"IMAGING IN ABDOMINAL TRAUMA "

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- Trauma causes **I0% of deaths** worldwide, Trauma is the leading cause of death **under the age of forty**.
- **Appropriate evaluation** of trauma patients is essential to avoid serious morbidity and mortality.
- Although the **physical examination** is still vital in the initial assessment of these patients, some studies have shown sensitivity in the range of only **55% to 65%** in the setting of blunt abdominal trauma.
- Furthermore, patients who show **no obvious signs of trauma** or physical examination findings (such as a seat belt sign, abdominal tenderness, or guarding) may still have **significant internal organ injury.**
- Therefore, imaging has come to play a **critically important role** in trauma diagnosis and management.
- **The spleen** is the **most commonly injured** intra-abdominal organ and may be the only affected organ in up to **60% of cases**. Following the spleen, in order of decreasing frequency, the other commonly injured organs are the liver, kidneys, small bowel or mesentery, bladder, colon or rectum, diaphragm, pancreas, and major vessels.

Mechanisms of Injury in Abdominal Trauma

PENETRATING 20%

more straightforward evaluation in that the point of wound entry is usually evident, and in the case of gunshooting wounds, the exit wound can also be identified

- stab wounds
- gunshot

BLUNT 80%

the extent of injury is less obvoius on physical examination and is thus associated with higher morbidity and mortality.

- vehicle collision
- falls,
- assaults
- sports injuries.

3 mechanisms

1.deceleration

lacerations,vascular tears, infarction of susceptible organs

2.crush injuries

injury of the organs between the abdominal wall and vertebral column

3.external compression

perforation of hollow viscera.

Diagnostic Techniques in Patients with Abdominal Trauma

- The diagnostic approach to trauma patients varies **according to their hemodynamic status**.
- **focused assessment with sonography for trauma (FAST)**
  - ✓ Rapid
  - ✓ noninvasive
  - ✓ 90% specificity for blood products in the abdomen and pelvis.
  - ✓ However, it is an operator-dependent. It also has a **low sensitivity (29%-35%)** for organ injury in the absence of hemoperitoneum
- **Diagnostic peritoneal lavage**
  - ✓ used to evaluate for intra-abdominal haemorrhage and hollow organ injury.
  - ✓ Its use has markedly decreased because of advances in imaging technology
- **Computed Tomography**
  - ✓ the speed and accuracy of CT as well as its widespread availability in emergency departments and trauma centres have led this imaging modality to **play a principal role** in the triage and diagnosis of trauma patients.
  - ✓ CT is used to evaluate patients with trauma not only initially, but also **for follow up,** when patients are treated non-operatively.
  - ✓ The sensitivity and specificity of CT in blunt abdominal injury **is 96 to 100% and 94 to 100%, respectively**.
  - ✓ In haemodynamically **unstable p**atients there is already an indication for surgery and you may skip the CT, unless to determine the damage outside the perioperative visual range.

CT Protocol

Multiphase CT

Arterial phase 25-35 seconds :for the diagnosis or exclusion of **vascular injury** or **active intra-abdominal haemorrhage.**

portal venous phase, which occurs 65 to 80 seconds after initiation of administration of the contrast material, is a good compromise in the diagnosis of **parenchymal injury**

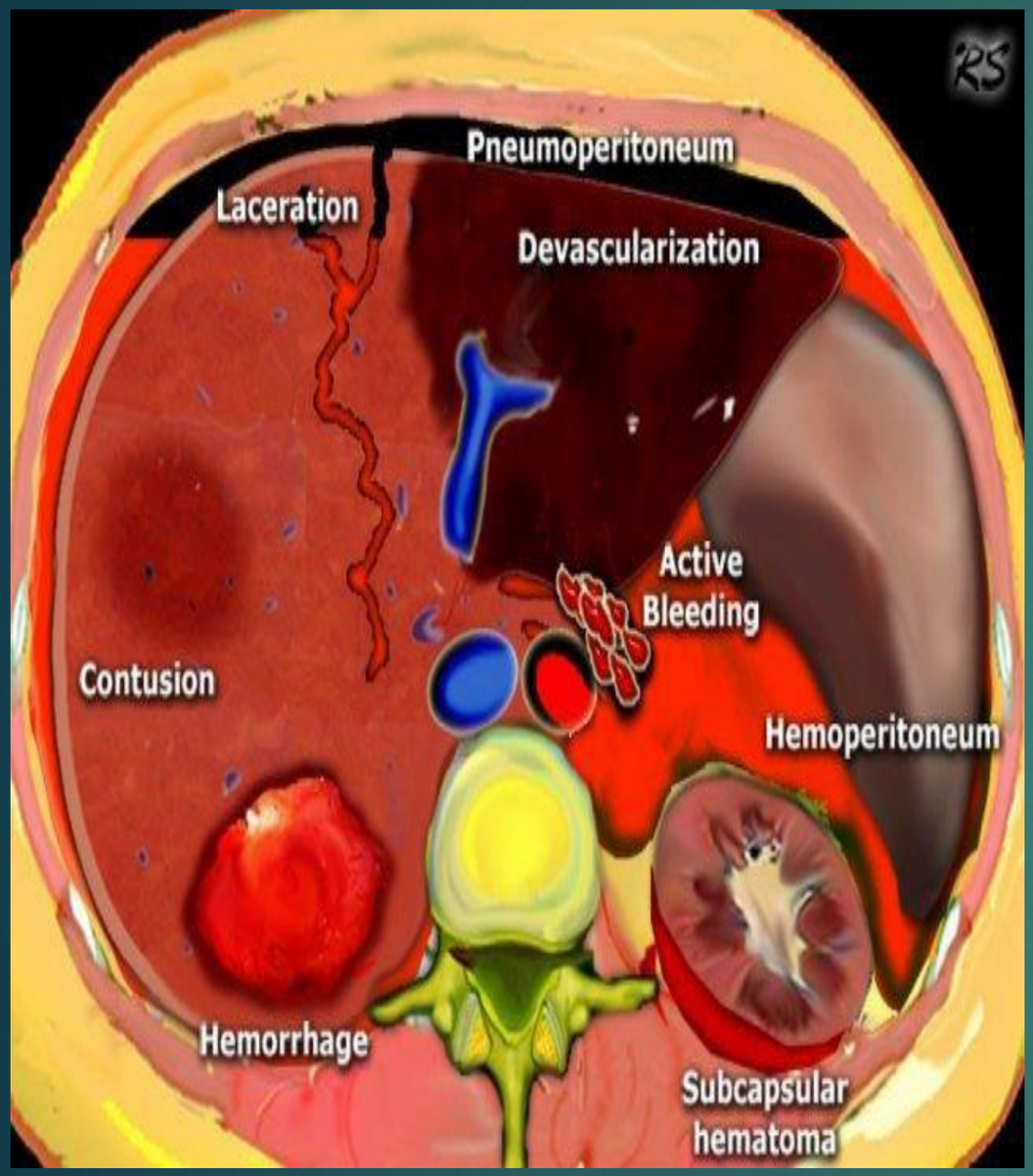
Secretory CT (in certain conditions) 7 to 10 minutes.

Macroscopic haematuria
Pelvic fracture
Kidney injury
Suspected bladder injury

Oral contrast the current consensus is not to use oral contrast in acute setting and in cases of diagnostic dilemma regarding bowel injury, use it for the subsequent CT scan after the patient becomes stable and acute event is managed**. therefore it is not indicated.**

CT cystography is mandatory in every case of **pelvic fracture** to rule out bladder injury.

CT urethrography can be done with dynamic urethral contrast injection in **suspected urethral injuries.**



The findings to look for in abdominal trauma are the following:

- ✓ Free fluid/Hemoperitoneum
- ✓ Contrast blush consistent with active extravasation
- ✓ Pneumoperitoneum
- ✓ Hypoperfusion complex
- ✓ laceration: Linear shaped hypodense areas
- ✓ Hematomas: oval or round shaped areas
- ✓ Subcapsular hematomas
- ✓ Contusions: vague ill-defined hypodense areas that are less well perfused
- ✓ Devascularization of organs or parts of organs

Free Fluid

- Common findings, seen in **75% of** patients with intra-abdominal injuries
- **Determine**

Where? (intra- or extraperitoneal)

Type? (blood, urine, bowel content, bile, ascites)

Volume? (minor, moderate, major)

Free Fluid: Where?

Intraperitoneal Blood	Extraperitoneal Blood
Wraps around liver tip	No
Location of primary organ injury in the peritoneum	No
Cul-de-sac, mesenteric root	Perivesical, anterior paravesical

Free Fluid: Where?

- **Intraperitoneal fluid:** Perisplenic, perihepatic, Morison pouch, paracolic gutters, inframesocolic space, lesser sac, between mesenteric leaves
- **Extraperitoneal fluid:** pararenal, perirenal, perivesical, pericholecystic spaces

0–20HU	Preexisting ascites Bile Urine Digestive fluid Diluted or old blood
30–45HU	Free Unclotted intraperitoneal blood
45–70HU	Clotted blood/sentinel clot sign hematoma
>100 HU	Extravasation of contrast medium (vascular or urinary)

Free Fluid: Type?

Always measure HU

- Fluid **does not enhance!** Changes in attenuation from pre to post contrast may be seen but should be minimal **(<5-10 HU)**

Intraperitoneal Fluid Quantity

	Amount (cc)	# compartments with fluid
Minor	100-200	1
Moderate	200-500	2
Large	>500	> 2

Free Fluid: Volume?

Intra peritoneal: can estimate volume of blood but this is **less important than hemodynamic status**

- Each compartment: Morison, perihepatic and perisplenic, paracolic gutters, pelvis

Retroperitoneal Hemorrhage Quantity

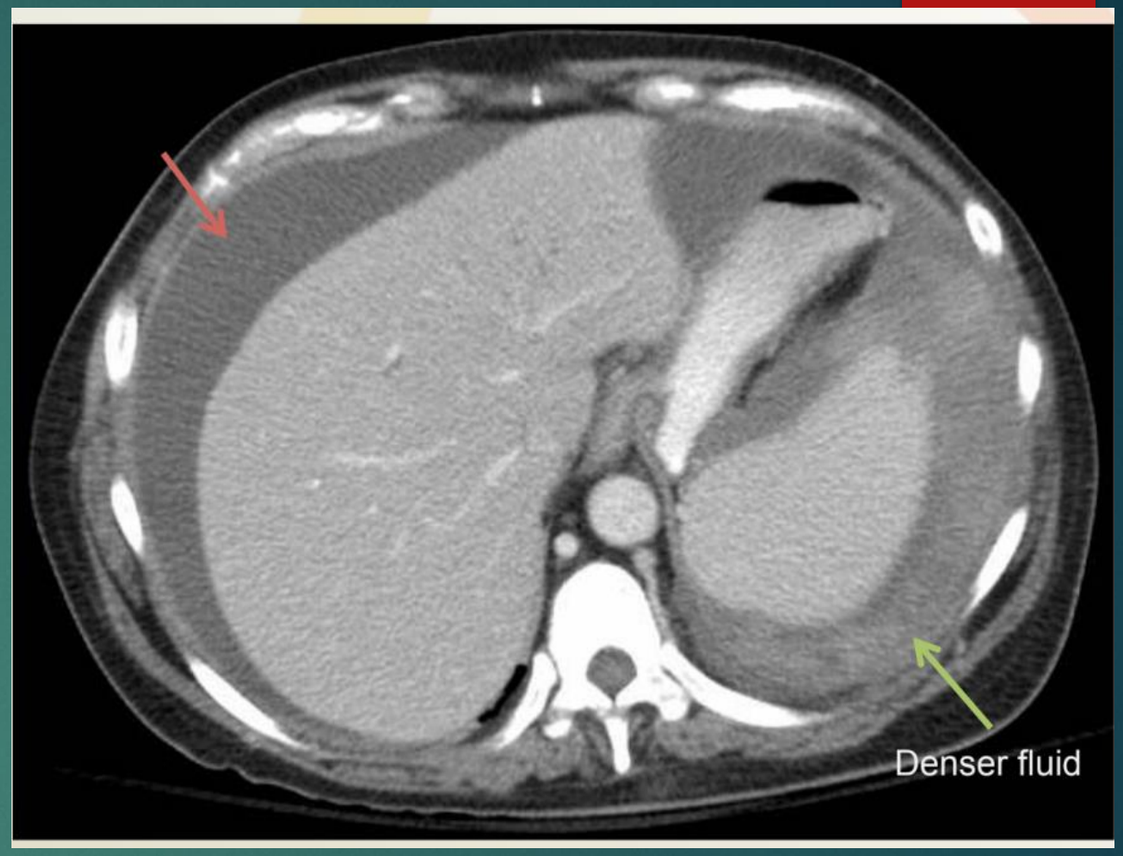
Amount	CT Character
Minor	Fascial thickening
Moderate	Confined to retroperitneal space adjacent to its origin (ie, perirenal, anterior/posterior pararenal)
Large	Multiple communicating retroperitoneal spaces

Difficult to quantify volume in retroperitoneal bleed

Free Fluid: Type

Low-density free fluid in blunt trauma patient proven to be urine leakage from intraperitoneal bladder on CT cystography

Sentinel Clot Sign



Blood accumulates adjacent to site of bleeding

- **Indirect sign of injury to an adjacent organ even if the lesion could not be identified**

– Sentinel clot seen in

84% of visceral injuries

Active Extravasation

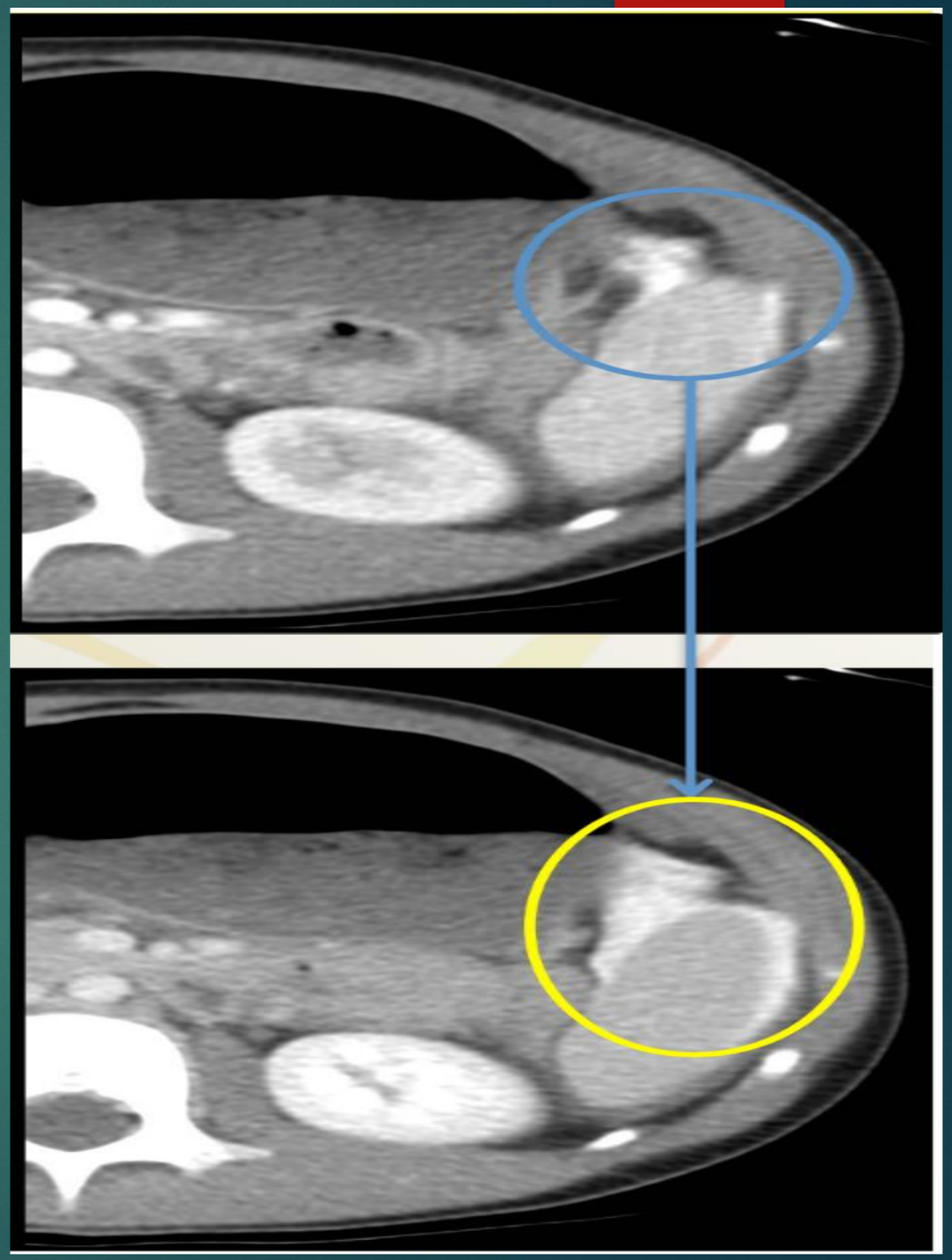
- Jet or focal area of hyperattenuation **(within 10 HU of adjacent major vessel source)**

within a **hematoma on initial images** that **fades into an enlarged, enhanced hematoma**

on delayed images.

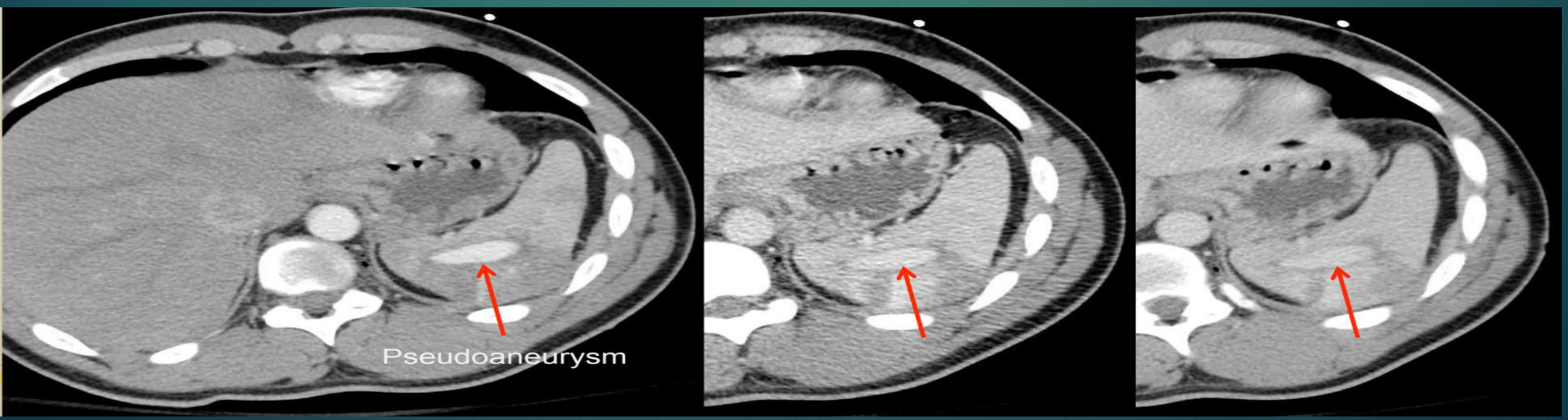
• Indicates **significant bleeding**

• Must be quickly communicated to the clinician (surgical or endovascular Rx may be necessary)



Pseudoaneurysm

- Contained by connective tissue or vessel wall (ie, adventitia).
- **Adjacent to a vessel**
- **<u>Does not enlarge. Same size in all phases</u>**
- >70% of pseudoaneurysms progress to rupture



Active Extravasation vs. Pseudoaneurysm

Characters	Active Extravasation	Pseudoaneurysm
Edges	Ill-defined	Defined
Shape	Commonly a jet (linear or layering); may be diffuse or focal	Often round or oval; possible neck adjoining artery
Delayed appearance	Increased attenuation or size; possible layering	Less apparent; in isolation, no change in size, similar attenuation with vessels
Management	Urgent embolization or surgery if significant injury present*	Urgent or ambulatory embolization or surgery if significant injury present*

*Not all injuries must be treated. Small pseudoaneurysms or those amenable to Rx by direct pressure do not

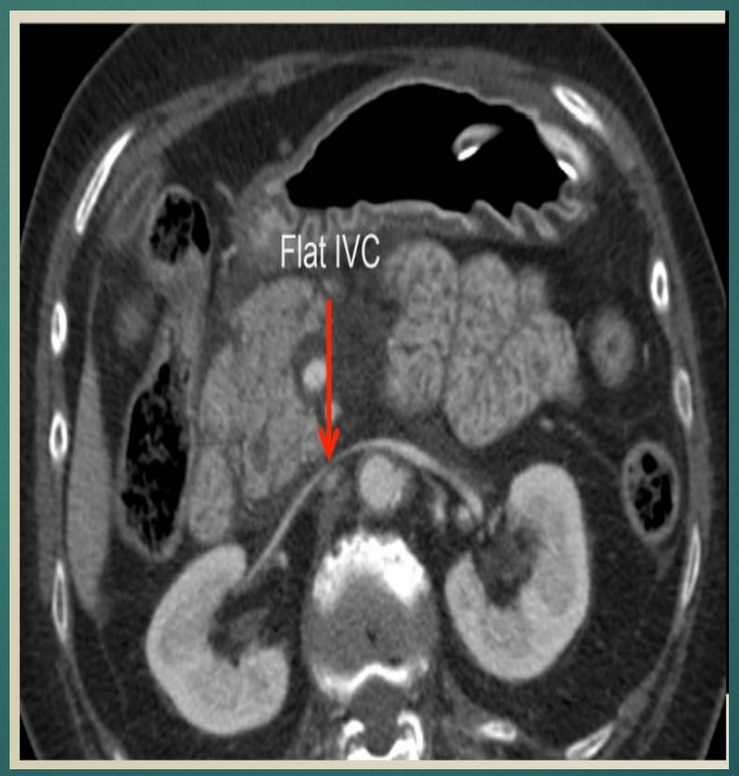
Hypoperfusion Complex

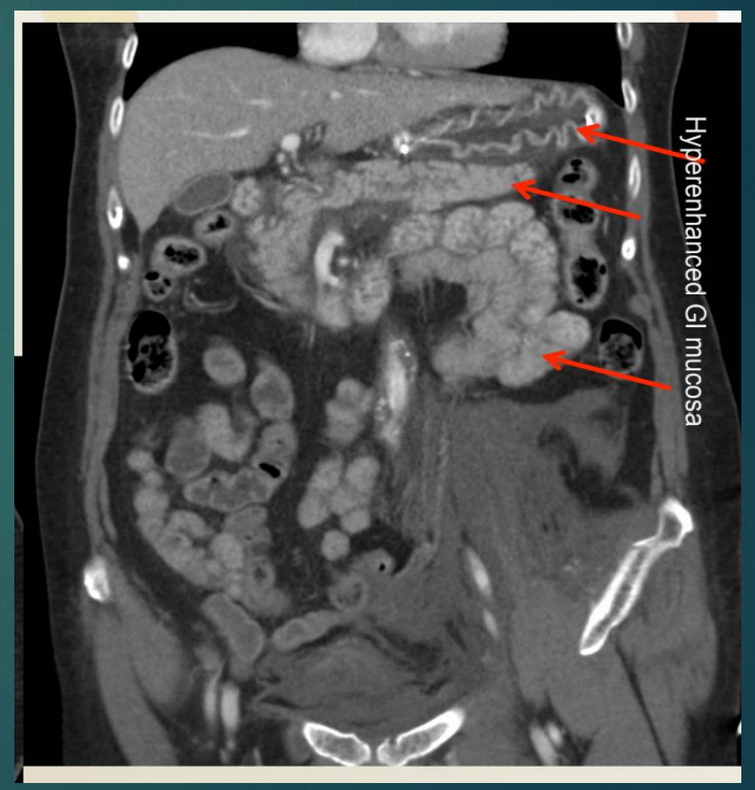
- Flat IVC, small aorta
- **Enhanced:** adrenals, kidneys, GB

mucosa, bowel mucosa

- **Hypo enhanced:** liver, spleen,

pancreas, peripancreatic edema





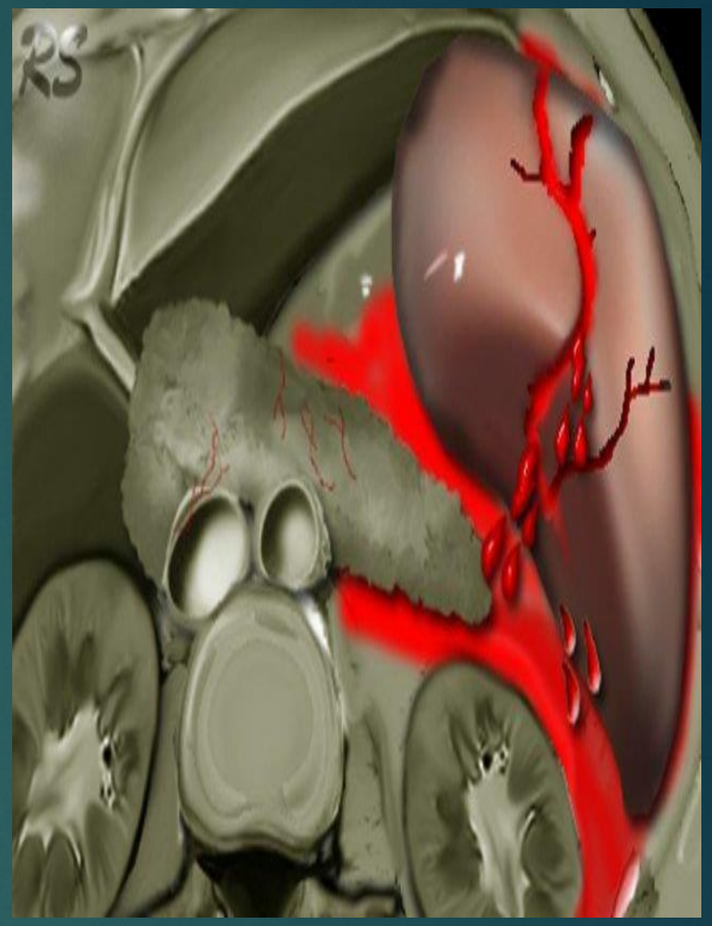
Flat IVC, small aorta, hyperenhanced adrenals ,kidneys, hyperenhanced GI mucosa, and
peripancreatic edema caused by hypoperfusion state from left pelvic ring injury

Specific Organ Injuries

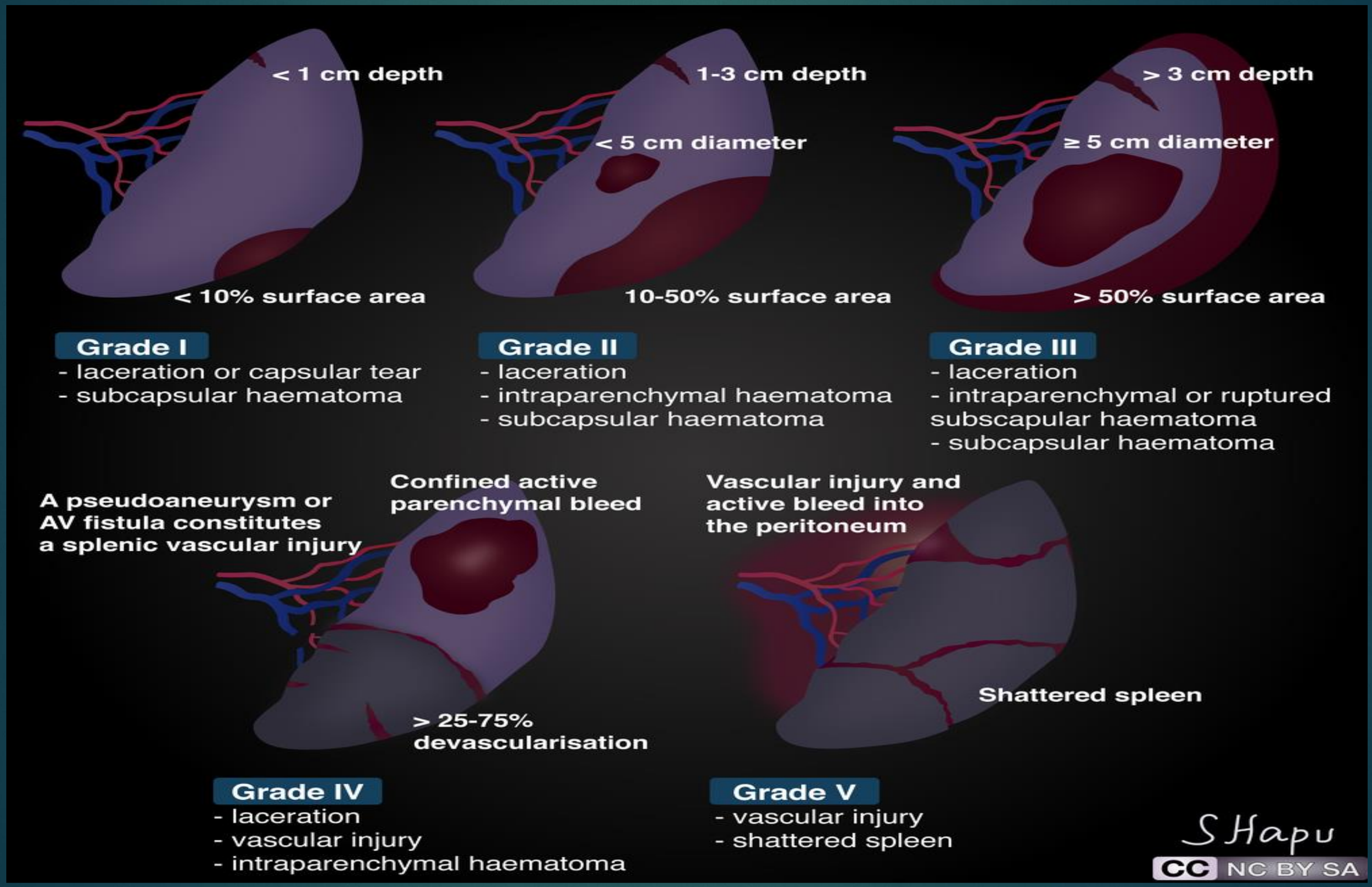
- Solid intraperitoneal organs
- Retroperitoneal organs
- Hollow organs

Spleen

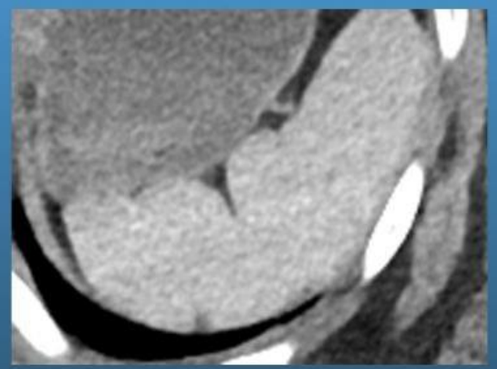
- The spleen is the **most commonly injured solid organ.**
- **Left lower rib fracture** with **hypotension** should prompt the search for a splenic trauma.
- **Patterns of splenic injury are**
  - ✓ Contusion
  - ✓ laceration
  - ✓ Subcapsular hematoma
  - ✓ perisplenic hematoma
  - ✓ Contrast blush.
  - ✓ Perfusion defects due to segmental devascularization
- subcapsular splenic hematomas, missed at USG or rarely at CT, **may bleed fatally even 48 h** after initial trauma. This is the **lucid interval of splenic trauma.**
- The finding of contrast extravasation has great impact on the patients management, because when there is **active bleeding, there will be failure of non-operative management in 80% of the cases**, In these patients the need for intervention is almost ten times as high compared to patients without extravasation.

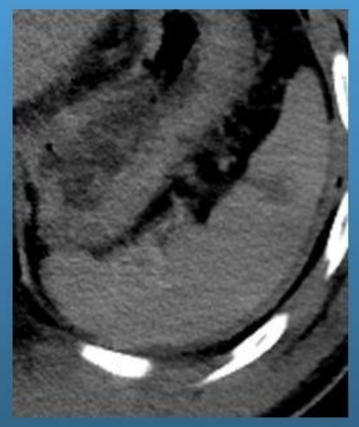


Grades of splenic injuries

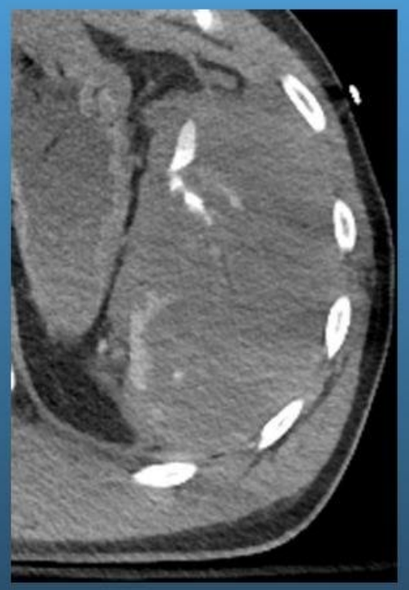


Grades of splenic injuries





Grade 4



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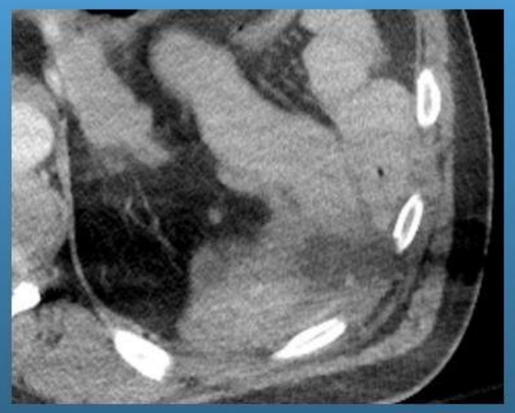
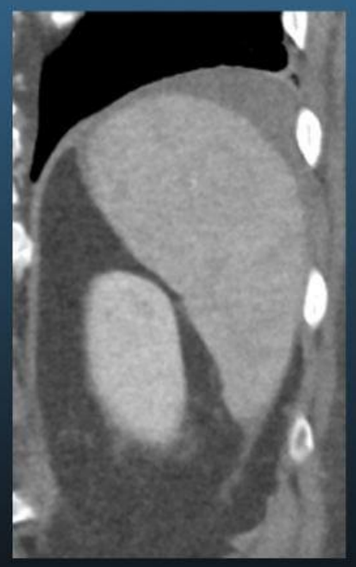
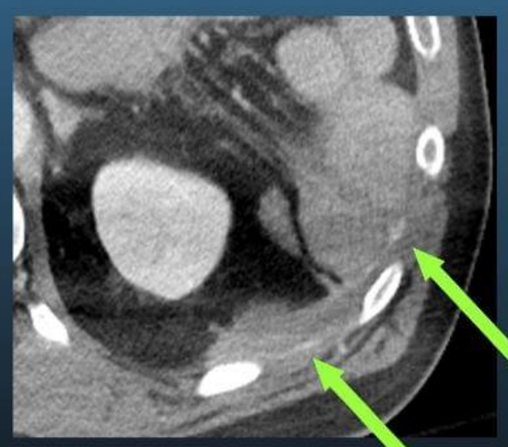






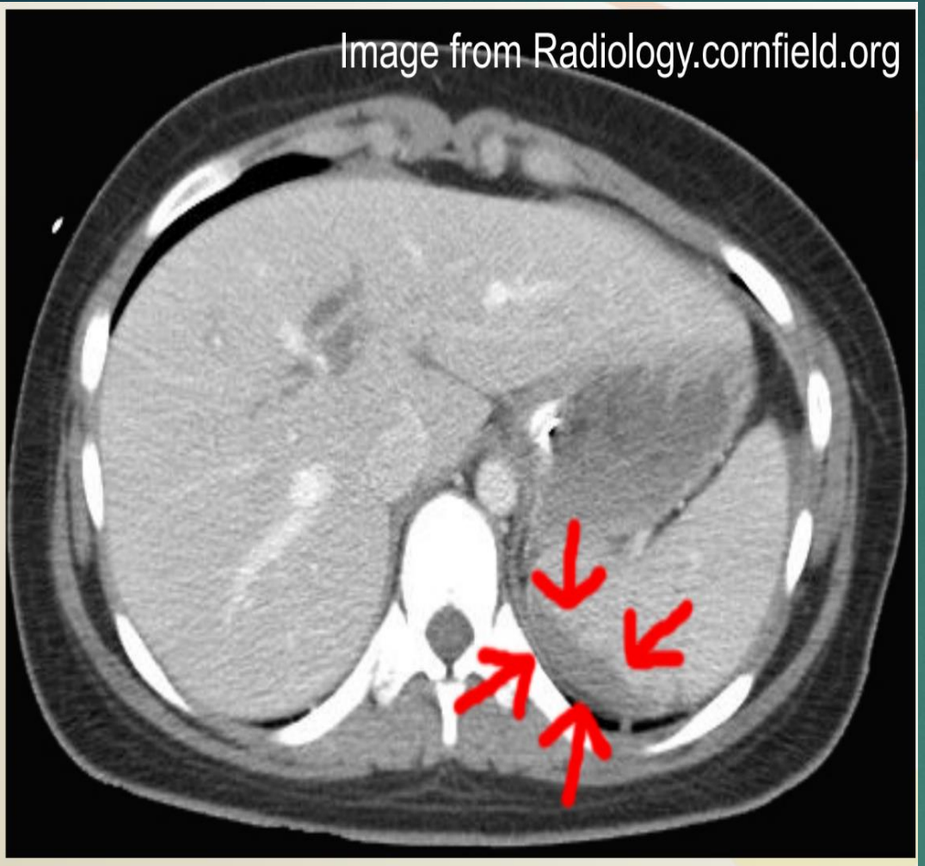
Grade 1

Grade 2

Grade 3

- Contusion = hypodense area within normally perfused splenic parenchyma

- Laceration = linear perfusion defect



- Subcapsular hematoma = lenticular shape with compression of adjacent splenic paenchyma
  - Difficult to confidently see splenic capsule
  - Sometimes difficult to distinguish btw subcapsular and perisplenic hematoma

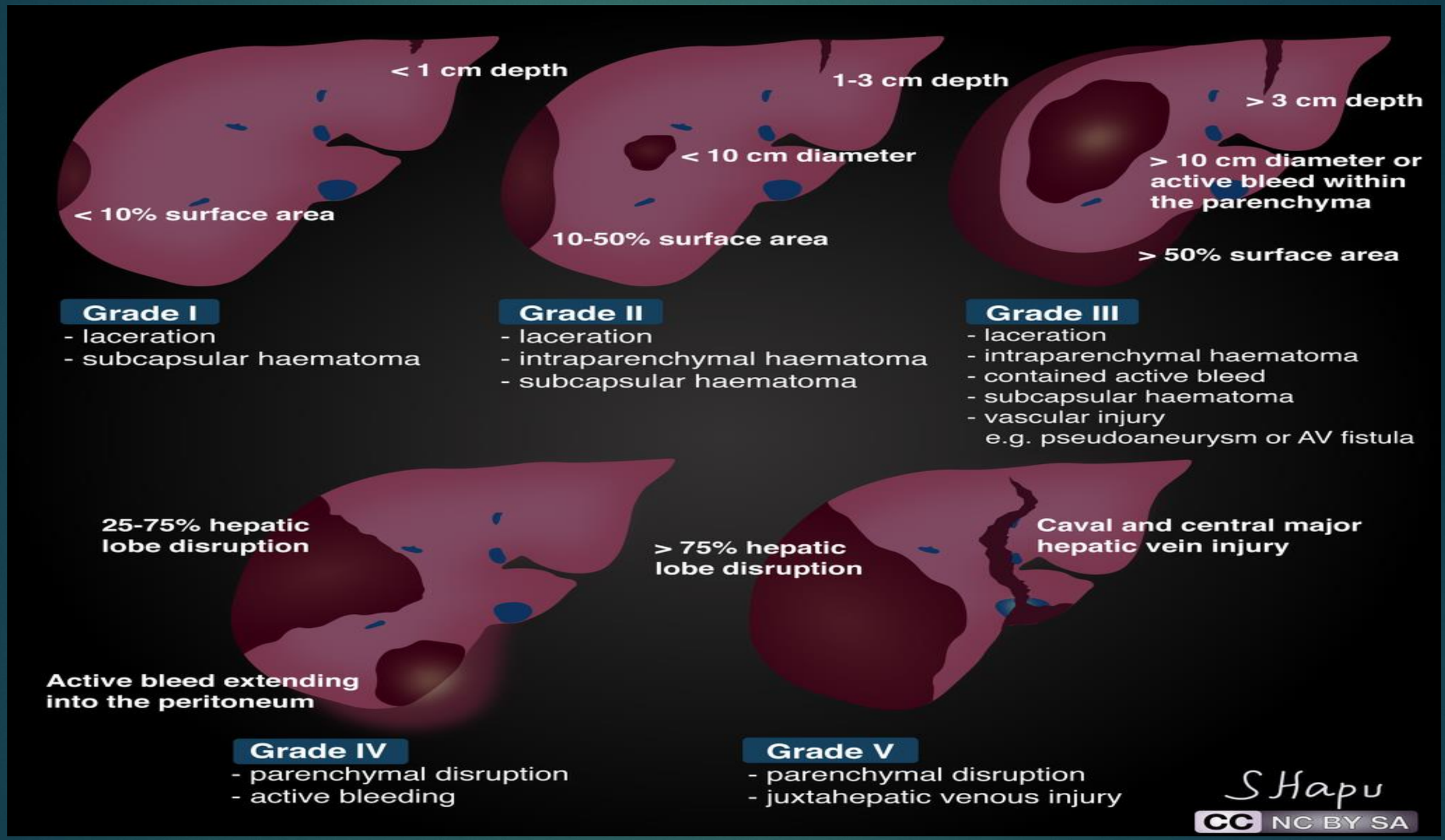
There are lacerations and also active bleeding with a contrast blush with the density within the range of the density of the aorta.
There also is hemoperitoneum, so this patient will probably need surgery.

Liver

- In trauma the **liver is the second most** commonly involved solid organ in the abdomen **after the spleen**.
- However liver injury is the **most common cause of death**, This is due to the fact that there are many **major vessels in the liver, like the IVC, hepatic veins, hepatic artery and portal vein.**
- The range of imaging findings is wide and includes **hematoma**, **contusion**, **laceration**, **active extravasation**, and **vascular injury**
- It is important to remember,, that the **posterior segment of the right liver lobe** is the **most frequently injured part.**

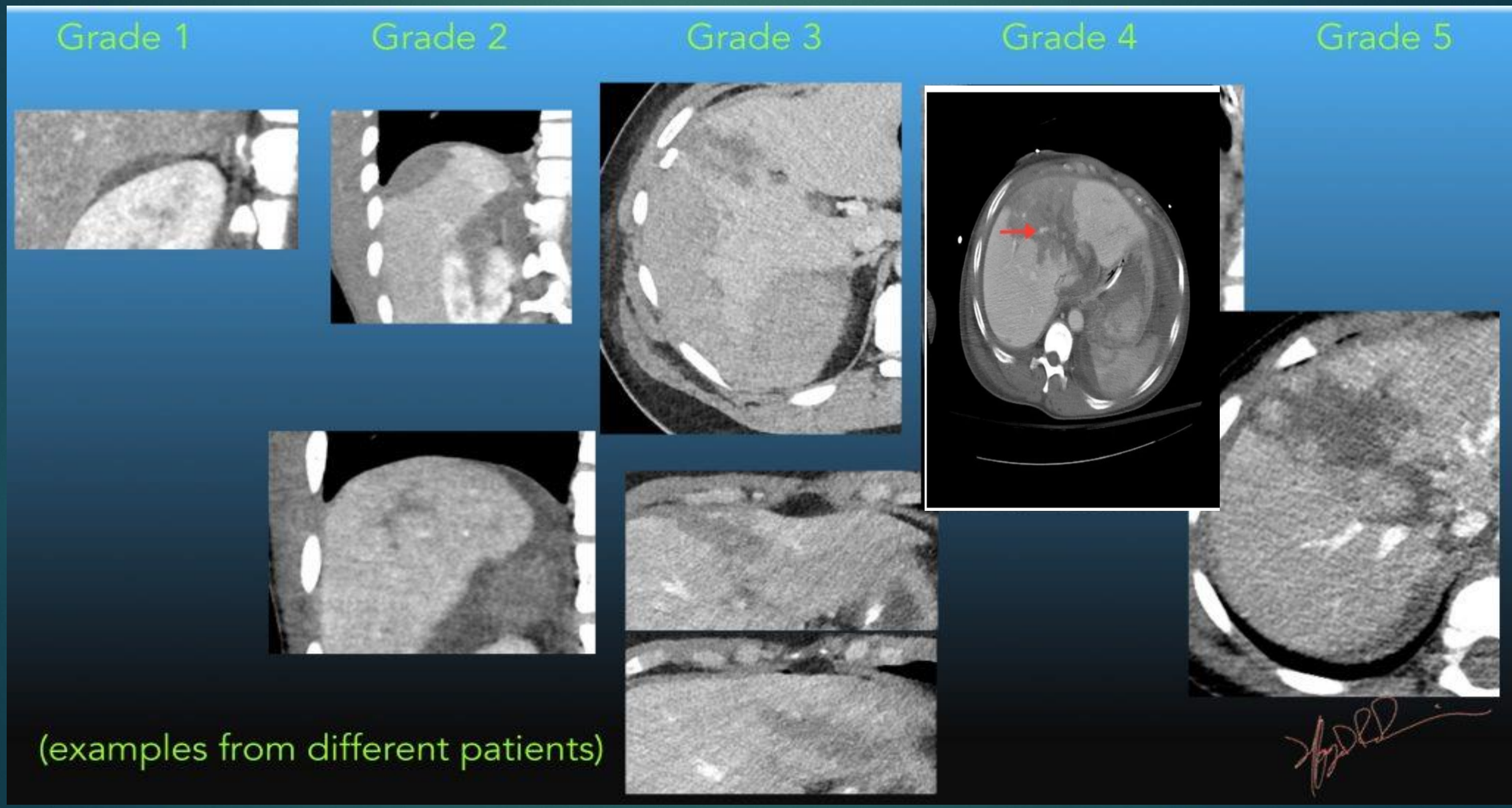
This part also involves **the bare area** and this can **lead to retroperitoneal bleeding** rather than bleeding into the peritoneal cavity.

Grades of liver injuries



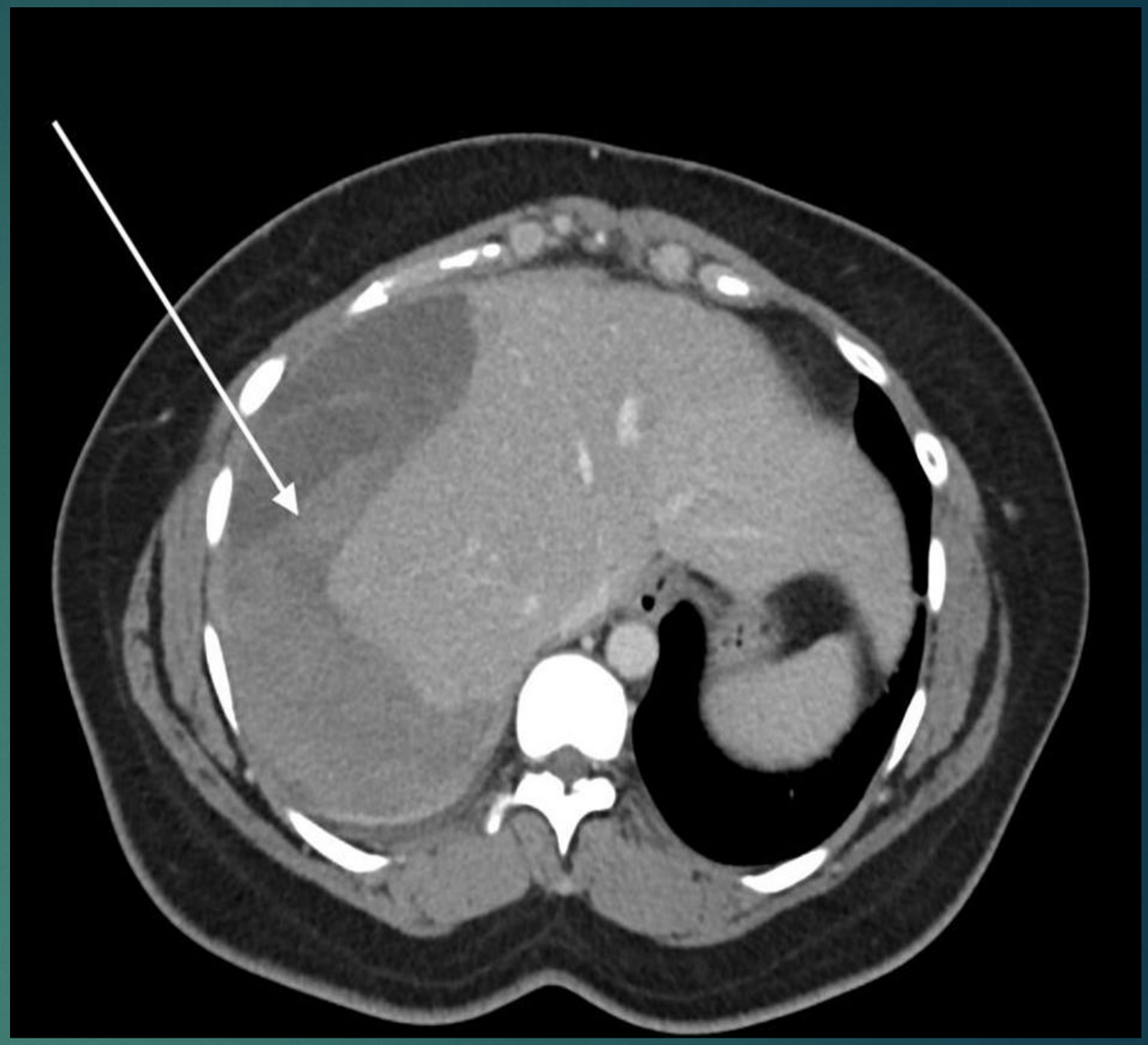
The AAST (American Association for the Surgery of Trauma) liver injury scale was revised in 2018.

Grades of liver injuries



Liver laceration.

Lacerations can be stellate, like the example on the left or branching like the one on the right.



Axial CT demonstrating the large subcapsular hepatic hematoma involving most of the right lobe of the liver, highlighted by the arrow.

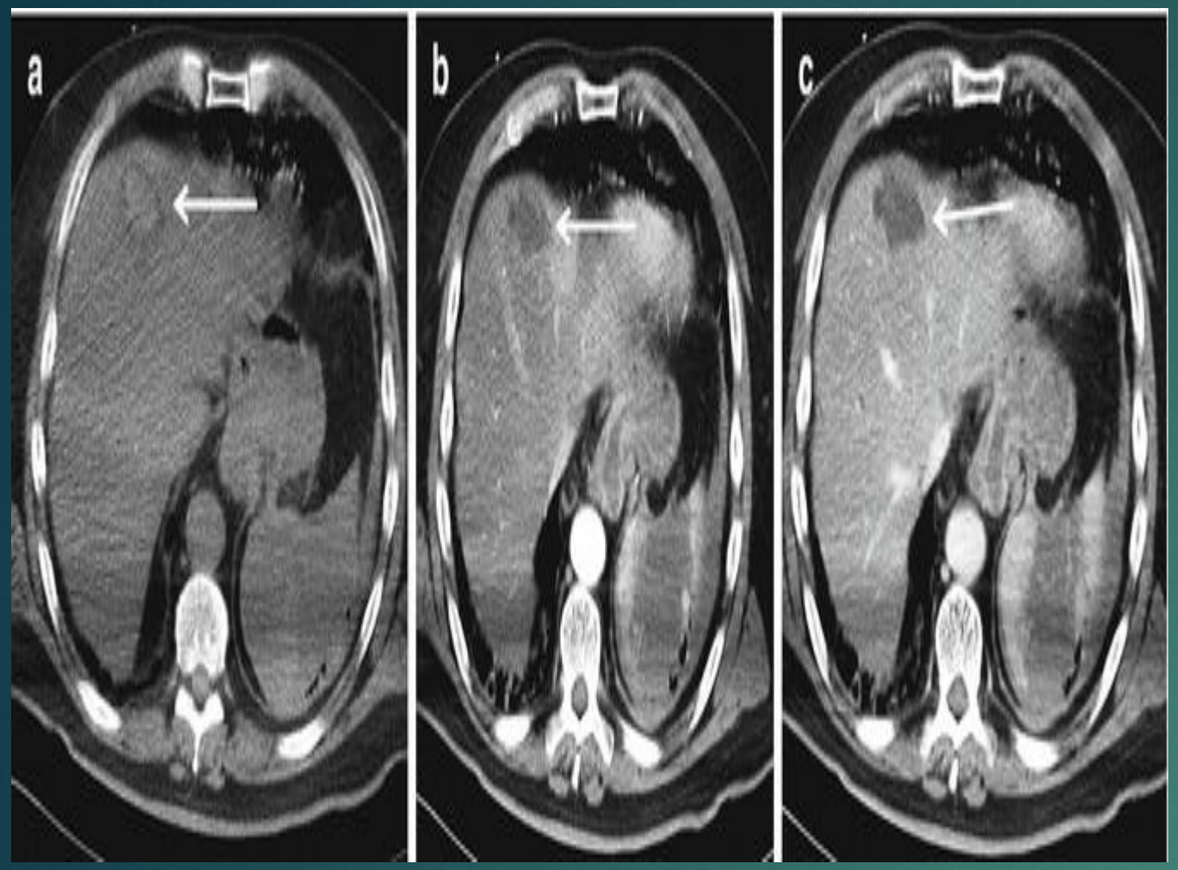
Liver injury. The arrows indicate
different types of injury.

The findings are:

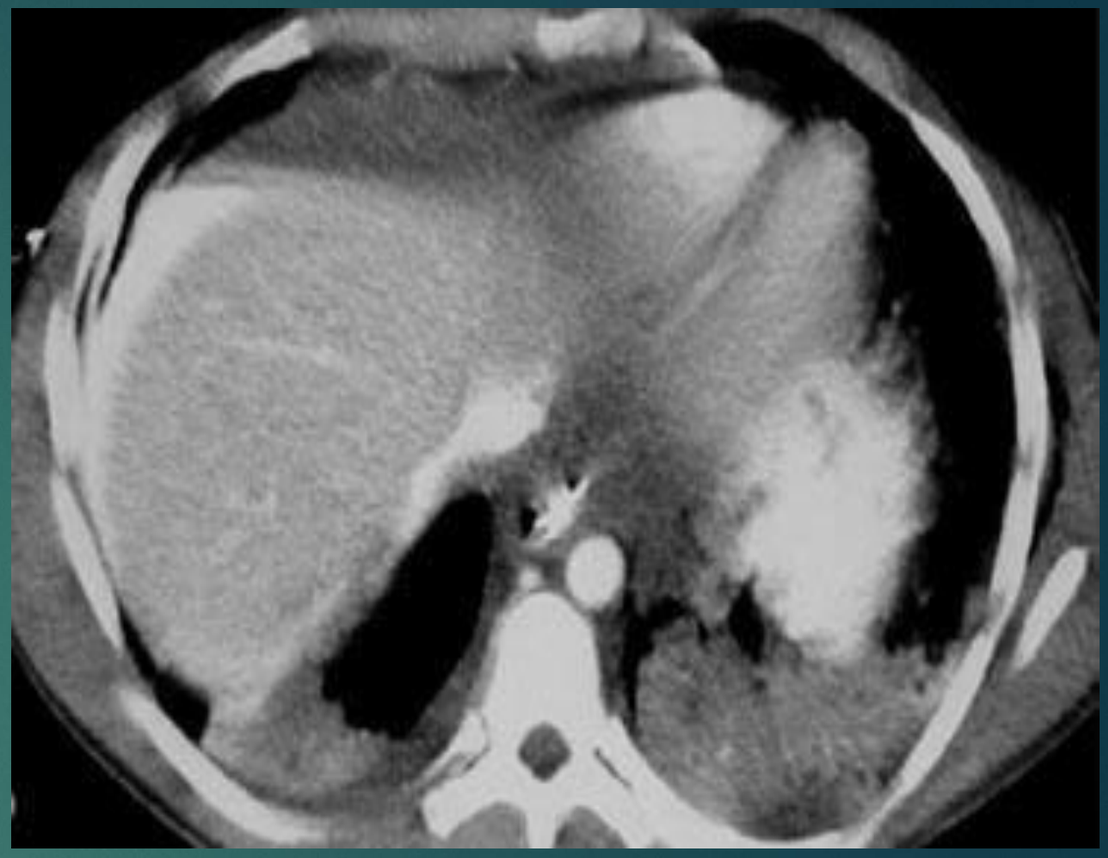
1.Yellow arrow: linear shaped hypodense area consistent with laceration. Notice that this laceration crosses the left portal vein

2.Blue arrow: vague ill defined hypodense area consistent with contusion

3.Fluid around the liver



(a) CT scan without contrast media administration, (b, c) CE-MDCT scan in arterial (b) and in venous phase (c) depict a parenchymal hematoma. The hematoma appears as a round hyperdense area in (a) (arrow), and hypodense in the post-contrast phases (b, c) (arrows)



Questions:

1.What contrast materials are on board?

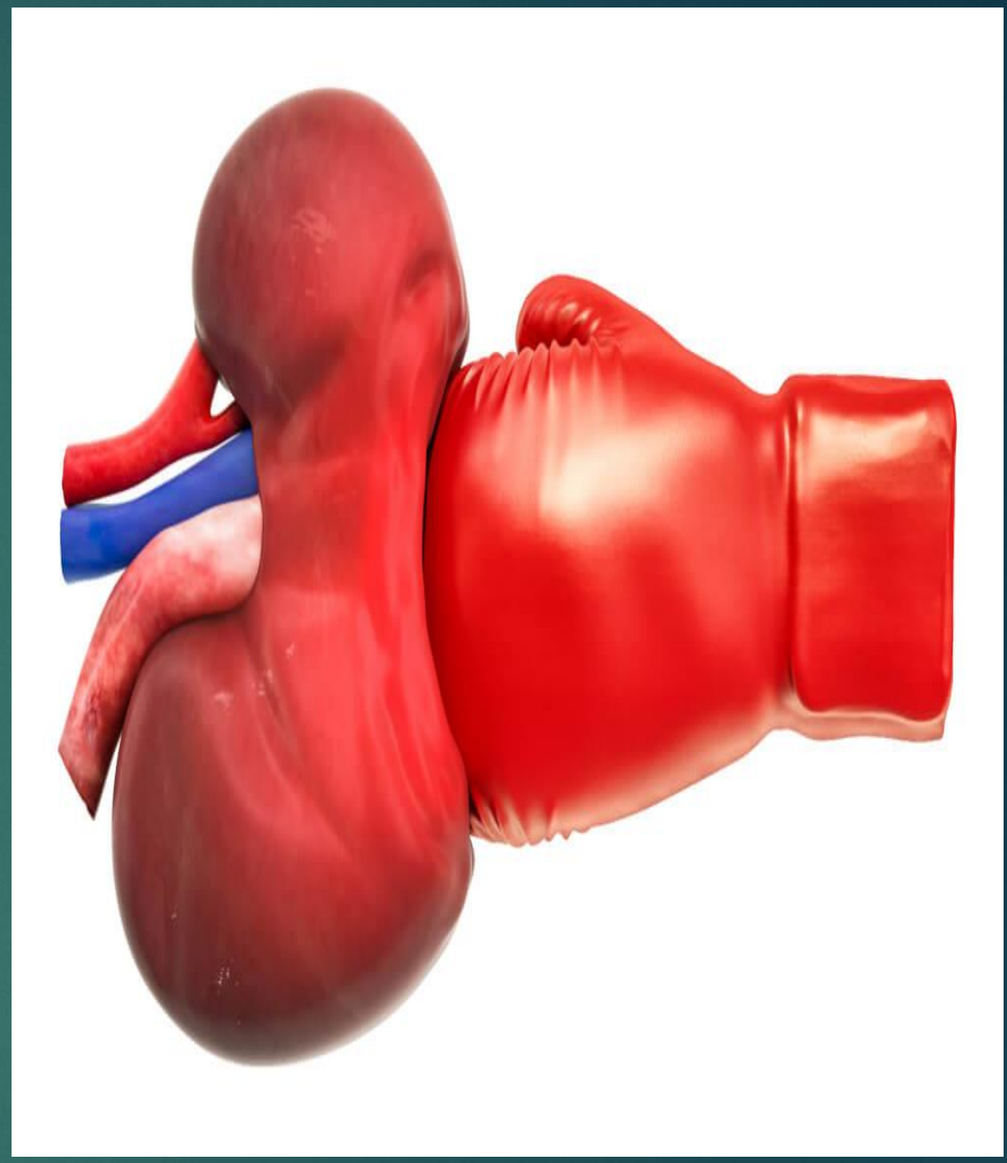
2.Where does the contrast surrounding the liver come from?

There is i.v. contrast and images were taken in the portal phase. There is also oral contrast filling of the stomach.
The contrast surrounding the liver could be a result of stomach or bowel perforation, but since there was no pneumoperitoneum, this was thought to be unlikely.
So the extravasation was thought to be a result of active bleeding and since there is a great amount of contrast surrounding the liver, this was thought to be a huge leak.

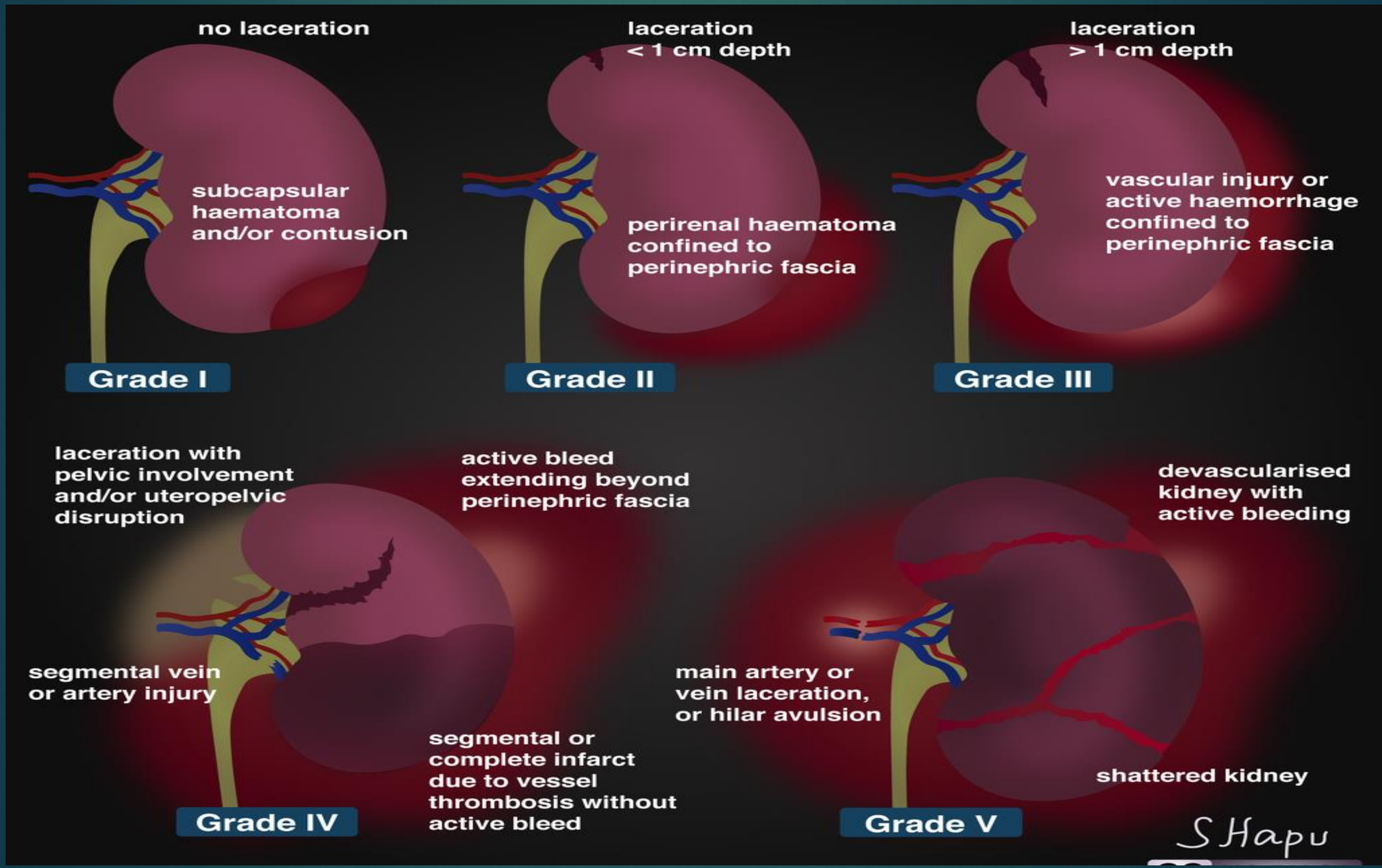
At the OR an avulsed right hepatic vein was found.
This diagnosis has a 90-100% mortality and this patient died in the OR.

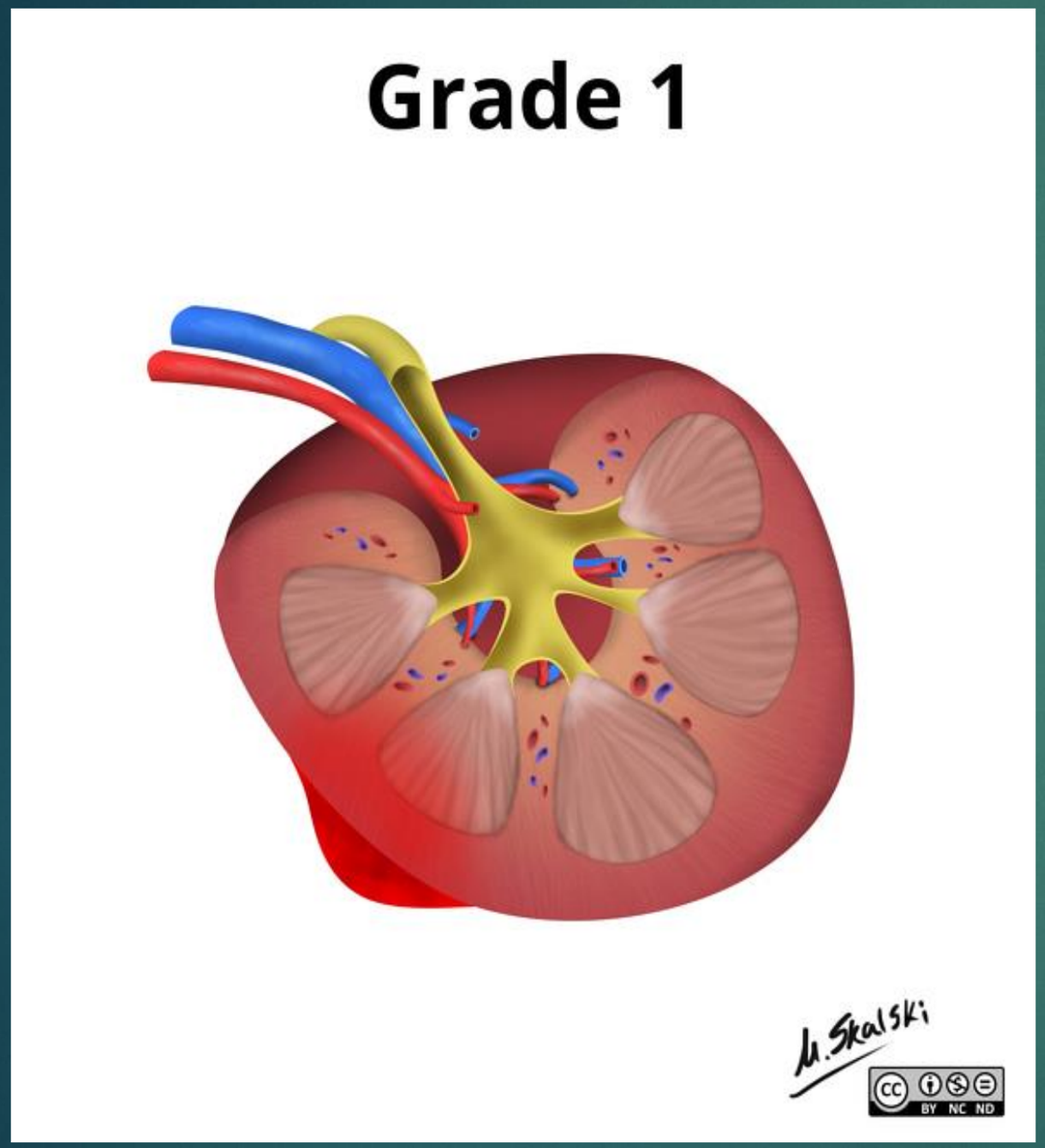
Kidney and ureters

- Kidney is the 3rd most common involved organ in trauma to adult, while in **children** it is the **most** common injured organ.
- **Blunt trauma** is more commonly associated with renal injury than the penetrating trauma .
- Haematuria, gross or microscopic, is associated with majority of renal trauma cases. However, **its absence does not rule out renal injury.**
- **Ureteropelvic junction is the most common site for the ureteric injury.** Compression against the transverse processes of lumbar vertebrae causes ureteric injury.
- Evaluation for:
  - ✓ **Parenchymal injuries**
  - ✓ **Vascular injuries**
  - ✓ **Collecting system injuries**



Grades of renal injuries

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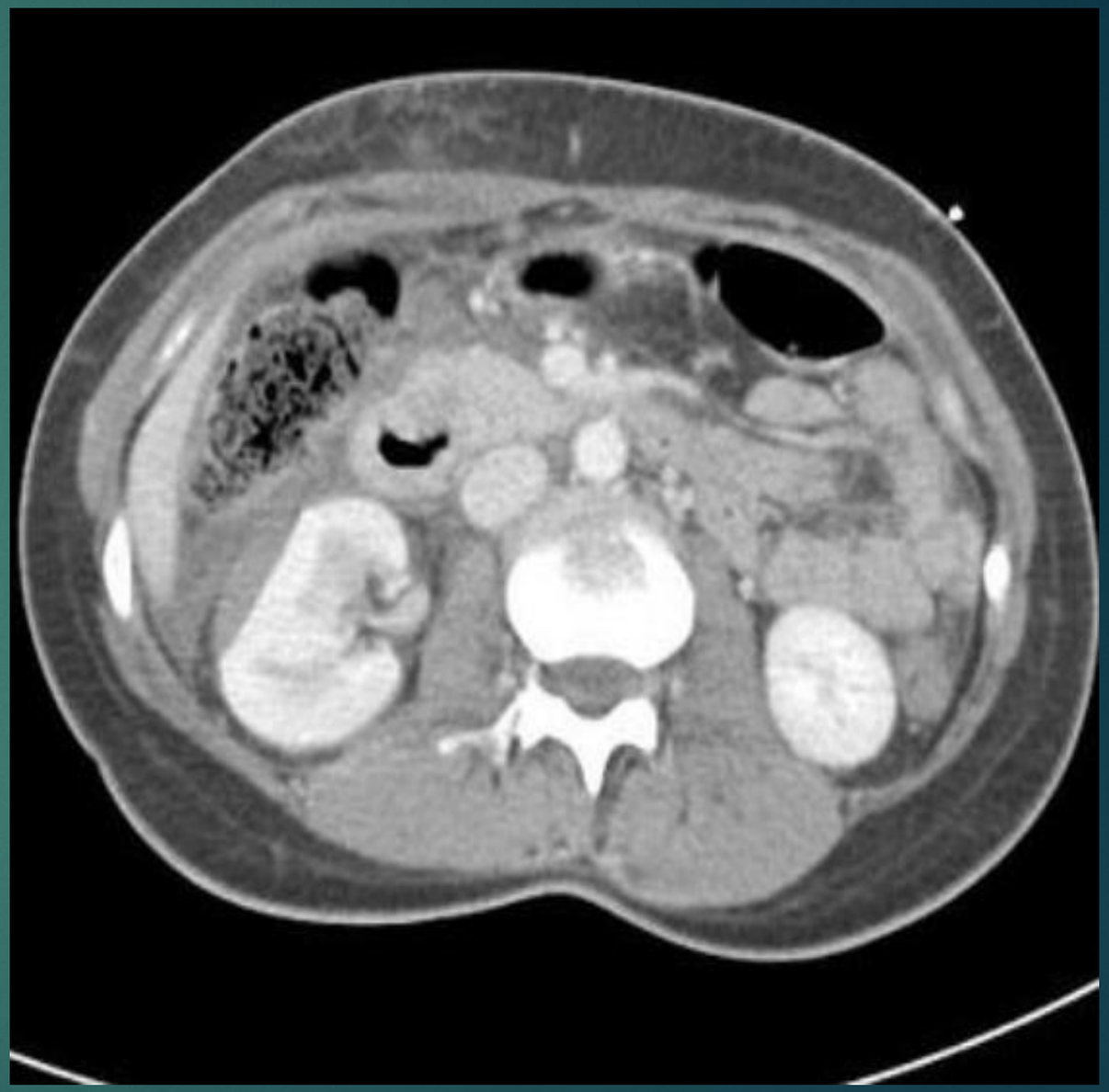
M. Skalski
BY NC ND



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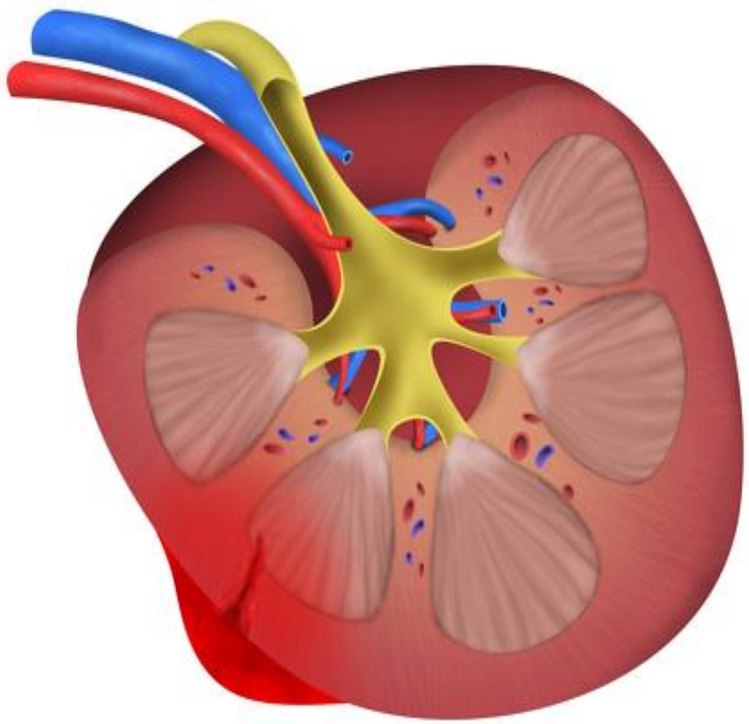

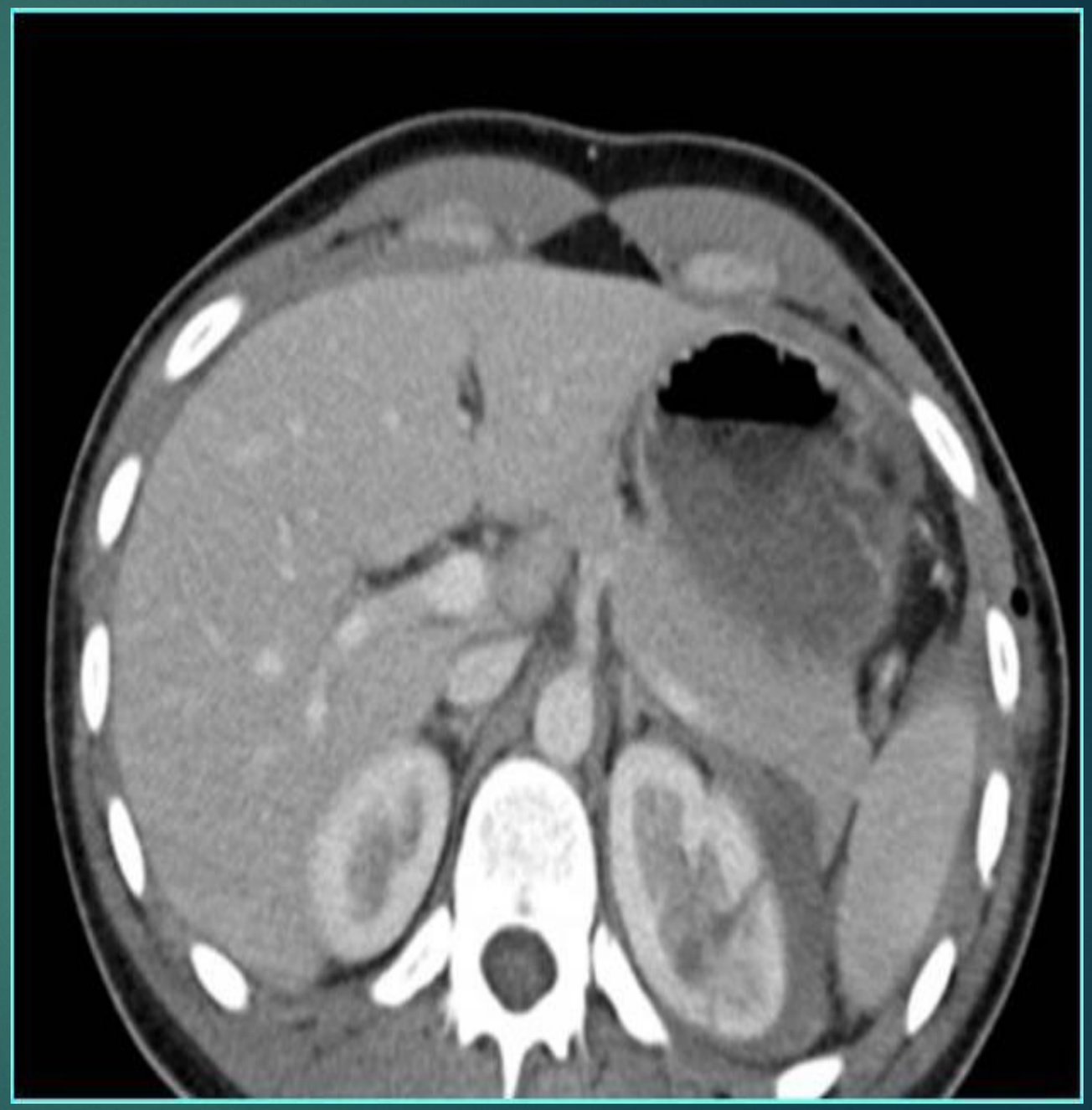

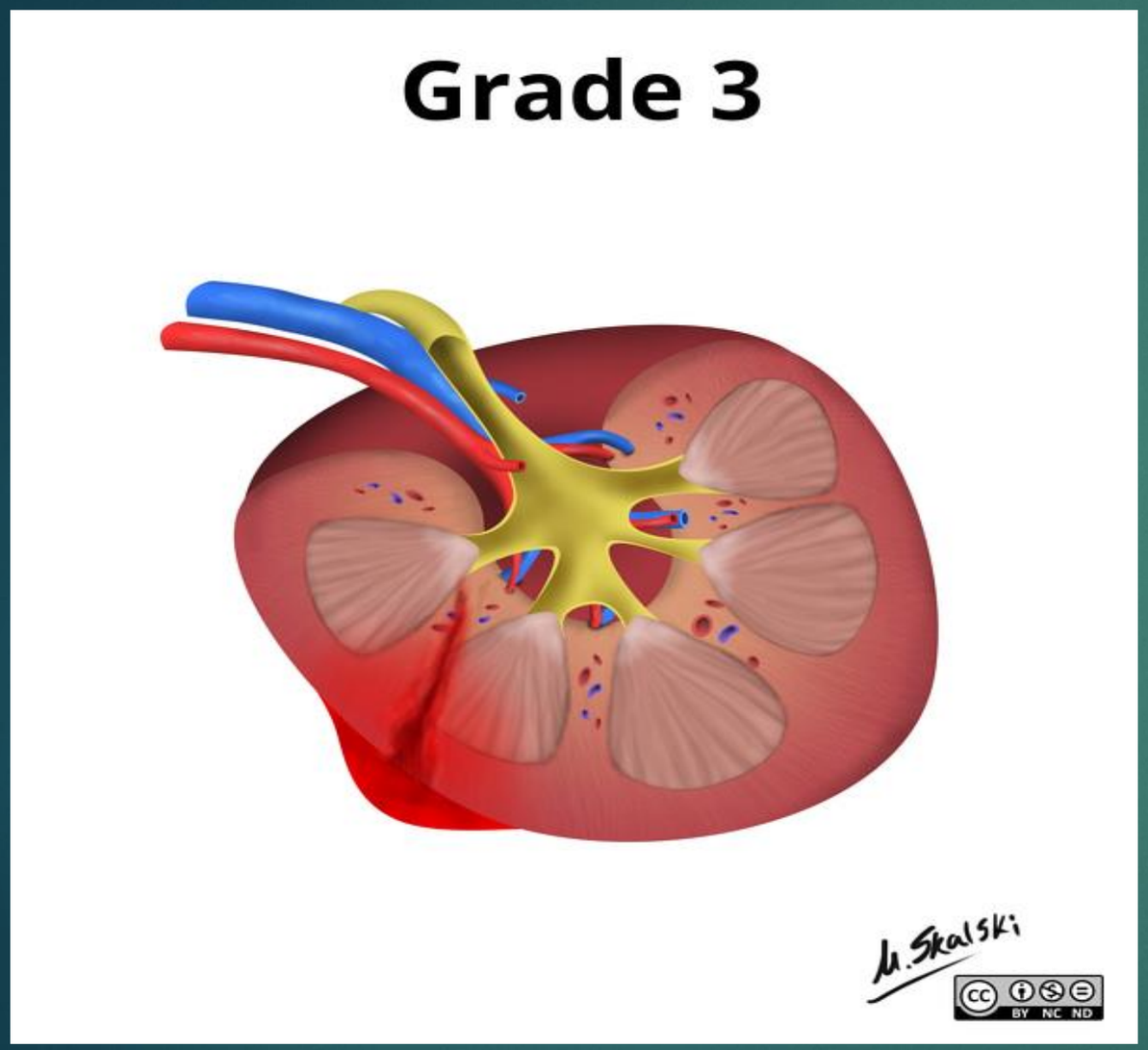
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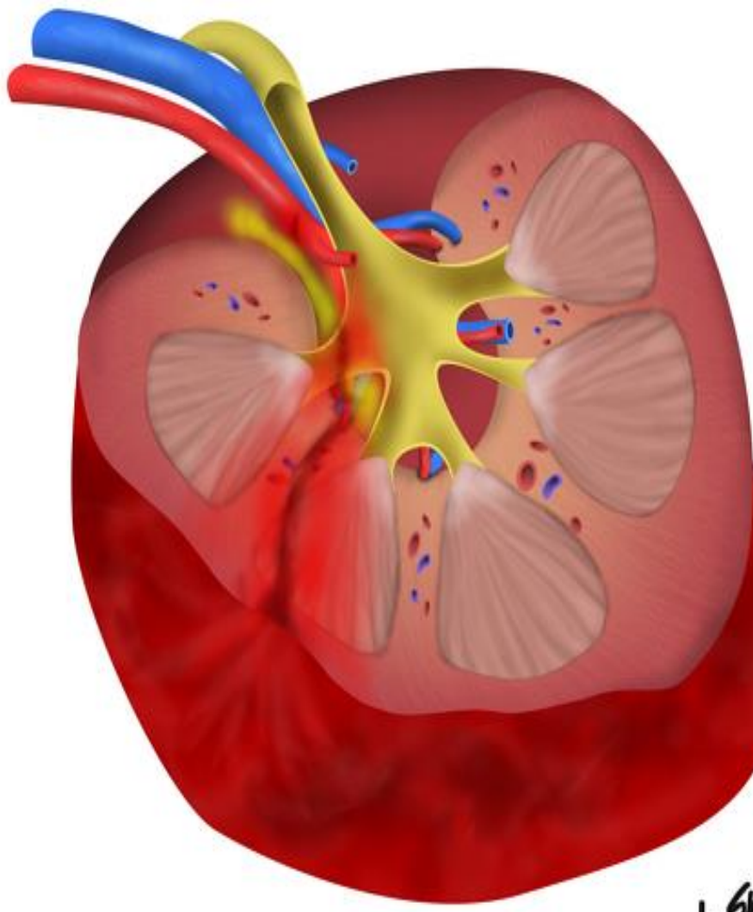

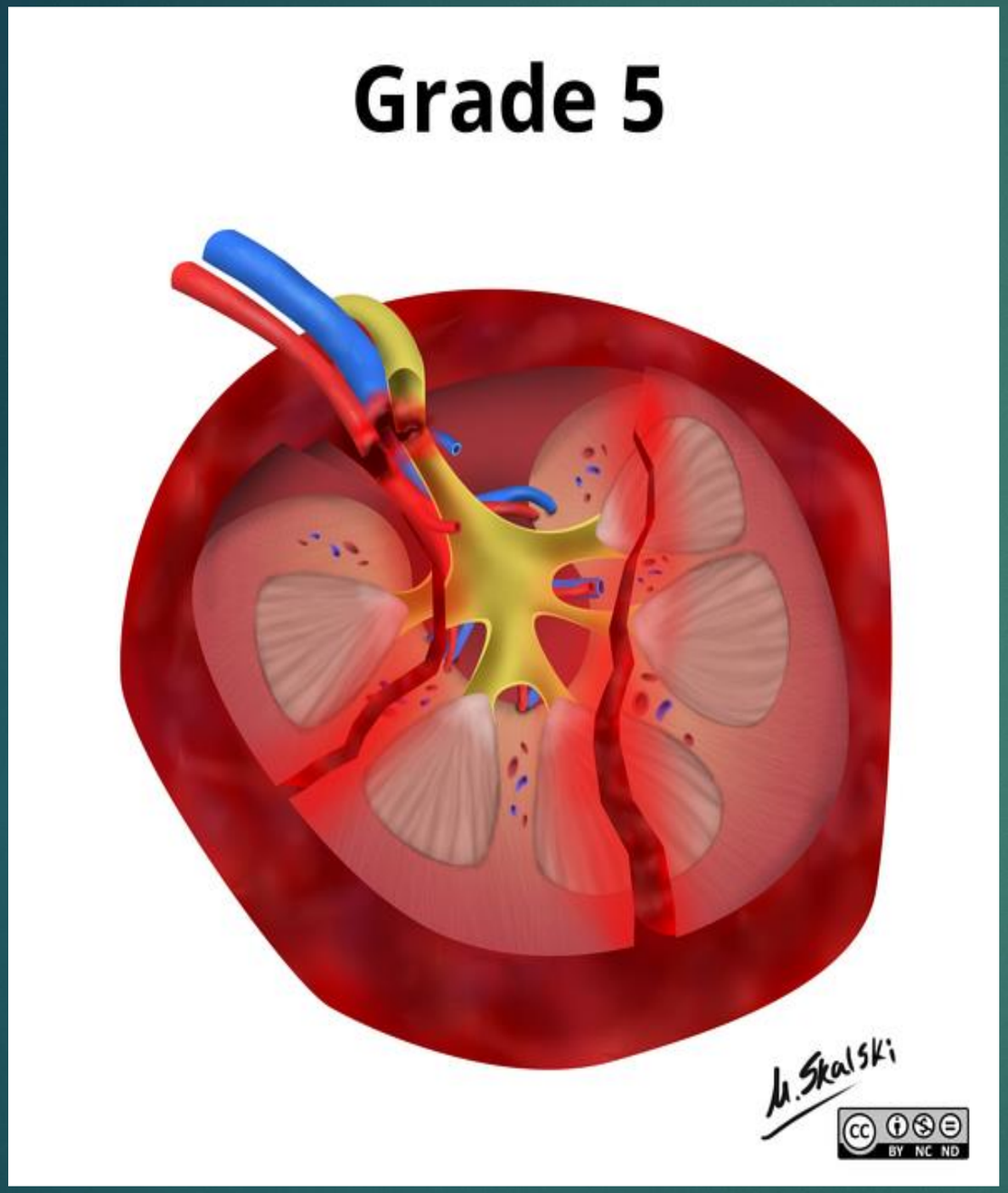
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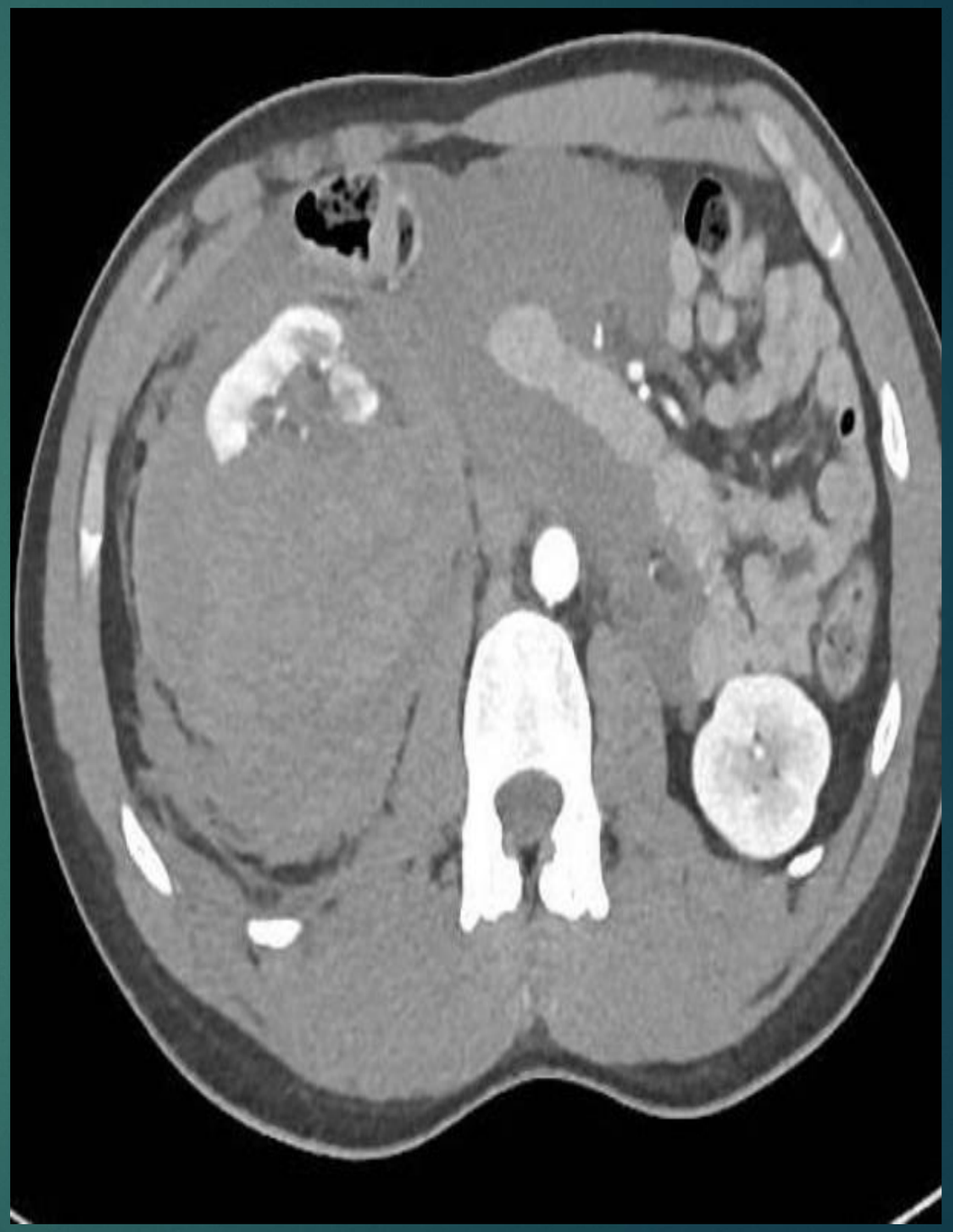
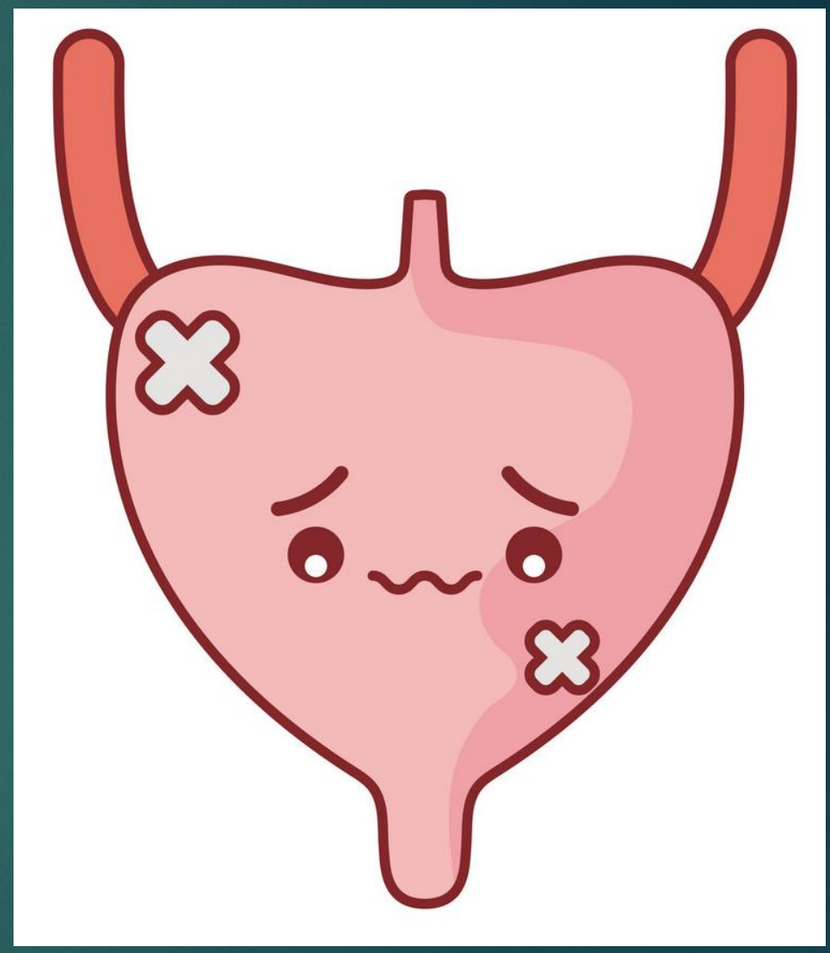
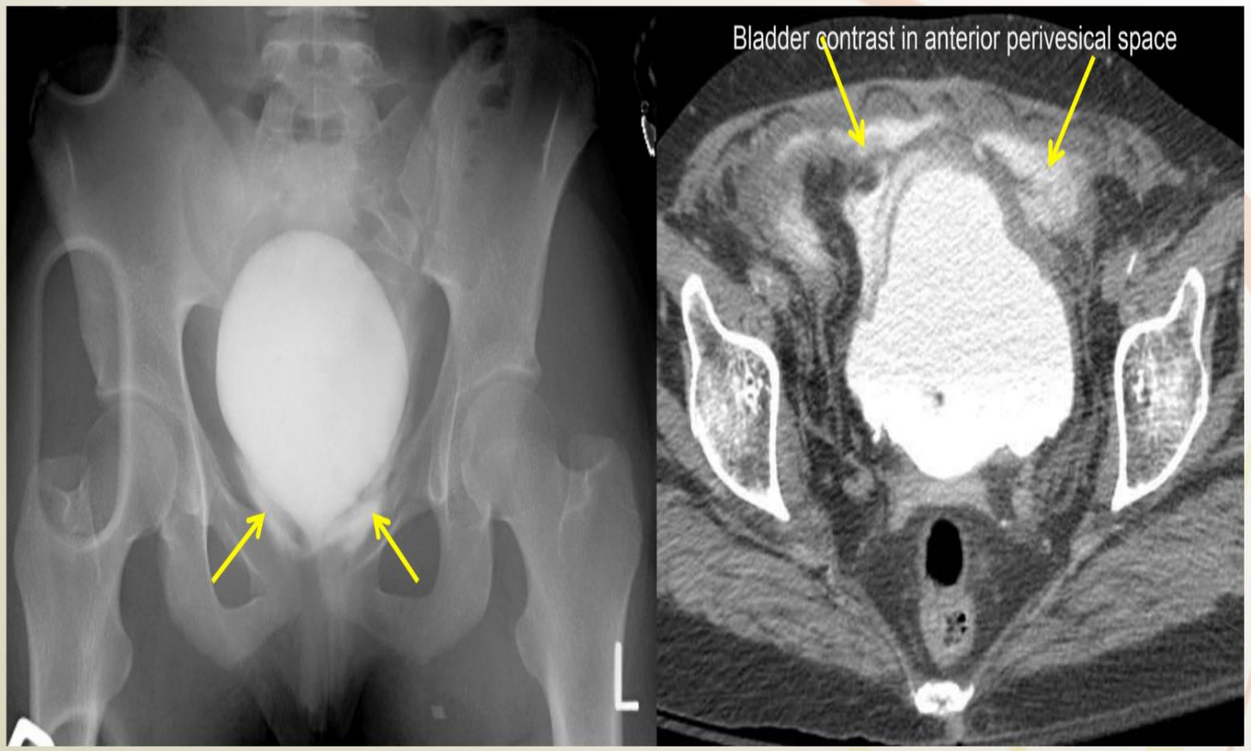


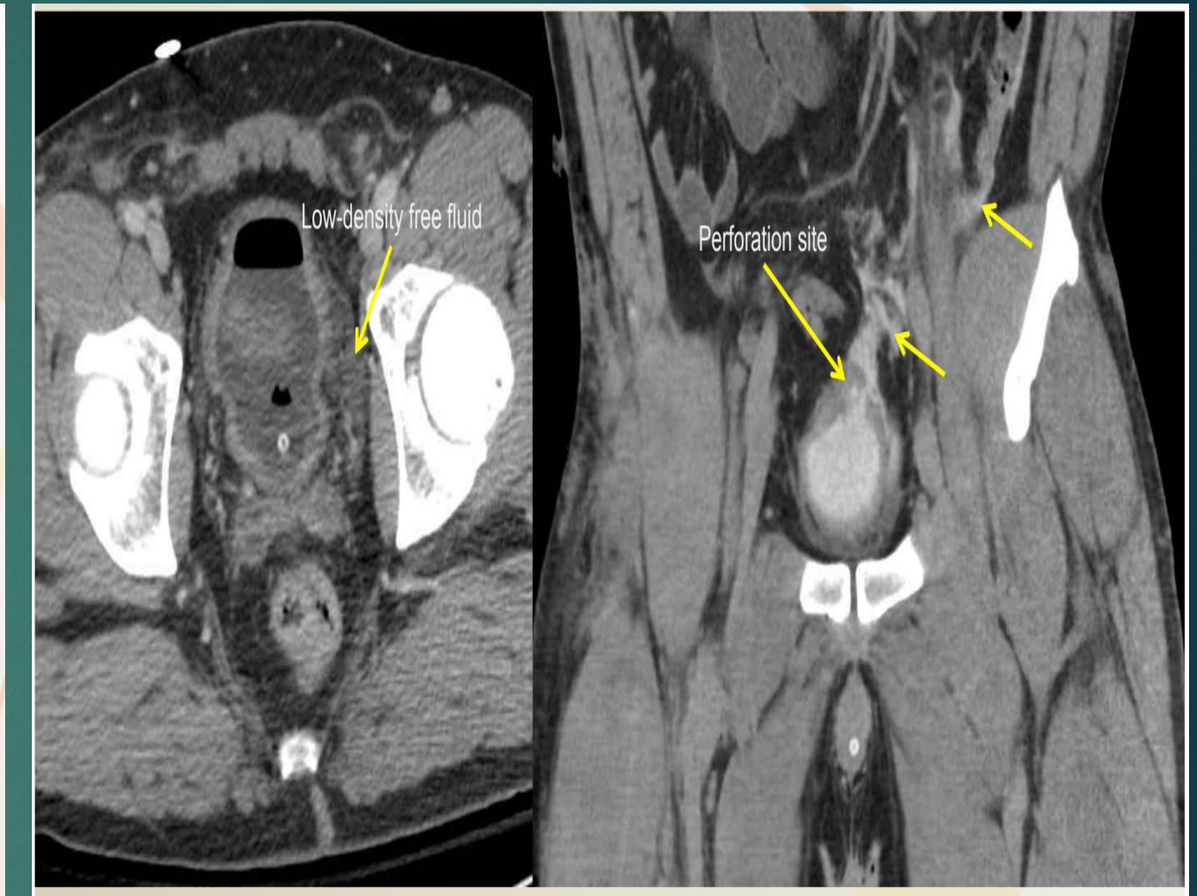
Bladder

- The type and extent of bladder injury depends not only on the **external mechanism of injury** but also on the **intrinsic state of the bladder** at the time of injury, that is, whether the bladder was collapse (empty) or distended (full) at the instance of injury .
- Diagnosis of bladder injury on MDCT can be **challenging** if the bladder **is not well distended** at the time of study.
- Decision of performing a **CT cystography** is taken on the basis of **clinical** and **radiological** findings. Presence of **pelvic fractures** is the main determinant. However, even in absence of these if clinical suspicion of bladder injury is present on the basis of findings such **as passage of blood-tinged urine**, CT cystography is performed.
- **Various bladder injuries that can be depicted on CT Cystography include ;**
  - **complete** transmural tear which can either be **intra or extraperitoneal.** Distinction between these is of paramount importance because **intraperitoneal** ruptures are managed **operatively** whereas **extraperitoneal** ruptures can be **conserved** depending on need of surgery for other injuries.
  - Less common injuries **are bladder contusion** and **interstitial injury** which are generally managed **conservatively**





- **Extraperitoneal rupture**
  - Direct perforation by bony fragment, rupture of pubovesical ligament near bladder neck after symphysis injury or contusion of distended UB
  - Often involves anterior bladder wall near neck
  - Conservative Rx



- **Intraperitoneal rupture**
  - More frequently caused by direct perforation of bone fragment (> rupture of distended bladder)
  - Plugged by omentum or bowel loops making it difficult to detect
  - Surgical Rx

Adrenal

- Adrenal gland trauma is present on 1-2% of CT imaging in blunt trauma
- The right adrenal gland is more commonly affected than the left with a ratio of 3-4:1
- Adrenal hemorrhage is the most common injury to the adrenal gland,Laceration of the adrenal gland is less common.

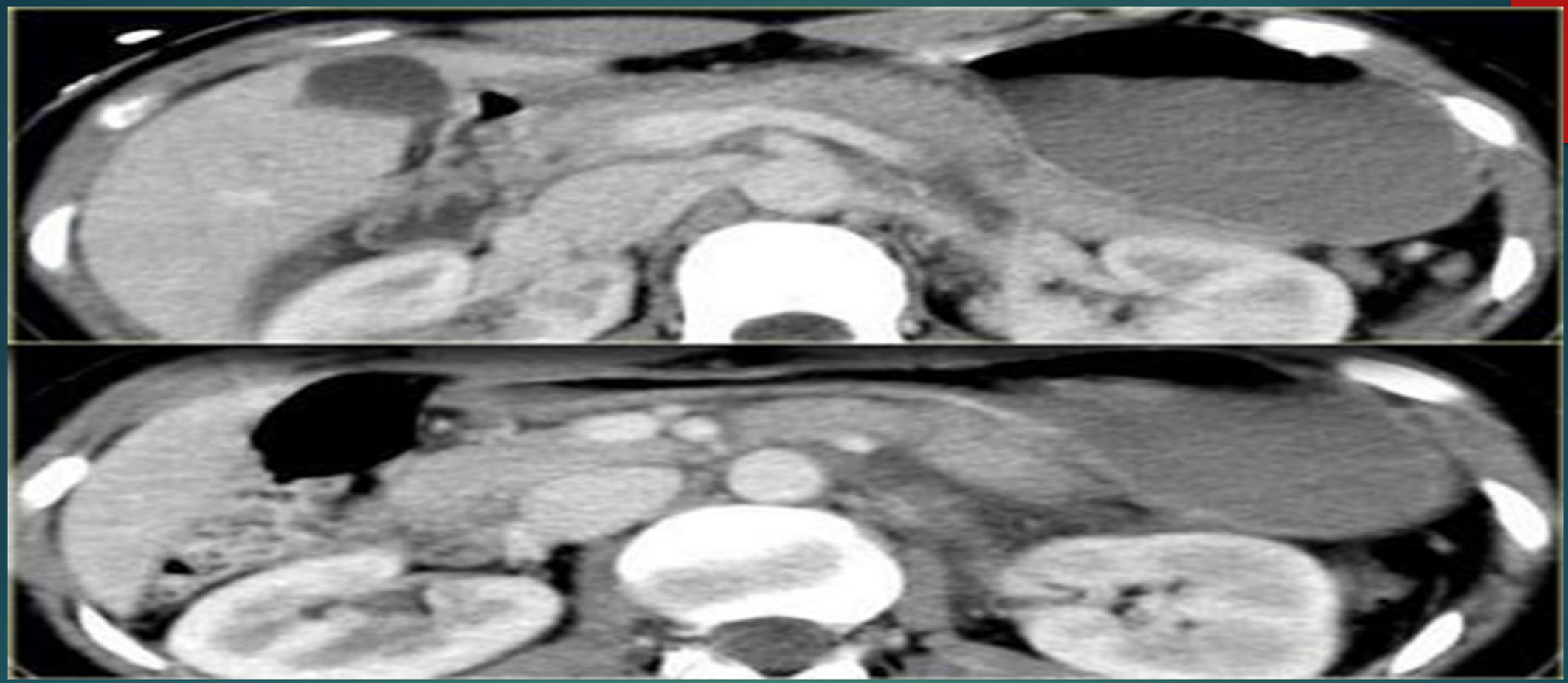
Pancreas

Concerning pancreatic injury the following remarks can be made:

1. **Uncommon** injury with a 0.4% overall incidence.
2. 1.1% incidence in penetrating trauma and only 0.2% in blunt trauma.
3. **Rarely an isolated injury**.
4. Usually **part of a 'package injury'**.
5. **Post-traumatic pseudocyst** formation is common, and probably the most common cause of pancreatic pseudocyst formation in children is trauma.

Vectors of Force - Trauma "Packages"

Right-sided	Midline	Left-sided
R hepatic lobe	Left hepatic lobe	Spleen
R kidney	Pancreatic body	L kidney
diaphragm	Aorta	Diaphragm
pancreatic head	Transverse colon	Pancreatic tail
duodenum	Duodenum	
IVC	Small bowel	

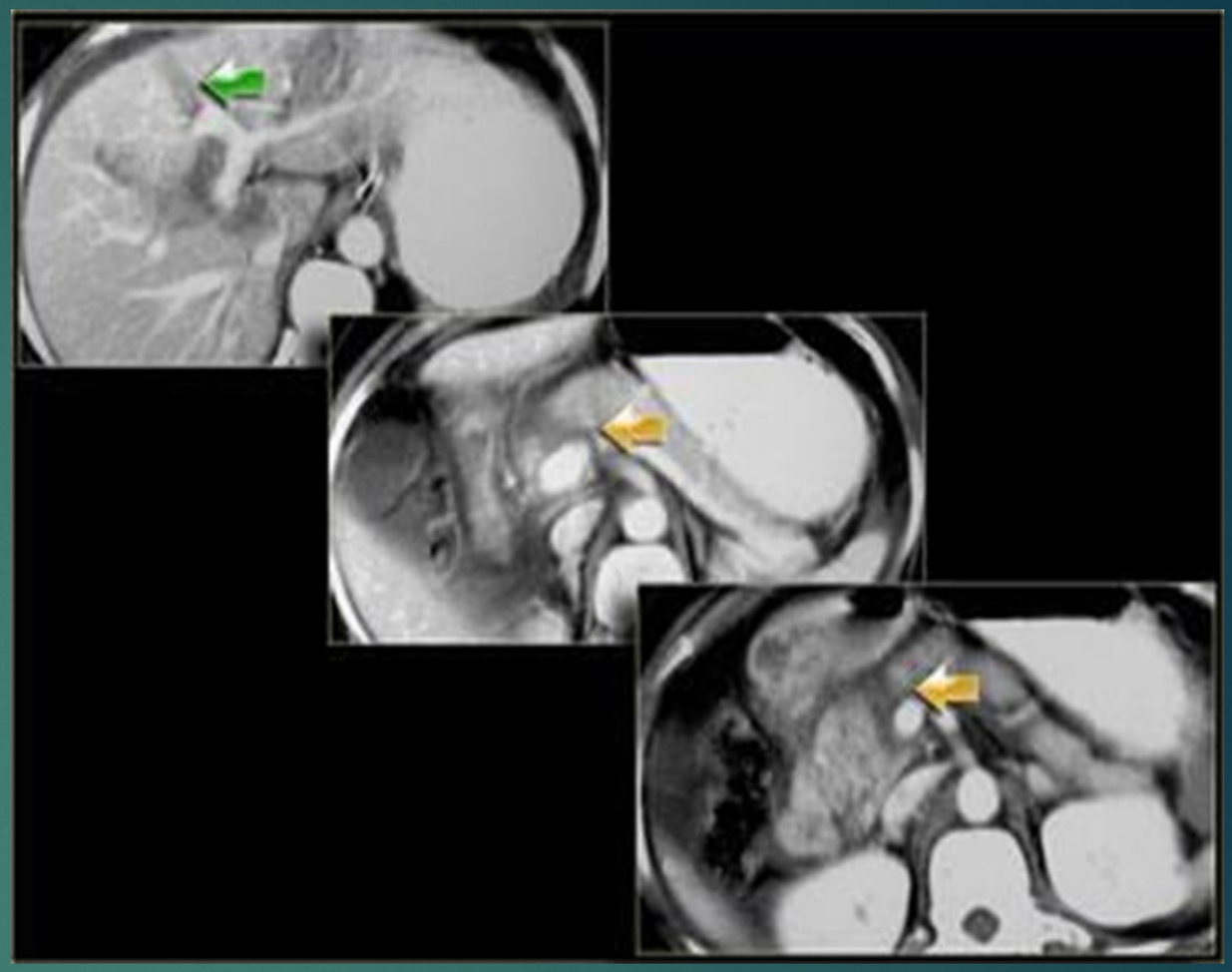


A case of driver who had a car accident.
Vital signs were stable and there was only a mildly tender abdomen.

All the intraperitoneal organs were normal and there was no intraperitoneal fluid.
The only findings were a **vague hypodense area in the pancreatic tail and some fluid behind the pancreas, best seen anteriorly to the left kidney.**

The more common presentation of pancreatic injury is what is seen on this CT .

This is a typical left sided package injury.
There is pancreatic tail injury and also splenic injury, renal injury and pneumoperitoneum.



Right sided package injury involving the pancreas.

There is a right sided package injury.
There is a liver laceration crossing the major vessels associated with a transsection of the pancreas at the junction of the head and the body.
The force must have come from the right anterior side squeezing the liver and the pancreas against the spine.
Sometimes this kind of injury also involves the duodenum.

Diaphragm

Diaphragmatic Injury

Incidence: 1-6% of blunt trauma patients
Incidence: penetrating 2x > blunt
Frequently other injuries (75-100%)
Left > Right
Bilateral 1-5% of cases
Posterolateral most frequent site

Specific signs

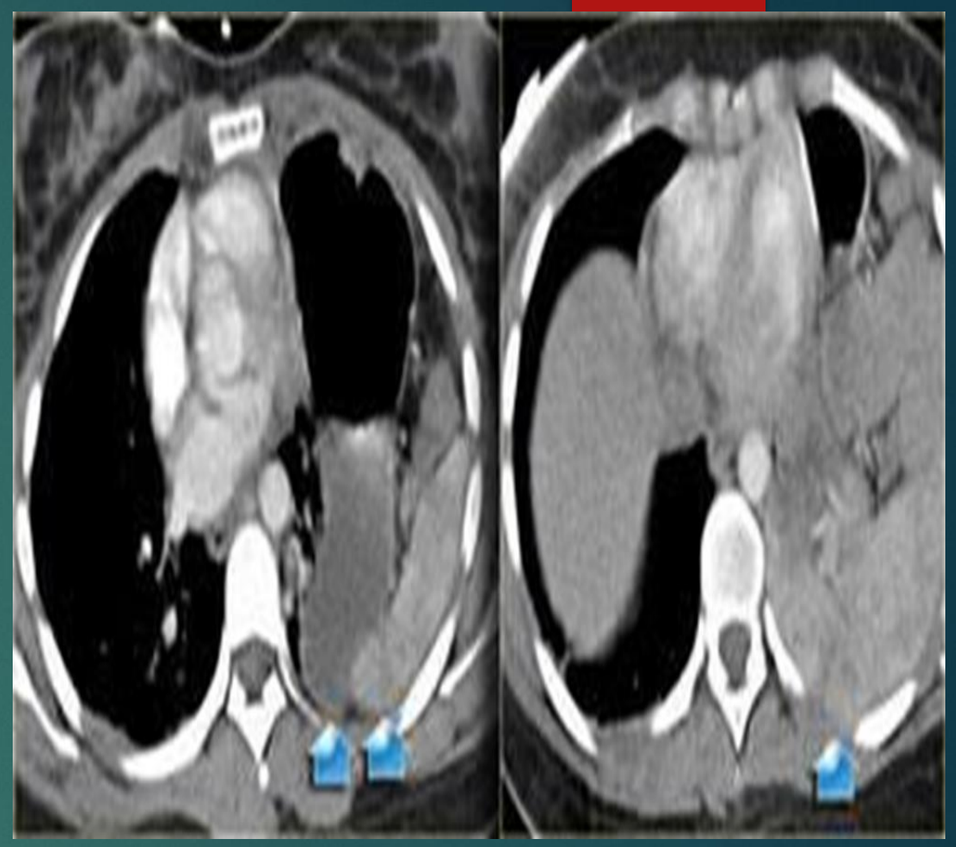
- Herniation of abdominal viscera into thorax
- CT "collar" sign

Non-specific signs

- Discontinuity of the crus
- Thickening of the diaphragm
- "Dependent viscera" sign

CT 'collar' sign

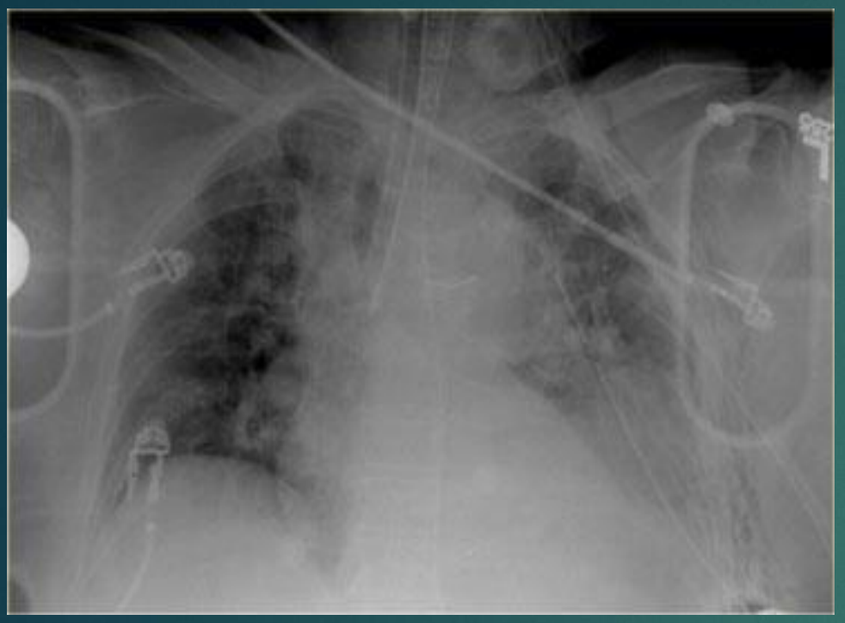
coronal reconstruction demonstrating the 'collar sign', where the stomach passes through the diaphragmatic rupture.



'Dependent viscera' sign

On the left side there clearly is a diaphragmatic rupture with herniation of the stomach. Notice that the stomach and the spleen lie against the posterior thoracic wall, which is abnormal. This is unlike on the right side where the liver is away from the chest wall due to the presence of the diaphragm.

Diaphragmatic injury



chest film of a 79-year old restrained driver who had a car accident. Initially unresponsive at the scene.

He was transferred from an outside hospital after placement of tubes.

The first thing you'll notice is that the tube is in the right main bronchus. Chest tube looks okay.

Nasogastric tube comes down and coils in the stomach.

The superior mediastinum looks widened and indistinct, so this certainly has to be evaluated. In the left lower zone we have an indistinct diaphragmatic border and an opacity.

This could be a lot of things like haemothorax, lung contusion, diaphragmatic rupture or splenic injury.

So based on the chest film we are conceirned about possible aortic injury, pulmonary contusion and injury to the diaphragm, spleenic and left kidney.

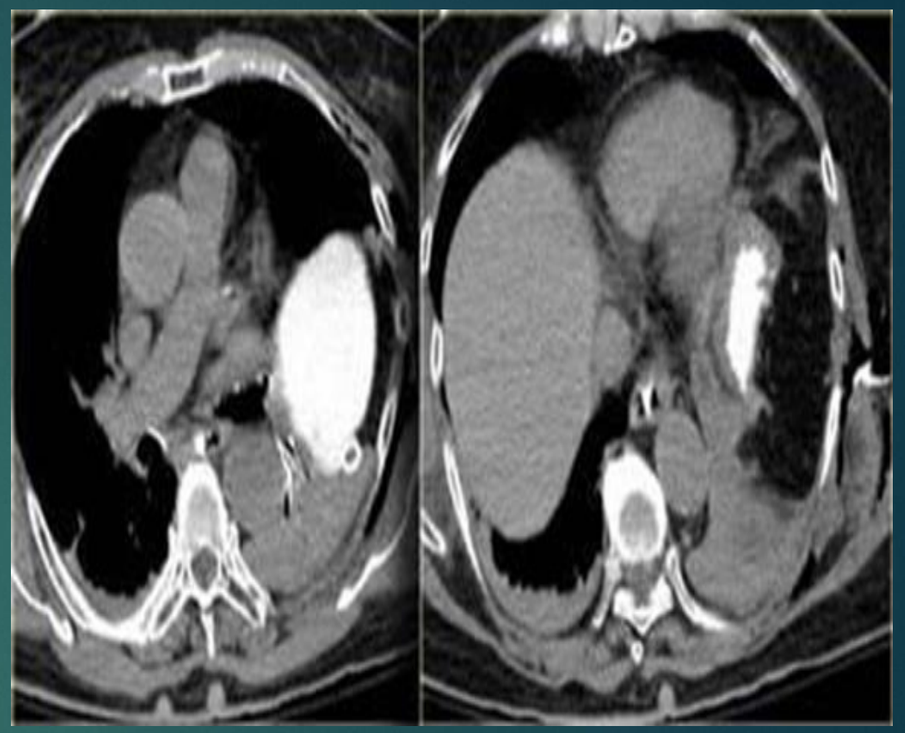
Continue with the CT images.

There is i.v. contrast in the late arterial phase and when we follow the nasogastric tube we will notice that there is no contrast in the stomach.

The most important finding in this case is the area of soft tissue density next to the atelectatic lower lobe of the lung and lateral to it an amount of fat.

This is very suggestive of diafragmatic rupture.

What can we do to get more certainty about this structure?



Since the nasogastric tube is in place, we can administer contrast to the stomach.

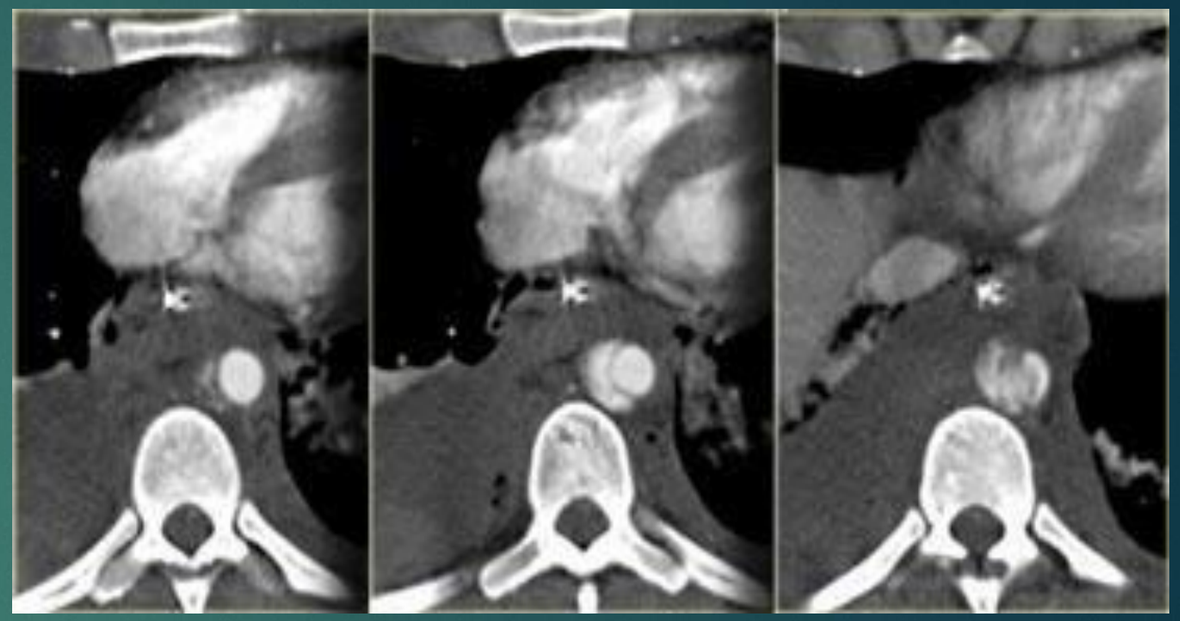
The images on the left prove that the structure is the stomach, which is in a high position.

Secondly there is a waist in the stomach compatible with the 'collar sign'.

These findings are specific for diafragmatic rupture.

Aortic injury

The most common location for injury is the thoracic aorta at the isthmus, because the aorta is fixated there.



unrestrained 22 y.o. male involved in a high-speed motor vehicle accident. He was ejected from the vehicle.
At presentation he was unconscious and intubated with diminished femoral pulses.

The findings are on CECT :

- *Pleural fluid with dependent high attenuation indicating hematothorax.*
- *Contrast blush near the spleen indicating active bleeding.*
- *Bilateral renal infarctions (additional images did show additional infarcts on the right side).*
- *Soft tissue density surrounding the aorta.*

So the questions are:

- What are the diagnostic considerations?
- Does bilaterality of renal infarcts matter?

✓ ***A unilateral renal infarct can be the result of a localized injury.***

✓ ***However when there are multiple bilateral infarcts, we have to think of an embolic source.***

- *Consecutive images of the aorta at the*
- *level of the diaphragm In this patient however the source was a traumatic dissection of the aorta at the level of the diaphragm.*

This is the second most common location for injury to the aorta due to the relative fixation.

Bowel injury

Multiple injuries due to 40 feet fall.

a 44 y.o. male who jumped 40 feet from building onto concrete surface in suicide attempt.
History of treatment for depression BP 90/54. Pale, diaphoretic, confused.
No head injury. Ecchymoses around chest and abdomen. Distended abdomen. Pelvis grossly unstable.
Gross hematuria.

The findings are:

- **Hypoperfusion of the spleen (yellow arrow).**
- **Multiple areas of contrast extravasation (green arrows).**
- **Hemoperitoneum and Pneumoperitoneum.**
- **Multiple segments of bowel with diffuse wall thickening (blue arrow).**

The questions in this patient are:

Is pneumoperitoneum diagnostic of full thickness bowel injury?
What does the diffuse wall thickening of the small bowel suggest?
Given vertical deceleration mechanism, where are bowel injuries most likely to occur?

Pneumoperitoneum

Uncommon finding, not diagnostic

Known causes of false positive (FP)

- › Peritoneal Lavage
- › Foley insertion with intraperitoneal Bladder rupture
- › Translocation from thorax (PTX)

Oral CM and re-scan

- › if surgery is not immediately necessary

Small Bowel Injury

Diffuse circumferential thickening
- › Hypoperfused "shock" bowel
- › Not direct injury

Focal thickening
- › Usually non-transmural injury

Specific findings, rare
- › OCM or bowel content extravasation
- › Focal bowel wall discontinuity

Most common finding
- › Unexplained non-physiologic free fluid (84%)

Other findings
- › Mesenteric stranding
- › Focal bowel thickening
- › Interloop fluid

If in combination, strongly suggestive

Concerning pneumoperitoneum some important remarks have to be made:

- When bowel injury is present, then **pneumoperitoneum is an uncommon finding**!
- When pneumoperitoneum is present, it is **not diagnostic of bowel injury,** since there are many **false positives and air** transmitted from the chest in pneumothorax is the most common cause of intraperitoneal air in a trauma patient .
- ***jejunum (ligament of Treitz) is the most common site of injury, followed by ileum, colon, rectum, duodenum, and stomach.***

In fact the most common findings in small bowel injury are **non-specific findings** like ***thickening of the bowel wall and unexplained intraperitoneal fluid.***

In the patient that we discussed the diffuse wall thickening was only a result of **hypoperfusion or 'shock' bowel due to the active bleeding.**

Direct injury to the bowel wall usually results in focal thickening and is mostly a non-transmural injury.

It is very uncommon to identify findings that are specific for bowel injury like extravasation of oral contrast or bowel content.
More commonly you will find a combination of intraperitoneal fluid and mesenteric stranding, focal bowel thickening or interloop fluid, that is very suggestive for bowel injury.

Post-traumatic Complications

- After the acute settings of trauma, there are numerous complications in the survivors like **bilioma, urinoma, arterio-venous fistulae, and abscesses.**

- CT is the investigation of choice for follow-up cases. In addition to diagnostic value, CT can guide the therapeutic intervention in these conditions.

REFERENCES

- Radiology assistant available at: https://radiologyassistant.nl/abdomen/acute-abdomen/ct-in-trauma

Accessed at 15-4-2023

- Joshi, A.R., Komwad, A.L. & Joshi, S.A. Role of CT in Abdominal and Pelvic Trauma. Curr Radiol Rep 2, 67 (2014).
- Ahmed, H.M., Borg, M., Saleem, A.EA. et al. Multi-detector computed tomography in traumatic abdominal lesions: value and radiation control. Egypt J Radiol Nucl Med 52, 214 (2021).
- Hassan R, Abd Aziz A. Computed Tomography (CT) Imaging of Injuries from Blunt Abdominal Trauma: A Pictorial Essay. Malays J Med Sci. 2010 Apr;17(2):29-39

Thank You

Questions?