoperation – definite surgery
Abdominal wall repair (much more later)

Civilian Trauma Combat Trauma

Indications:

- Bleeding patient *in extremis*
- "bloody vicious cycle"
- Lethal triad of
  - Hypotermia
  - Coagulopathy
  - Methabolic acidosis

Rotondo MF., et al.: Surg Clin North Am. 1997;77(4):761-77.
Kashuk JL., et al.: J Trauma. 1982;22(8):672-9.

Damage Control Surgery (DCS)

Hypothermia:

- Clinically important if less than 35 C for more than 4 h.
- Can lead to cardiac arrhythmias, decreased cardiac output, increased systemic vascular resistance.
- Can induce and exacerbate coagulopathy by inhibition of clotting cascade reaction.

Acidosis:

- Uncorrected hemorrhagic shock induces inadequate cell perfusion, anaerobic metabolism and production of lactate.
- Interferes with blood clotting mechanisms and induces coagulopathy and blood loss.

Damage Control Surgery (DCS)

Coagulopathy:

- Hypothermia, acidosis and the consequences of massive blood transfusions all lead to the development of coagulopathy.
- Platelet dysfunction induced by hypothermia.
- Activation of the fibrinolytic system.
- Hemodilution due to massive resuscitation.

Damage Control Surgery (DCS)

Key factors in patient selection

- **Conditions**
  - Hemodynamic instability
  - Presenting coagulopathy a/o hypotermia
- **Complexes**
  - Abdominal vascular with multiple visceral injuries
  - Multicavitary exanguination with concomitant visceral injuries
  - Multiregional injuries with competing priorities (CNS, spine)

Sagraves et al, J Int Care Med, 2006

Critical factors:

- pH < 7.3
- Temperature < 35°C
- Resuscitation and OR time > 90 min
- Coagulopathy evidenced by nonmechanical bleeding
- MASS > 10 units of packed RBC

Sagraves et al, J Int Care Med, 2006

Damage Control Surgery (DCS)

Definitive operation

Time schedule 12-48 h after initial DCS

Pack removal

Abdominal exploration

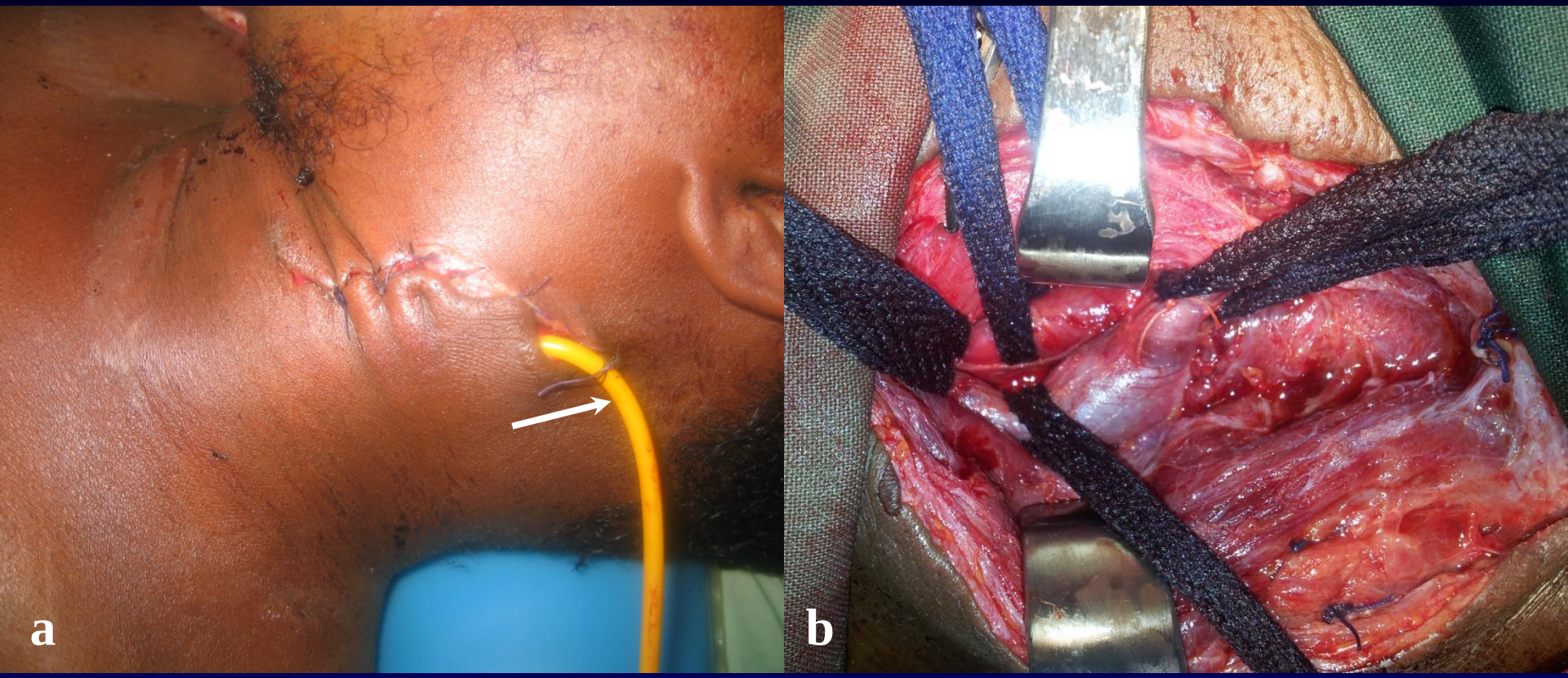
Injury reassessment

Reestablish intestinal continuity

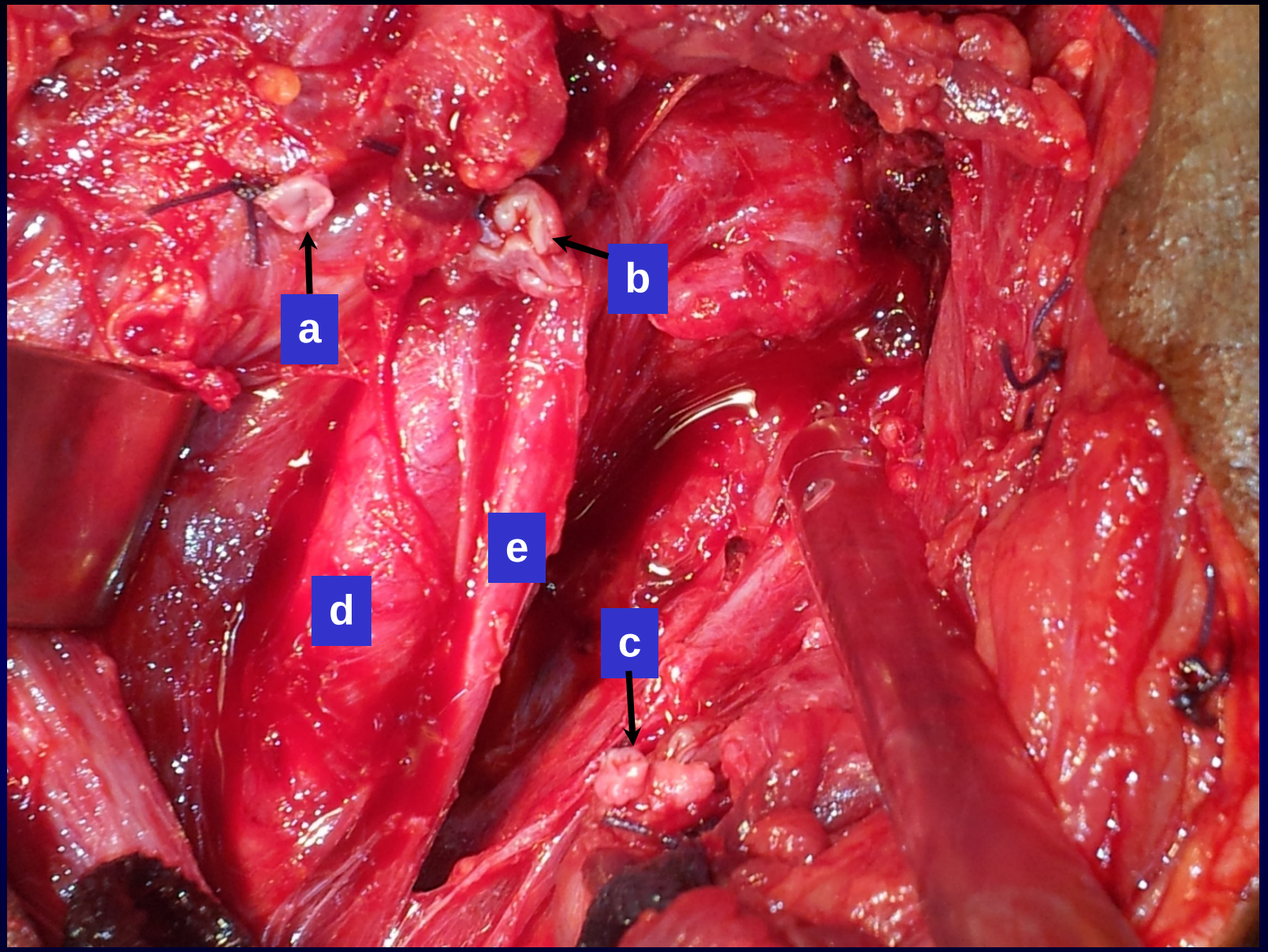
Access for intestinal nutrition: jejunostomy

Before closing: plain radiograph to find retained sponges

Damage control surgery for penetrating zone 2 neck injury



a – initial procedure, temporary haemostasis using Foley catheter tamponade (→)
b – neck exploration (24 h. later), exposure of the left common carotid artery, internal jugular and middle thyroid veins.



Final view

a – middle thyroid vein
b – proximal stump of the internal jugular vein
c – distal stump of the internal jugular vein
d – common carotid artery
e – vagus nerve

48 h. postoperative


QUESTIONS?