MODERN RADIOLOGY eBook

Emergency Radiology

EUROPEAN SOCIETY OF RADIOLOGY

Preface

Modern Radiology is a free educational resource for radiology published online by the European Society of Radiology (ESR). The title of this second, rebranded version reflects the novel didactic concept of the ***ESR eBook*** with its unique blend of text, images, and schematics in the form of succinct pages, supplemented by clinical imaging cases, Q&A sections and hyperlinks allowing to switch quickly between the different sections of organ-based and more technical chapters, summaries and references.

Its chapters are based on the contributions of over 100 recognised European experts, referring to both general technical and organ-based clinical imaging topics. The new graphical look showing Asklepios with fashionable glasses, symbolises the combination of classical medical teaching with contemporary style education.

Although the initial version of the ***ESR eBook*** was created to provide basic knowledge for medical students and teachers of undergraduate courses, it has gradually expanded its scope to include more advanced knowledge for readers who wish to 'dig deeper'. As a result, *Modern Radiology* covers also topics of the postgraduate levels of the *European Training Curriculum for Radiology*, thus addressing postgraduate educational needs of residents. In addition, it reflects feedback from medical professionals worldwide who wish to update their knowledge in specific areas of medical imaging and who have already appreciated the depth and clarity of the ***ESR eBook*** across the basic and more advanced educational levels.

I would like to express my heartfelt thanks to all authors who contributed their time and expertise to this voluntary, non-profit endeavour as well as Carlo Catalano, Andrea Laghi and András Palkó, who had the initial idea to create an ***ESR eBook***, and - finally - to the ESR Office for their technical and administrative support.

Modern Radiology embodies a collaborative spirit and unwavering commitment to this fascinating medical discipline which is indispensable for modern patient care. I hope that this ***educational*** tool may encourage curiosity and critical thinking, contributing to the appreciation of the art and science of radiology across Europe and beyond.

Minerva Becker, Editor

Emergency Radiology

CHAPTER OUTLINE:

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Emergency Radiology

CHAPTER OUTLINE:

MODERN RADIOLOGY eBook

Based on the ESR Curriculum for Radiological Education

Emergency Radiology

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CHAPTER OUTLINE:

Chapter Outline

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Principles of Emergency Radiology

CHAPTER OUTLINE:

/ Principles of Emergency Radiology

It takes the effort of several people of different professions to transport, examine conduct diagnostics and treat a patient in an emergency setting. The radiology staff is part of this team and engages in the communication and the decision-making process.

The exchange of information between the various disciplines involved is important to initiate the right diagnostic steps and to choose the appropriate therapy. The radiologist must select an appropriate imaging protocol while ensuring to limit the radiation exposure based on ALARA principles (As Low As Reasonably Achievable)[1].

A focused primary assessment of the scans in an emergency setting followed by the immediate communication of life-threatening imaging findings is crucial.

This chapter will explain the role of various imaging modalities in common emergencies and how to systematically approach and identify critical and important imaging findings expediently that need urgent treatment.

Diagnostic Imaging Techniques

CHAPTER OUTLINE:

/ Diagnostic Imaging Techniques

Choosing the appropriate imaging technique is crucial in making the correct diagnosis.

The following factors need to be considered in an emergency setting:

- What are the most relevant differential diagnoses and can I rule them out using the chosen modality?
- What imaging modality is available?
- Is the patient stable enough for the examination?
- Can the patient hold still, is sedation an option?
- Is there an imaging modality with or without less radiation exposure and comparable sensitivity available?

In general, the imaging modalities used in an emergency department are ultrasound, X-ray, Computed tomography (CT) and Magnetic resonance imaging. Of course, technical equipment of the emergency department may vary depending on institution size, location and type of cases treated.

/ Ultrasound

>|< COMPARE

ADVANTAGES:

+ Widely available
+ Low costs
+ Fast
+ Safe
+ Enables bedside imaging
+ Allows visualisation of blood flow
+ Helps to safely place tubes and catheters
+ No radiation exposure
+ Can reduce the use of CT[2]

DISADVANTAGES:

– Operator dependant
– Visualisation can be limited due to meteorism or obesity
– Low reproducibility[2]

<∞> REFERENCE

> see also eBook chapter Ultrasound

CHAPTER OUTLINE:

Typical indications for ultrasound in the emergency room:

Acute cholecystitis, acute appendicitis, ovarian/testicular torsion, vascular pathologies (stenosis, occlusion, aneurysm, venous thrombosis), urinary stasis, free fluid, bleeding (FAST and E-FAST[3], see below for more details), intestinal obstruction, infectious foci in lung parenchyma or abdomen.

FAST and E-FAST

- FAST = focused assessment with sonography for trauma
- E-FAST = extended FAST, additionally assessing for thoracic injuries
- FAST/E-FAST assumes that all clinically significant injuries are associated with haemorrhage in the pleural, pericardial or peritoneal space or with pneumothorax
- FAST includes four basic sonographic views to exclude free fluid:
  - pericardial, perihepatic, perisplenic, pelvic
- E- FAST additionally includes the examination of the thorax anteriorly to assess for pneumothorax and the pleural recesses for haemothorax
- FAST/E-FAST is an important component of trauma algorithms for the initial evaluation of trauma patients

/ X-Ray Imaging

>|< COMPARE

ADVANTAGES:

+ Widely available
+ Low costs
+ Fast
+ Can be used to control the positioning of tubes and catheters[4]
+ Can be used bedside

DISADVANTAGES:

– Radiation exposure
– Patient must hold still
– Limited sensitivity and specificity compared to CT[4]

<∞> REFERENCE

> see also eBook chapter X-Ray Imaging

CHAPTER OUTLINE:

/ Computed Tomography (CT)

>|< COMPARE

ADVANTAGES:

+ Allows the evaluation of multiple organ systems with 1 scan
+ Enables visualisation of pathologies in situations when ultrasound and X-ray are of limited help
+ Contrast medium allows the evaluation of pathologies of vascular structures, parenchyma and soft tissue[5]

DISADVANTAGES:

– Radiation exposure
– Patient positioning, planning, performing and reading the scan takes time
– Higher costs compared to ultrasound and X-ray
– Potential allergic reactions to contrast medium[5]

<∞> REFERENCE

> see also eBook chapter Computed Tomography

CT imaging is widely used in emergency settings. In some cases, only one or two body regions will be scanned, in other cases, for example in polytraumatised patients, a whole-body CT scan will be performed.

<!> ATTENTION

Prior to performing a CT scan, we need to ensure that the additional information we expect from the CT scan outweighs the disadvantage of dose exposure and potential risks related to contrast medium administration.

Furthermore, we need to ensure that no other imaging modality, for example ultrasound or MRI are more appropriate compared to CT. However, in polytrauma the benefits of CT scan outweigh the risk of radiation or contrast agents[6].

Once a CT scan is determined to be the appropriate imaging modality, the following principles need to be considered:

- Discuss the likely and differential diagnoses with the referring doctors
- Consider any potential limitations regarding the scan, for example: can the patient hold their breath, can they hold still and are there any contraindications to contrast medium administration
- Apply the most appropriate CT protocol
- Limit the scan to the body region of interest

Choosing the Appropriate CT Protocol

NON-CONTRAST ENHANCED SCANS FOR:

- intracranial haemorrhage
- elevated intracranial pressure
- pulmonary infections
- fractures
- sinusitis
- hollow organ perforation
- renal colic
- spinal, pelvic and complex skeletal trauma

CONTRAST ENHANCED SCANS FOR:

- vascular pathologies (dissection, stenosis, aneurysms, bleeding, pulmonary embolism)
- abdominal infections
- soft tissue infections (for example abscess or empyema)
- penetrating or blunt trauma
- polytrauma patients
- bowel obstruction

/ Magnetic Resonance Imaging (MRI)

>|< COMPARE

ADVANTAGES:

+ Excellent visualisation of the central nervous system (brain, spinal cord)
+ Excellent visualisation of soft tissue (abdominal parenchymal organs, muscles, fat tissue)
+ Excellent visualisation of bone involvement in soft tissue infections
+ No radiation exposure[7, 8]

DISADVANTAGES:

– Limited availability in emergency departments
– Long examination duration
– Higher costs compared to ultrasound, X-ray and CT
– Potential allergic reactions to contrast medium
– Contraindicated in patients with certain medical implants or metallic foreign bodies[7, 8]

<∞> REFERENCE

> see also eBook chapter Magnetic Resonance Imaging

Head and Neck Emergencies

CHAPTER OUTLINE:

/ Stroke

If a patient is admitted to the hospital due to symptoms of a stroke, imaging is used to:

- Differentiate between ischaemic and haemorrhagic stroke, localise the pathology, look for signs of increased intracranial pressure
- If ischaemic: look for infarct demarcation, arterial occlusion and collaterals, penumbra and core of the ischaemic area
- If haemorrhagic: look for a potential source of bleeding
- If a stroke is suspected CT and MRI imaging are appropriate imaging modalities

<∞> REFERENCE

> see also eBook chapter Central Nervous System

How to approach the scan

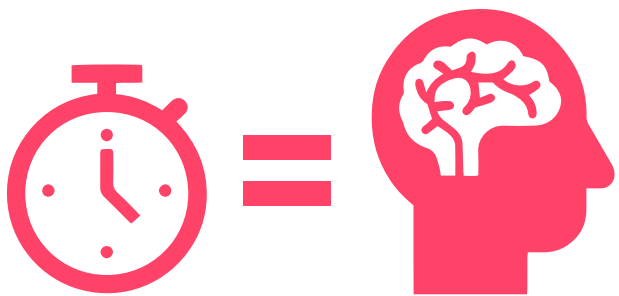
- **First step** is always to rule out cerebral haemorrhage and to clearly communicate the detection or exclusion of a haemorrhage to the treating physicians. This is important because intracranial haemorrhage is a contraindication for intravenous lysis therapy.

  If there are no other contraindications for lysis therapy (for example uncontrolled blood pressure despite intravenous application of antihypertensive medication or a major operation in the current patient history), lysis therapy will be started as quickly as possible.

- **Second step** is to look for hypoattenuating areas of brain parenchyma and for a hyperdense artery sign in CT or for signal alterations on MRI.

<=!> ATTENTION

Remember: **Time is brain**



Detecting hypoattenuating areas in a brain CT can be challenging, these tips might help:

- The symptoms tell you where to look first:

  Patient can't move the left leg and arm > look on the right hemisphere

- Lean back in your chair and reduce the image magnification for a good overview

- Choose a narrow window to enhance contrast, this "stroke window" is often saved as a pre-set on the keyboard, see fig. 1 to compare brain window and stroke window[9]

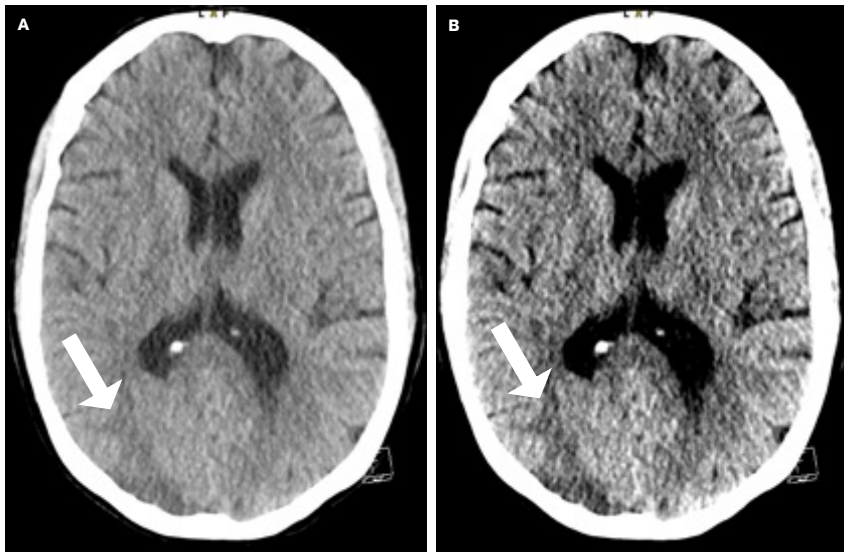


FIGURE 1

Axial image of a head CT scan of a patient with symptoms of a stroke.

A) Brain window pre-set. Right occipital infarct (**white arrow**).

B) Same patient with narrow window settings ("stroke window"). The infarct is better delineated (**white arrow**).

/ Subarachnoid Haemorrhage

- The most common causes of subarachnoid haemorrhage are trauma (> see next page) and aneurysm rupture.
- Depending on the location of an aneurysm the haemorrhage can not only result in subarachnoid but also in intraventricular haemorrhage, see fig. 2 A. & B.
- Saccular aneurysms are most frequently localised in the anterior or posterior communicating artery (35%, respectively), middle cerebral artery (20%) or basilar artery (5%), see fig. 2 B.
- Therapeutic options are endovascular (coils and/or stents, see fig. 2 C.) or neurosurgical (clipping) occlusion of the aneurysm.

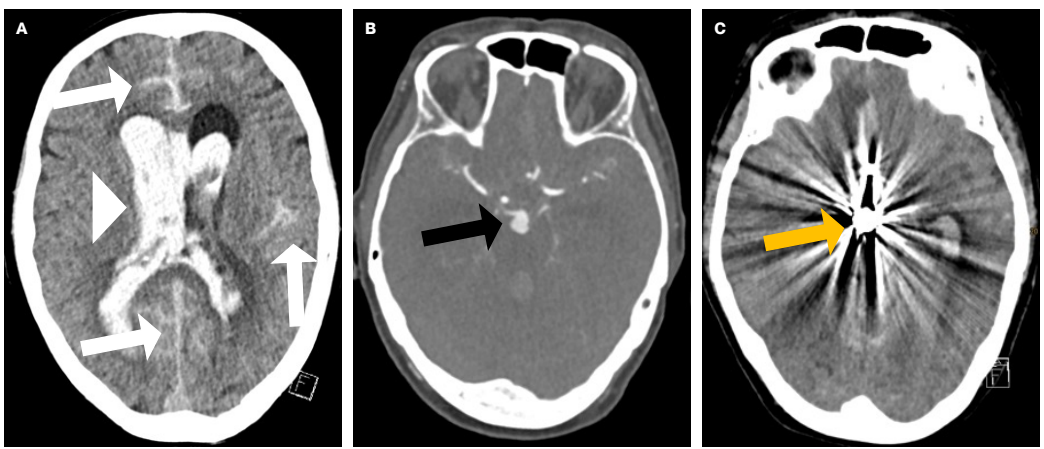


FIGURE 2

Axial images of a brain CT of the same patient.

A) Subarachnoid (**white arrows**) and intraventricular haemorrhage (**white arrowhead**).

B) CT angiography visualising a large aneurysm of the basilar artery (**black arrow**).

C) Control CT four days after endovascular therapy using coils. Note the extensive artefacts caused by the coils in the aneurysmal sac (**orange arrow**).

/ Trauma

If a patient is admitted to the hospital due to suspected traumatic brain injury, imaging is used to identify:

- / Location, size and type of intracranial haemorrhage
- / Signs of increased intracranial pressure
- / Fractures
- / Signs of open traumatic head injury
  > foreign bodies, intracranial gas bubbles

HOW TO APPROACH THE SCAN

Finding small intracranial haemorrhages can be challenging, these tips might help:

- / Look for a subgaleal haematoma first, this is the site of the coup, check for intracranial haemorrhage here.
- / Then look at the opposite site of the skull, this is the contra-coup site, check for haemorrhage here, fig. 3.

FIGURE 3

Domestic fall. The patient has hit his left forehead sustaining a small right frontal subgaleal haematoma. (**asterisk**). This is the site of the coup.

On the opposite side is a small contra-coup occipital subarachnoid haemorrhage (**white arrow**).

CHAPTER OUTLINE:

HOW TO APPROACH THE SCAN

Distinguishing between the different types of intracranial haemorrhage can be tricky, these tips might help:

- Check the coronal reconstruction, subdural haematoma will be formed like a sickle, fig. 4
- An epidural haematoma will have lenticular shape in the axial and the coronal reconstruction, fig. 5. These are commonly associated with skull fracture so look carefully for a fracture
- Subarachnoid haemorrhage will be linear and follow the sulci, fig. 6
- Traumatic intraparenchymal haemorrhage can be round or oval and often shows a hypoattenuating ring, a perifocal oedema, fig. 7
- In many cases you will find more than one type of intracranial haemorrhage[10]

FIGURE 4

Thin subdural haematoma on the left side, marked by a **white arrow**.

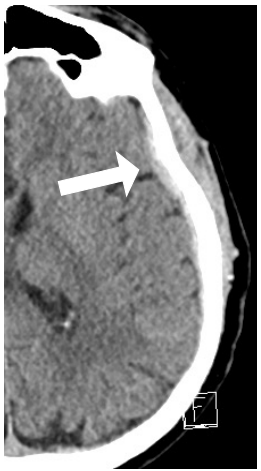


FIGURE 5

Epidural haematoma on the left side **(white arrow)**. There was a fracture adjacent to the haematoma (Not shown on the image).

FIGURE 6

Small subarachoid haemorrhage frontal left **(white arrow)**.

FIGURE 7

Intra-parenchymal haemorrhage left frontal lobe with perifocal oedema **(white arrow)**.

Emergency Radiology

CHAPTER OUTLINE:

/ Infectious Disease

- Common infections in the head and neck region are sinusitis, odontogenic infection, tonsillitis, peritonsillar or laryngeal abscess
- Due to the close anatomical position of the different structures in the head and neck region infectious diseases in this area can cause life-threatening conditions
  - Spread of the infection to the mediastinum, spine or intracranial compartments
  - Airway obstruction
  - Vascular complications (thrombosis, haemorrhage)

>=< FURTHER KNOWLEDGE

https://pubs.rsna.org/doi/full/10.1148/rg.2019190159

FIGURE 8

Young male patient with fever, unable to open his mouth, and dysphagia.

Post contrast neck CT at the level of oropharynx.

Large right tonsillar abscess (**white arrow**).

HOW TO APPROACH THE SCAN

Look for:

- Hypoattenuating muscles (oedema)
- Fat stranding (soft tissue oedema)
- Fluid collections with hyperattenuating ring (abscess)
- Enlarged lymph nodes

Chest Emergencies

CHAPTER OUTLINE:

/ Acute Chest Pain

- Is one of the most common complaints in the emergency department, so have your differential diagnoses at hand, most common DD's are listed in table 1.
- Chest pain can be caused by acute life-threatening and harmless diseases, therefore it is important to exclude diagnoses with the highest short-term mortality risk first: acute coronary syndrome, pulmonary embolism and acute aortic syndrome.
- Symptoms, medical history, physical examination, ECG and laboratory results help to confirm or eliminate acute life-threatening disease[11].

CARDIAC CAUSES	RESPIRATORY CAUSES	OTHER CAUSES
Acute coronary syndrome	Pulmonary embolism	Musculoskeletal
Aortic dissection	Pneumonia	Gastro-oesophageal reflux disease
Pericarditis	Pneumothorax	Anxiety/panic attack
Myocarditis	Pleurisy	–

TABLE 1

Most common causes of acute chest pain[12].

/ Pulmonary Embolism

- / Clinical signs and symptoms are nonspecific, it may be asymptomatic or discovered incidentally
- / Common symptoms: dyspnoea, chest pain, presyncope or syncope or haemoptysis
- / Assessment of clinical pre-test probability: The Wells score and PERC rule are the most validated tools that assist in clinical decision making and are important to limit overuse of imaging[11]
- / Ventilation/perfusion (V/Q) scanning, especially in the presence of a normal chest X-ray, is a more reliable test in pregnancy than in the non-pregnant population as they are generally younger and have fewer comorbidities

>|< COMPARE

ADVANTAGES:

+ CT pulmonary angiography (CTPA) is the method of choice:

  Readily available in most centres, excellent accuracy, may provide alternative diagnosis, short acquisition time

DISADVANTAGES:

– Radiation exposure, exposure to iodine contrast (limited use in iodine allergy and hyperthyroidism, tendency to overuse because of easy accessibility[11, 13]

HOW TO APPROACH THE SCAN

- Check the main pulmonary arteries first to find central thromboembolism, fig. 9
- Then follow the lobar, segmental and then the subsegmental arteries in each lobe for thromboembolism, fig. 11
- Check if the right ventricle has a larger diameter than the left, a sign of right ventricular pressure overload, fig. 10
- Check for other pathologies (pneumonia, pleural or pericardial effusion, pulmonary oedema, etc.)

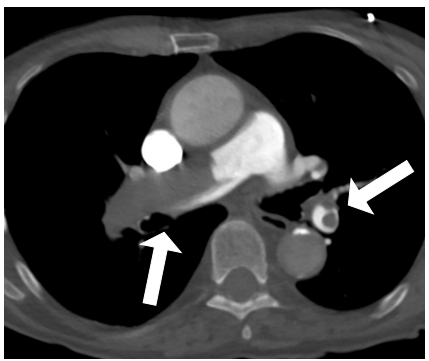


FIGURE 9

Transverse images of a CT pulmonary angiography scan. Extensive pulmonary embolism in the right main pulmonary artery and the left upper lobe artery (**white arrows**).

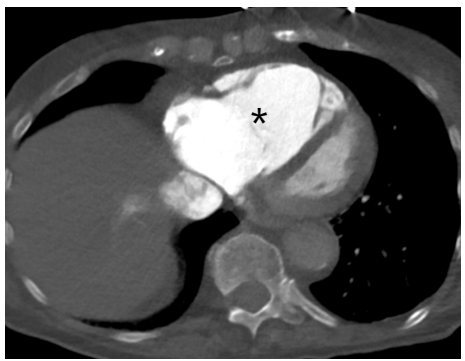


FIGURE 10

Same patient as in fig. 9. The right ventricle (**black asterisk**) is enlarged with mild leftward deviation of the interventricular septum, demonstrating right ventricle pressure overload caused by extensive pulmonary embolism.

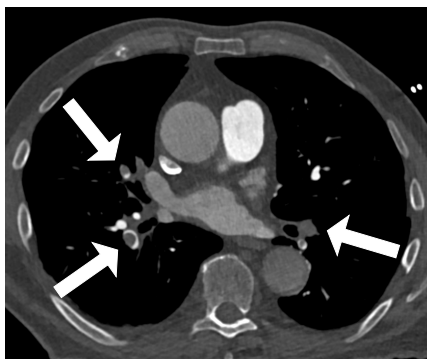


FIGURE 11

CT pulmonary angiography with bilateral segmental pulmonary embolism (**white arrows**).

/ Acute Aortic Syndrome

/ Acute aortic syndrome includes the following pathologies: aortic dissection, intramural haematoma and penetrating atherosclerotic ulcer (PAU).

/ Risk factors: hypertension, genetic disorders (Marfan and Turner syndrome), inflammatory vasculitis, infective arteritis, iatrogenic factors (cardiac valve or aortic surgery), pregnancy.

CT-IMAGING

/ It is important to perform a non-enhanced and a contrast enhanced scan. The non-enhanced scan helps to visualise a hyperdense, thickened aortic wall in case of an intramural haematoma[11] (fig. 12).

/ We perform the CT using ECG gating to avoid moving artefacts in the ascending aorta caused by the beating heart, compare fig. 13 a) and b).

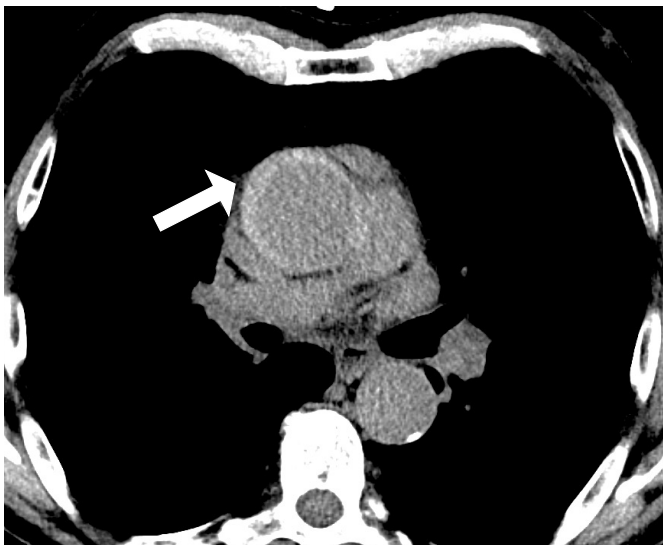


FIGURE 12

Non-contrast enhanced, ECG gated CT thorax. Hyperdense intramural haematoma of the ascending aorta, marked by a white arrow.

<!> ATTENTION

Life-threatening complications of aortic dissections include organ ischaemia (abdominal, see fig. 14, limb, myocardial, brain), aortic rupture and pericardial tamponade[11]

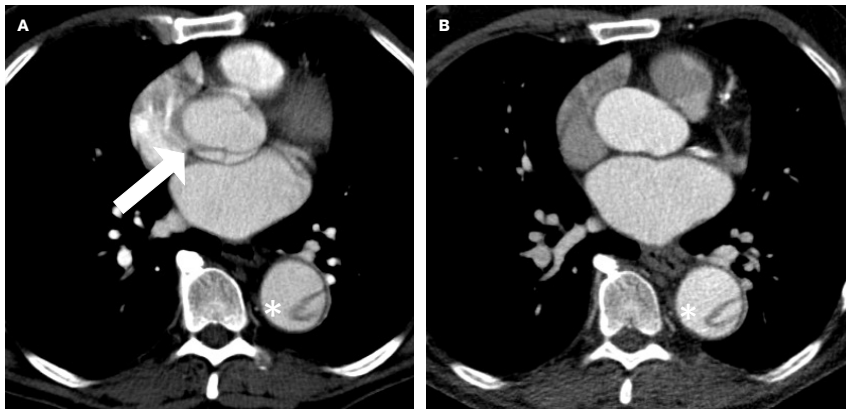


FIGURE 14

A) Non ECG gated CT scan of the thoracic aorta. The white arrow marks artefacts in the ascending aorta. Note the dissection in the descending aorta (**asterisk**).

B) Same patient as in figure 13 a) ECG gated CT scan eliminates the artefact in the ascending aorta.

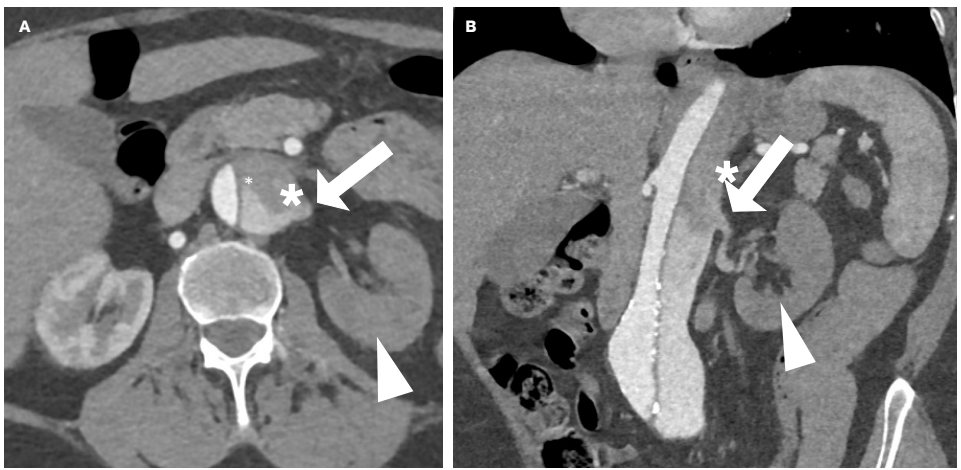


FIGURE 13

Transverse (**A**) and coronal (**B**) image of CT angiography of a patient with Stanford A dissection. The left renal artery (**white arrow**) originates from the false lumen (**asterisks**) and thus the perfusion of the left kidney (**white arrowhead**) is significantly reduced. The right renal artery arises from the true lumen and the right kidney enhances regularly.

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CHAPTER OUTLINE:

HOW TO APPROACH THE SCAN

- First check the non-contrast scan for a crescent hyperdense area (= intramural haematoma), it can be subtle, fig. 12
- Then check the contrast enhanced scan for a hypodense line (= intimomedial flap) within the aortic lumen. Aortic dissection is classified as Stanford A (involving the ascending aorta, fig. 15) or Stanford B (distal to the left subclavian artery)
- The intimomedial flap separates the aortic lumen in 2 parts: true lumen (= normal lumen) and false lumen (= pathologic lumen within the wall)

Check if you can trace the intimomedial flap to

- The coronary arteries
  > this can cause myocardial ischaemia
- To the supracoronary arteries
  > this can cause a stroke
- To the abdominal aorta and the visceral branch vessels
  > this can cause abdominal organ ischaemia[11], fig. 14

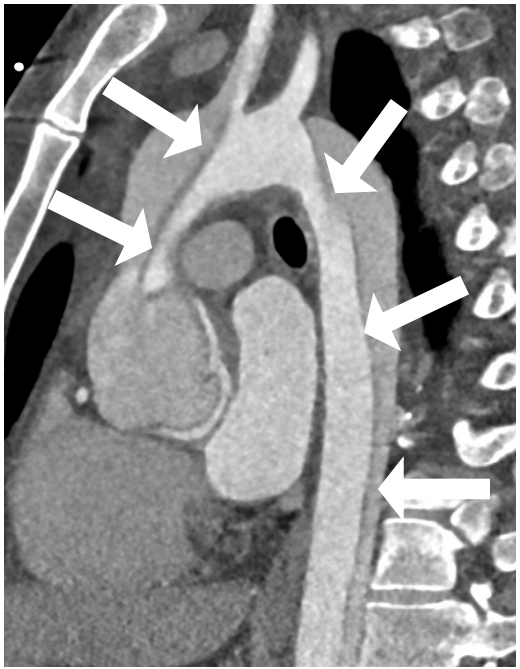

FIGURE 15

Contrast enhanced CT thorax in arterial phase, sagittal image. Stanford A aortic dissection extending from aortic valve to the descending aorta. The intimomedial flap is marked by white arrows.

/ Pneumothorax

- Imaging modality of choice in case of suspected pneumothorax is an X-ray
- Severely injured patients will get a CT scan to simultaneously check for injuries of the vessels, mediastinum, lung parenchyma, bones and pleural space
- Pathophysiology: gas collection within the pleural space
- A tension pneumothorax occurs if intrapleural gas accumulates progressively, the mediastinal shift compromises the blood flow to the heart. A tension pneumothorax is an emergency clinical condition > immediate recognition, communication and therapy are very important[11]

HOW TO APPROACH THE SCAN

- Check if you can see fine vessels in the periphery of both lungs
- Check if you can detect a very fine hyperattenuating line = visceral pleura
- Check if you see a radiolucent area peripheral to the pleural line
- Check if the mediastinum is moved to the other side and if the diaphragm is flattened > tension pneumothorax [11], figure 16

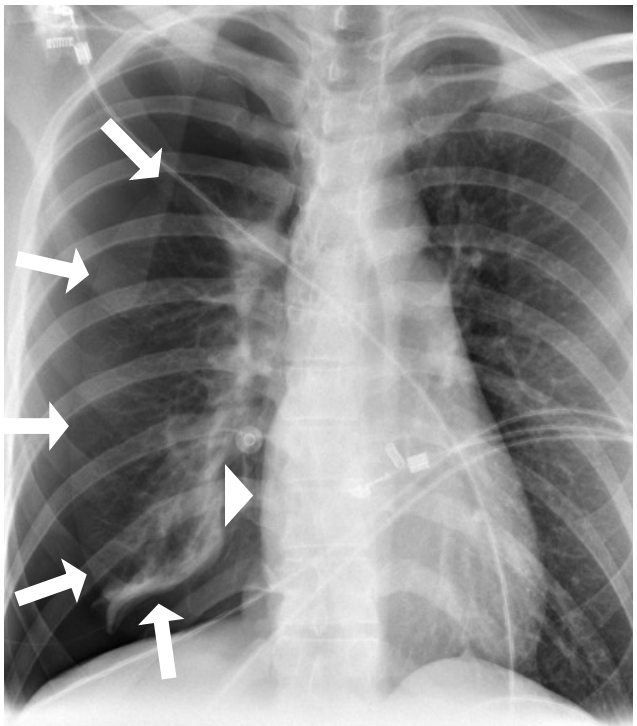

FIGURE 16

Tension pneumothorax. White arrows mark the visceral pleural edge on the right side. Note that the right heart contour is pushed to the contralateral side (**white arrowhead**) and the right side of the diaphragm is pushed downward and flattened.

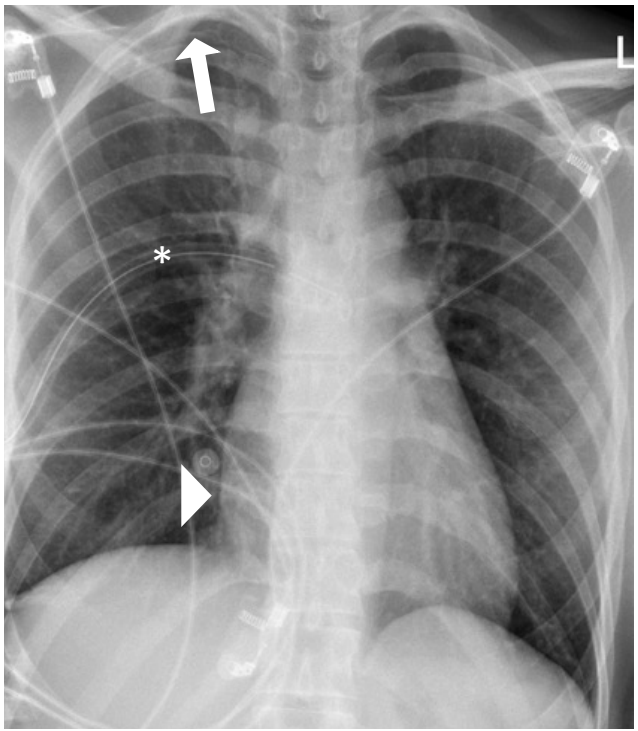

FIGURE 17

Same patient as in fig. 16, after placement of a chest drain (**white asterisk**) the mediastinum (**white arrowhead**) and right diaphragm contour and position are now normal. A small residual pneumothorax is marked by a white arrow.

CHAPTER OUTLINE:

/ Pneumonia

- / Common symptoms are fever, cough, purulent expectoration and deep chest pain
- / Community-acquired pneumonia (CAP) can be classified into lobar pneumonia, broncho-pneumonia and interstitial pneumonia, imaging features are listed in table 2[11]

LOBAR PNEUMONIA	BRONCHO-PNEUMONIA	INTERSTITIAL PNEUMONIA
Infection of alveoli	Bronchial mucosal inflammation	Infection of pulmonary interstitium
Limited to one segment or lobe	Spreads through the airway into alveoli	Frequently peribronchial lobular tissue involved

TABLE 2

Characteristic imaging features of CAP[11].

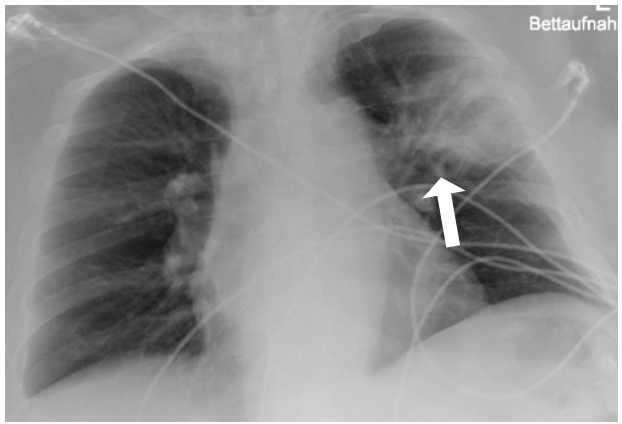

FIGURE 18

Chest X-ray of a patient presenting with a fever and cough. Lobar pneumonia on the left upper lobe (**white arrow**).

HOW TO APPROACH THE SCAN

- / Check for patchy, reticular or homogeneous changes in the lung parenchyma
- / Then check the pattern: one side or both sides involved? More than one lobe involved?
- / Check for parapneumonic effusion

/ Airway and Lung Trauma

/ Trauma to the thorax can be blunt (for example fall from a height or a car accident) or penetrating (for example knife stabbing).

/ We look for bleeding in the lung parenchyma, which can be patchy or homogenously consolidated, for pneumothorax, emphysema of the soft tissues or the mediastinum, haemothorax and active bleeding[11].

HOW TO APPROACH THE SCAN

Check for

/ Air in the pleural space > pneumothorax

/ Air in the soft tissue > emphysema

/ Fluid in the pleural space, if the fluid has increased density > haemothorax, fig. 19

/ Ground glass opacities and consolidation in the parenchyma > bleeding[10], fig. 20

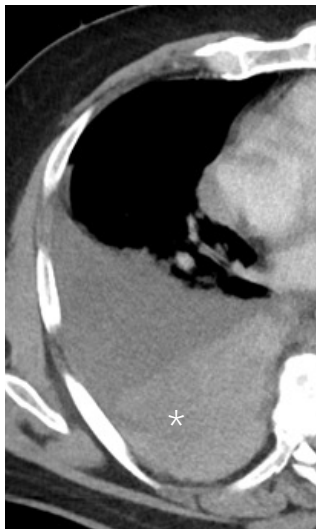

FIGURE 19

Haemothorax with clotted blood (**asterisk**) on the right side in a patient who fell down the stairs.

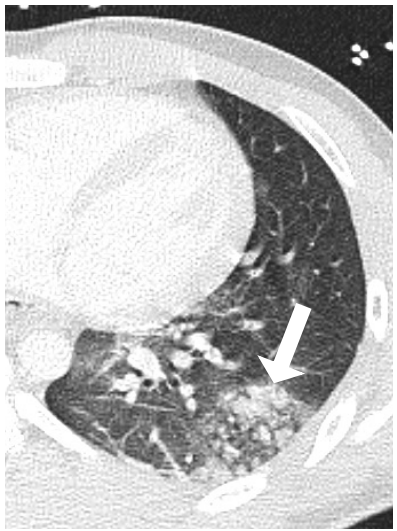

FIGURE 20

Pulmonary haemorrhage in the left lower lobe (**white arrow**) in a young patient who had a motorbike accident.

/ Oesophageal Trauma

- Oesophageal injuries are uncommon, but you should consider a potential oesophageal injury in case of penetrating wounds to the lower neck or mediastinum, following cervicothoracic instrumentation, following forceful retching/vomiting (Boerhaave syndrome) or in case of blunt thoracic trauma.
- The patient's history is very important. A patient with deep chest pain might not report vomiting or a medical procedure such as a gastroscopy.

HOW TO APPROACH THE SCAN

Check for

- Air in the mediastinum
  > be aware that the air could originate from the airways as well
- Check if the oesophageal wall is oedematous
- Check for fluid in the mediastinal fat surrounding the oesophagus[10]

- Oesophageal injury can result in mediastinitis and abscess formation, hence important to diagnose and treat early[11].

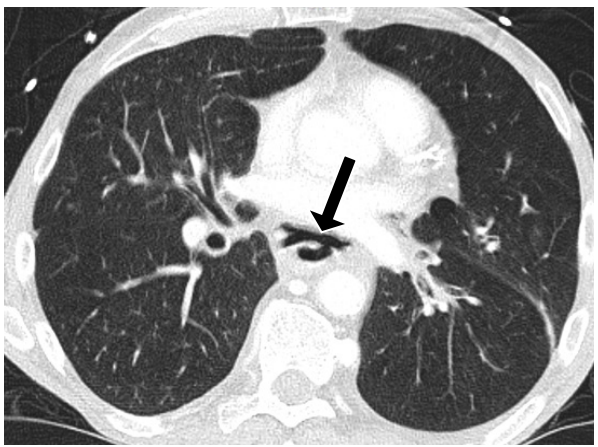

FIGURE 21

Pneumomediastinum (**black arrow**) in a patient who presented with deep chest pain 24 hrs post gastroscopy.

Abdominal Emergencies

CHAPTER OUTLINE:

/ Acute Abdomen

/ Is a frequent reason for consultation in the emergency department.

/ Various conditions can cause an acute abdomen and it is important to know the potential differential diagnoses.

/ Fig. 22 and table 3 demonstrate the most common differential diagnoses in relation to pain localisation.

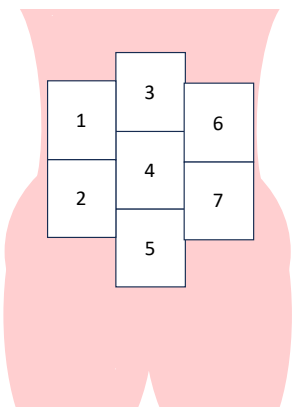

FIGURE 22

Schematic drawing of localisations of the differential diagnoses discussed in table 3.

1	/ Cholecystitis, choledocholithiasis, cholangitis / Hepatitis, liver abscess, pancreatitis / Pyelonephritis / Basal pneumonia, myocardial infarction
2	/ Appendicitis, bowel obstruction, inflammatory bowel disease, infectious enteritis, hernia / Adnexitis, ectopic pregnancy, gonadal torsion / Kidney stones
3	/ Appendicitis (early stage), gastritis, duodenal ulcer, oesophagitis / Pancreatitis
4	/ Appendicitis (early stage), gastroenteritis, enterocolitis, bowel obstruction
5	/ Bladder infection, acute bladder retention / Gonadal torsion
6	/ Pancreatitis / Gastritis / Pyelonephritis / Basal pneumonia, myocardial infarction
7	/ Acute diverticulitis / Adnexitis, ectopic pregnancy, gonadal torsion / Kidney stones

TABLE 3

Common differential diagnoses of an acute abdomen.

CHAPTER OUTLINE:

/ -itis

/ If the patient's history, clinical examination and the laboratory results indicate an abdominal inflammation there are many differential diagnoses to be considered, the location of the pain gives important information, see fig. 22 and table 3.

/ **In an acute setting a CT of the abdomen in the portal venous phase is the imaging protocol of choice.**

/ Important CT findings are such as free fluid, stranding of the abdominal fat tissue, wall thickening of bowel/ bladder/ gallbladder, will lead you to the organ inflamed, fig. 23.

FIGURE 23

Patient presented with severe lower right abdominal pain, fever and elevated inflammation parameters.

CT abdomen in portal-venous phase confirms acute appendicitis - enlarged and oedematous appendix (**white arrow**) with surrounding fat stranding (**asterisk**) and a small amount of adjacent free fluid (**white arrowhead**).

/ Hollow Organ Perforation

- / Ulcer, inflammation, ischaemia, tumour or gastro-intestinal instrumentation can result in perforation.
- / The patient's history can assist in identifying an aetiology.
- / Free abdominal gas is normal in the first days after abdominal surgery.
- / X-ray of the abdomen can be performed in an erect or in a lateral decubitus position, but small amounts of free abdominal gas can be missed using X-ray.
- / Using CT very small amounts of free gas as well as the origin of the free gas can be detected, fig. 24 A. and B.

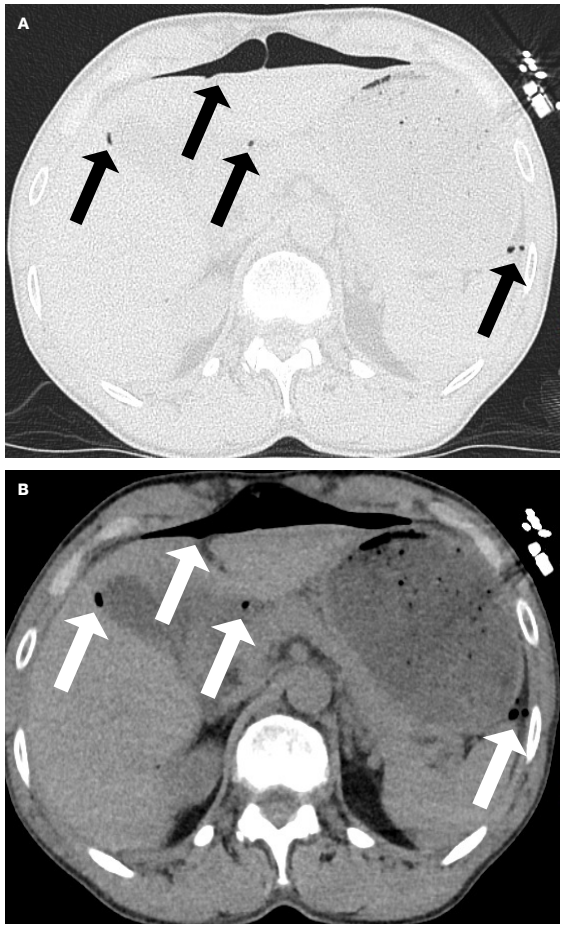

FIGURE 24

The patient presented with acute epigastric pain and guarding on examination.

A CT scan of abdomen in lung window (**A**) and soft tissue window (**B**) shows a large amount of free intra-peritoneal gas (**black and white arrows**).

At surgery a perforated gastric ulcer was found.

/ Bowel Obstruction

- Common causes in the small bowel obstruction are adhesions or hernia and in the large bowel malignancy or volvulus. Inflammatory/ anastomotic strictures can be seen in small and large bowel obstruction.
- Imaging is important to differentiate it from an adynamic ileus and to find the location of the mechanical obstruction, fig. 26.

HOW TO APPROACH THE SCAN

- Think of it as a traffic jam: the roads are crowed up to the point where the accident happened and beyond the accident the road is empty = the bowel will be dilated and filled up to the point of the obstruction and collapsed beyond that.
- To find the obstruction you must follow the dilated bowel from oral to aboral.

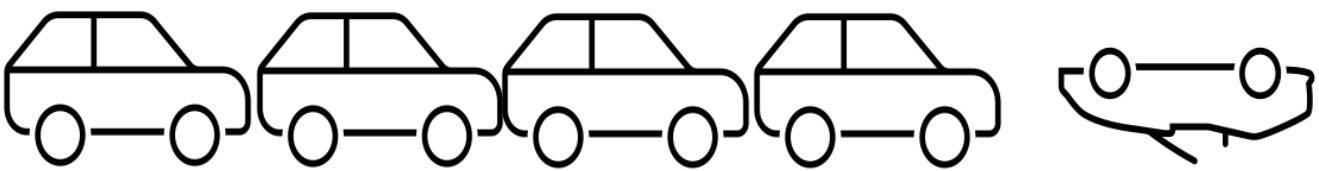

FIGURE 25

Schematic drawing of a traffic jam. Beyond the accident the road is empty.

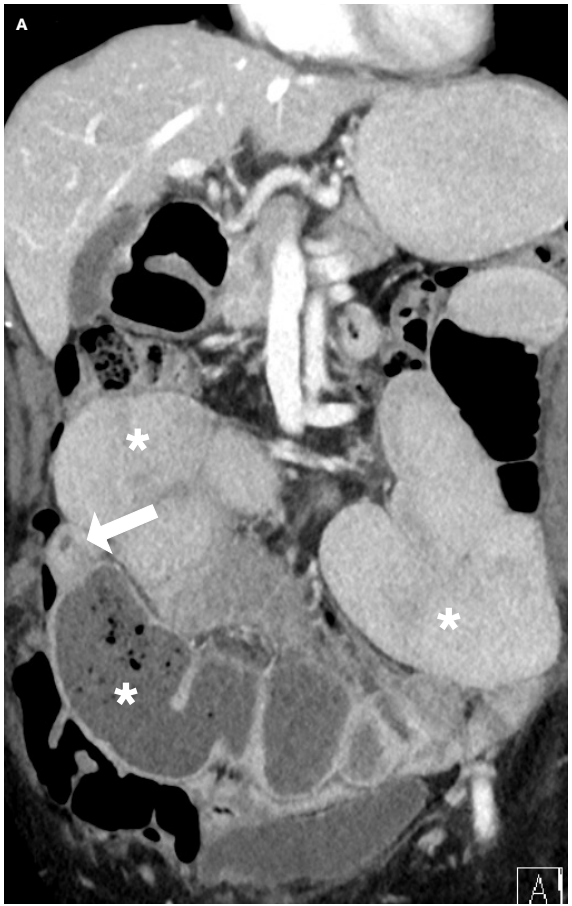

FIGURE 26

The patient had a history of hemicolectomy for ascending colon carcinoma. CT scan of abdomen (**A**) transverse and (**B**) coronal images show dilated bowel loops (**asterisks**) and a transition point (**white arrow**) with collapsed loops distally. Diagnosis of bowel obstruction caused by an adhesion was confirmed during operation.

CHAPTER OUTLINE:

/ Bowel Ischaemia

- It can be caused by arterial embolism (e.g. caused by atrial fibrillation), arterial thrombosis (caused by arteriosclerosis), venous thrombosis (e.g., hypercoagulation disorders) or nonocclusive (e.g. use of vasoactive agents).
- Symptoms are often nonspecific with diffuse or periumbilical, constant, severe pain.
- Begins with reversible mucosal ischaemia > irreversible ischaemia > bowel necrosis causing pneumatosis, perforation, peritonitis, and possibly death.
- CT-imaging is important to look for patency of the arteries (arterial phase), patency of the veins and ischaemic bowel wall changes (venous phase)[14].

HOW TO APPROACH THE SCAN

Check if

- the celiac trunk, superior and inferior mesenteric artery are patent
- the mesenteric veins and the portal veins are patent
- the bowel walls are enhancing with contrast media (see fig. 27A.) or not (wall look grey fig. 27B.). Non-enhancing bowel wall looks similar to the fluid inside the bowel loops

TIP: The coronal view gives a better overview of the small and large bowel and makes comparing the contrast enhancement easier

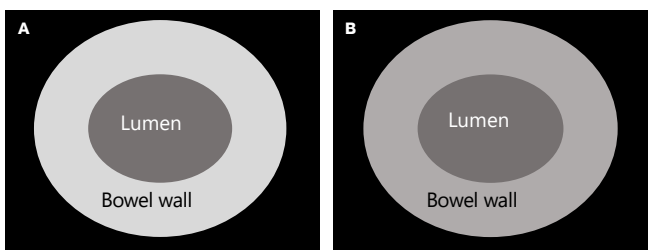

FIGURE 27

A) Schematic drawing of a normal bowel wall enhancement.

B) Schematic drawing of a non-enhancing bowel wall in ischaemic bowel.

/ Emergency Radiology

CHAPTER OUTLINE:

FIGURE 28

CT abdomen in portal venous phase, coronal view, demonstrating normal contrast enhancement and calibre of bowel loops.

FIGURE 29

Different patient. CT abdomen in portal venous phase, coronal view. Ischaemic bowel loops (**asterisks**) lack adequate contrast enhancement and are dilated due to ileus. White arrows mark extraluminal gas caused by focal perforation of ischaemic bowel loops.

CHAPTER OUTLINE:

/ Bleeding

- Can occur anywhere in the body: pleural or peritoneal cavity, intramuscular, subcutaneous, intraparenchymal.
- Can be caused by trauma, blood thinner, operations/interventions, tumours, inflammation, vascular anomalies, coagulopathy in sepsis, congenital coagulopathies.
- For unstable patients CT is the imaging modality of choice; the bleeding protocol includes a non-contrast scan to highlight any pre-existing hyperdense material (calcifications, clips, blood clots etc.), an arterial phase to demonstrate vascular anatomy and contrast extravasation and a venous phase to visualise the increasing contrast extravasation[15].

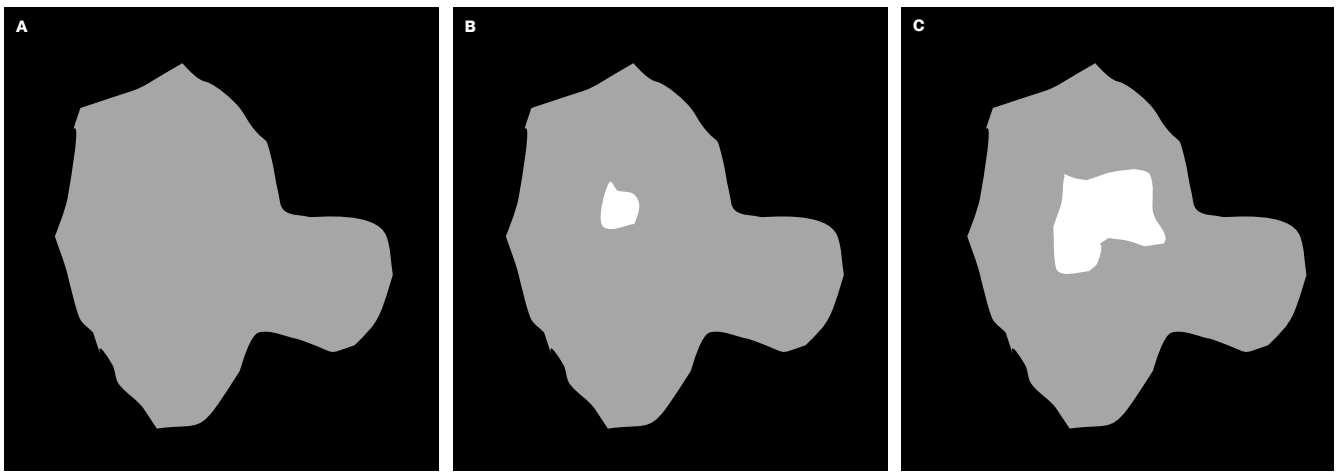

FIGURE 30

Schematic drawing of a haemorrhage in A) a non-contrast scan, B) a scan in arterial phase with arterial extravasation within the haemorrhage and C) in a scan in venous phase showing increasing extravasation within the haemorrhage.

HOW TO APPROACH THE SCAN

- Look for hyperdense blood clots, asymmetry in the soft tissue, fat stranding or blood-filled bowel loops (in case of gastrointestinal bleeding) in the non-contrast scan, see fig. 31 A.
- When you find a haematoma look for contrast extravasation (**white arrow**), which is visualised as hyperdense spots/areas within the haematoma that can't be found in the non-contrast scan, see fig. 31 B., then check if the extravasation becomes larger in size in the venous phase (**white arrowhead**), see fig. 31 C.

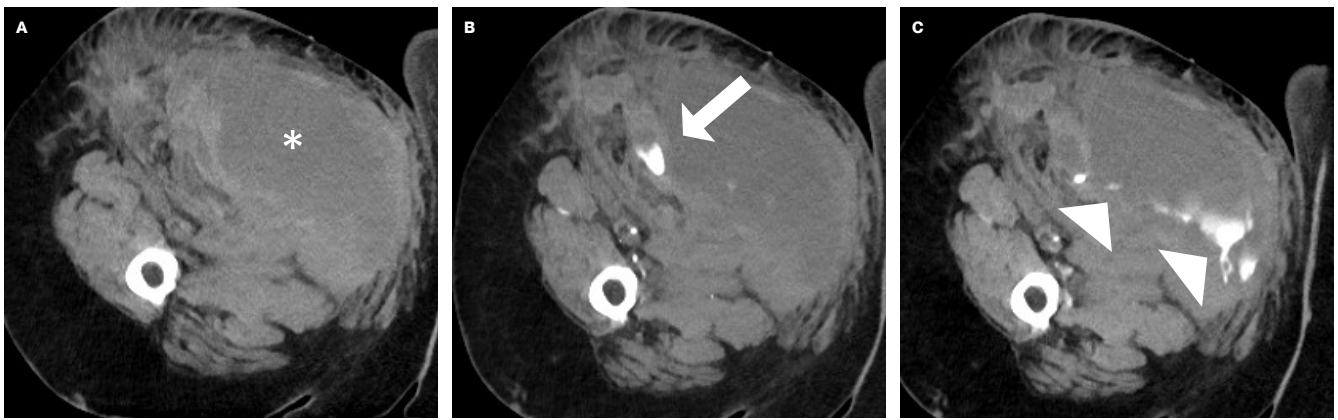

FIGURE 31

Triphasic CT scan of the right proximal thigh with non-enhanced (**A**), arterial phase (**B**) and venous phase scan (**C**). The patient had a massive swelling in the right groin and upper thigh after cardiac intervention. The asterisk marks the haematoma, the white arrow marks the contrast extravasation in the arterial phase and the white arrowheads marks the enlarging contrast extravasation.

Musculo-skeletal Emergencies

CHAPTER OUTLINE:

/ Spinal Trauma

- / 2 important components:
  - / Vertebral body fractures can be detected using X-ray, CT and MRI.
  - / Spinal cord, ligamentous and intervertebral disc injuries are detected using MRI.
- / Most often caused by motor vehicle accidents or fall from a great height.
- / The patho-mechanism can assist in predicting the injuries: we differentiate between compression (fig. 32 A), distraction fig. 32 B) and translation (fig. 32 C) injuries.
- / Spinal cord injury is more likely to occur in distraction and translation injuries.
- / The patients are often seriously injured.

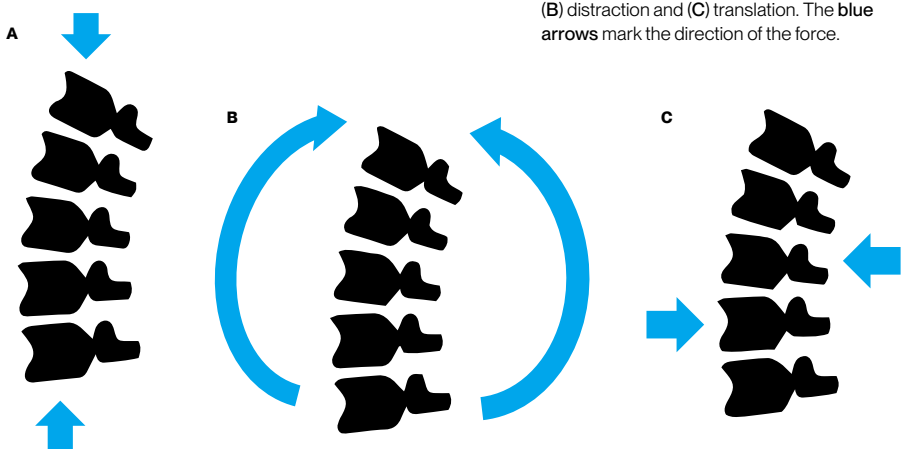

FIGURE 32

Schematic drawing of the three main mechanisms of spinal trauma: (**A**) compression, (**B**) distraction and (**C**) translation. The **blue arrows** mark the direction of the force.

<∞> REFERENCE

> see also eBook chapter Conventional X-Ray Imaging

>▪< FURTHER KNOWLEDGE

Link to the poster of the AO Spine thoracolumbar injury classification system

HOW TO APPROACH THE SCAN

Look for:

- Dislocation or displacement within the vertebral column
- Asymmetric ventral or dorsal gap between the osseous structures
- Fracture lines, dorsal fragments and reduction in height of the vertebral bodies

<!> ATTENTION

In distraction and translation injuries the structures linking the vertebral bodies (ligaments, intervertebral discs) **and** the vertebral bodies are damaged.

FIGURE 33

Sagittal image of a CT scan of an 85-year-old patient who fell on the left hip. Burst compression fracture of L3 (L3: A4 AO spine) is marked by a white arrow. Note previous vertebroplasty of L4 and L5 (**asterisks**).

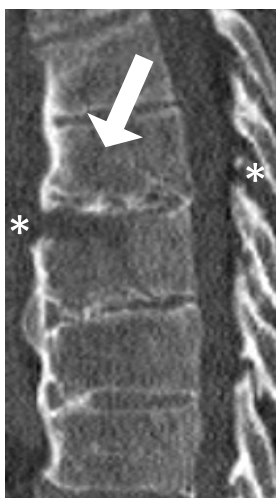

FIGURE 34

Sagittal image of a CT scan of an 80-year-old patient who fell down the stairs. A distraction fracture of Th7/8 (Th7/8: B3, Th8: A2 AO spine) is marked by a white arrow. Note the widening (**asterisks**) ventrally and dorsally caused by the distraction.

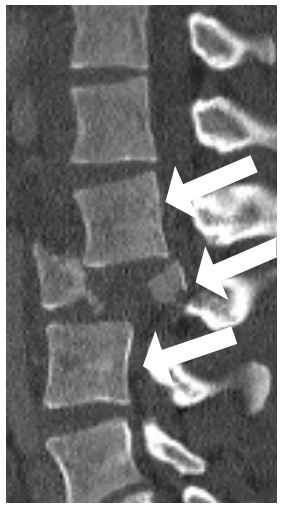

FIGURE 35

Sagittal image of a CT scan of a translation injury of L2-4 (L2-4: C AO spine) (**white arrows**) in a patient involved in a motorbike accident. Note the burst fracture of L3 and the disruption of the posterior vertebral line.

/ Pelvic Trauma

/ The pelvis is a complex ringlike structure composed by bones and ligamentous structures, the interosseous sacroiliac ligaments are the strongest, while the symphysis is the weakest link in the pelvic ring.

/ In young patients, pelvic fractures result from high energy trauma, such as motor vehicle accidents or falls from a height and can be associated with injuries of arteries, veins, the bladder or nerves.

/ In elderly patients, non-displaced pelvic fractures can also result from low-energy trauma or falls[16].

HOW TO APPROACH THE SCAN

/ First, search for fractures in the anterior and posterior pelvic ring and for widening of the pubic symphysis and the sacroiliac joint.

/ Second, look for pelvic and surrounding soft tissue haematomas.

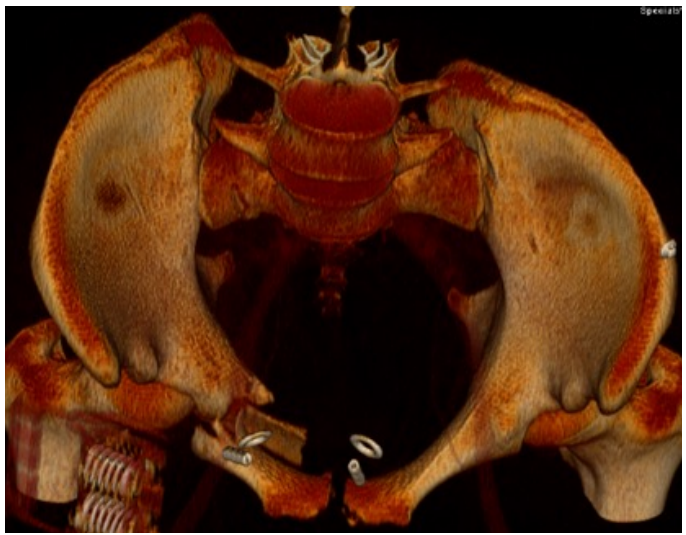

FIGURE 36

3-D reconstruction of a CT scan of a complex, unstable pelvic ring fracture (anterior and posterior ring is injured). The patient was hit by a truck.

/ Spondylodiscitis

- Most of the patients present with back pain, only a few have a fever.
- > 50 % are caused by Staphylococcus aureus.
- Caused by
  - Haematogenous spread secondary to bacteraemia (commonly caused by endocarditis or intravenous drug use),
  - Extension from an adjacent abscess (oropharyngeal infection or sacral decubitus ulcers) or,
  - Direct inoculation after spinal surgery or penetrating trauma.
- Most frequent presentation: single level involvement commonly in the lumbar spine.
- MRI is the imaging modality of choice; sensitivity and specificity are higher compared to CT.

HOW TO APPROACH THE SCAN

- Look for a high signal on T2 sequences and for enhancement on T1 post contrast in the disc space, adjacent endplates and paravertebral soft tissue[17], fig. 37.

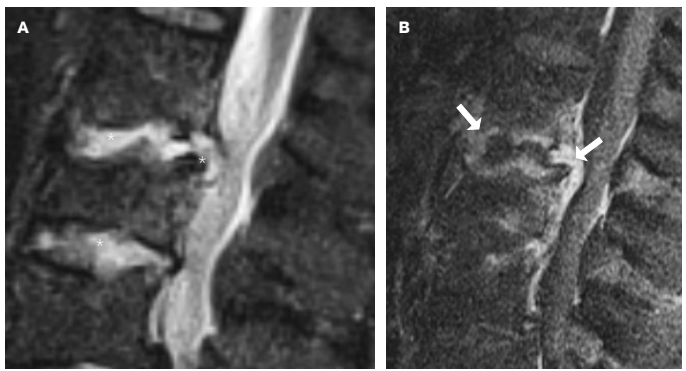

FIGURE 37

MRI scan of a patient with history of intravenous drug use and back pain, diagnosed with spondylodiscitis L1-L3.

A) Sagittal T2 sequence with fat suppression. Asterisks marks fluid signal in the disc and epidural space.

B) Sagittal T1 sequence post contrast with fat suppression. White arrows marks contrast enhancement in the discs, the endplates and epidural space.

Polytrauma

CHAPTER OUTLINE:

/ Polytrauma

= major trauma

<!> ATTENTION

- The definition of "polytrauma/major trauma" has changed over time and different definition exist in the literature. It can be defined based on the Abbreviated Injury Score (AIS) or the Injury Severity Score (ISS). The most pragmatic definition is the following: combination of injuries in different body regions of which at least one or the combination of different injuries is potentially life-threatening[18].
- Polytraumatised patients are evaluated in an inter-disciplinary team in the shock room.
- The extent of imaging depends on the mechanism of injury and the suspected injuries and can include:
  - E-FAST – checking for free fluid and pneumothorax,
  - Polytrauma CT scan – checking for injuries of head, neck, thorax and abdomen,
  - X-ray – checking for injuries of the extremities.
- When reporting on a polytrauma scan it is important to **diagnose first what kills first**: e.g. large intracranial haemorrhage, signs of increased intracranial pressure, spine injury, hemopericardium, injury of large vessels, large pneumothorax, haemothorax, haemo-peritoneum, extensive injury to parenchymal abdominal organs, active bleeding, mispo-sitioning of foreign material [19, 20].

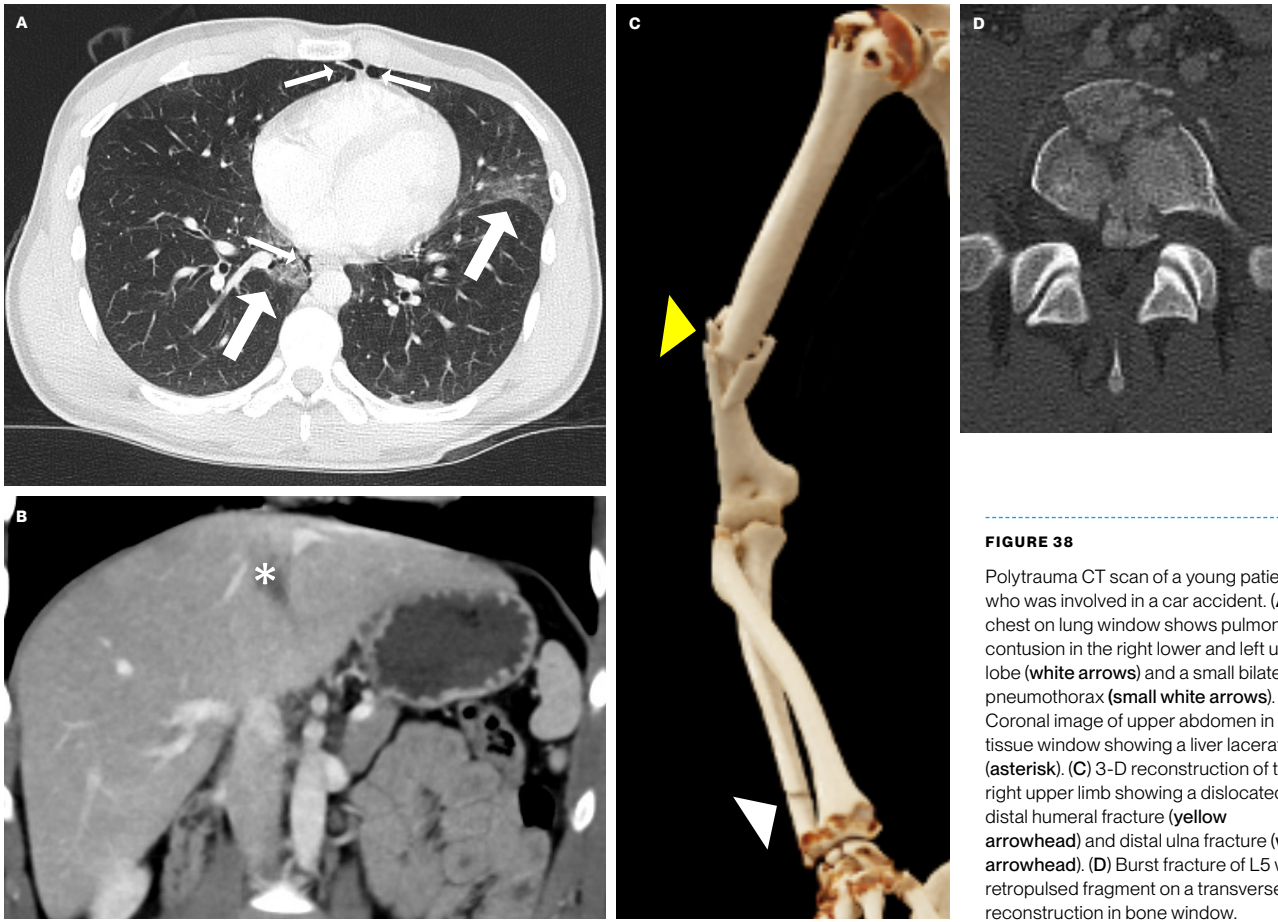

FIGURE 38

Polytrauma CT scan of a young patient who was involved in a car accident. (**A**) CT chest on lung window shows pulmonary contusion in the right lower and left upper lobe (**white arrows**) and a small bilateral pneumothorax (**small white arrows**). (**B**) Coronal image of upper abdomen in soft tissue window showing a liver laceration (**asterisk**). (**C**) 3-D reconstruction of the right upper limb showing a dislocated distal humeral fracture (**yellow arrowhead**) and distal ulna fracture (**white arrowhead**). (**D**) Burst fracture of L5 with retropulsed fragment on a transverse reconstruction in bone window.

CHAPTER OUTLINE:

/ Take-Home Messages

- A detailed patient history, clinical examination and laboratory results are very important in considering which imaging modality is necessary to confirm or exclude the suspected diagnosis.
- Do you need intravenous contrast? Do you need one phase or a multiphasic scan?
- Check for contraindications to intravenous contrast in CT and any absolute contraindications for MRI.
- It is important to communicate critical findings immediately that require urgent treatment and intervention.
- **First look**: look for life-threatening pathologies.
- **Second look**: look for other pathologies and incidental findings.

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Emergency Radiology

CHAPTER OUTLINE:

Test Your Knowledge

CHAPTER OUTLINE:

/ Test Your Knowledge

<?> QUESTION

1 What is a possible respiratory cause for acute chest pain?

- ☐ Pericarditis
- ☐ Pleurisy
- ☐ Acute coronary syndrome
- ☐ Myocarditis

/ Test Your Knowledge

<?> ANSWER

1 What is a possible respiratory cause for acute chest pain?

- ☐ Pericarditis
- ■ Pleurisy
- ☐ Acute coronary syndrome
- ☐ Myocarditis

> see page 24 for further information

/ Test Your Knowledge

<?> QUESTION

2 What is ultrasound used for in an emergency setting?
(Multiple answers might be correct)

- ☐ In a patient with abdominal pain and elevated inflammatory parameters to exclude cholecystitis
- ☐ To exclude free fluid in a polytraumatised patient
- ☐ To look for deep vein thrombosis in a young female patient with dyspnoea and shortness of breath
- ☐ To look for urinary stasis in a patient with colicky abdominal pain

/ Test Your Knowledge

<?> ANSWER

2 What is ultrasound used for in an emergency setting?
(Multiple answers might be correct)

- In a patient with abdominal pain and elevated inflammatory parameters to exclude cholecystitis
- To exclude free fluid in a polytraumatised patient
- To look for deep vein thrombosis in a young female patient with dyspnoea and shortness of breath
- To look for urinary stasis in a patient with colicky abdominal pain

> see page 12 for further information

/ Test Your Knowledge

<?> QUESTION

3 A patient fell and hit his head against a rock. What is the diagnosis?

- ☐ Subdural haematoma
- ☐ Epidural haematoma with skull fracture
- ☐ Intraparenchymal haemorrhage
- ☐ Subarachnoid haemorrhage

/ Test Your Knowledge

<?> ANSWER

3 A patient fell and hit his head against a rock. What is the diagnosis?

- ☐ Subdural haematoma
- ■ Epidural haematoma with skull fracture
- ☐ Intraparenchymal haemorrhage
- ☐ Subarachnoid haemorrhage

/ Test Your Knowledge

<?> QUESTION

4

A 78-year-old male patient is brought to the emergency department. He has a severe abdominal pain, is pale and sweaty and on examination shows abdominal guarding. His blood pressure is 80/50 mmHG. His wife reported to the paramedics that he has a known abdominal aortic aneurysm. Which answer is correct?

- ☐ A ruptured abdominal aortic aneurysm is a likely diagnosis. The patient should undergo MRI imaging to visualise the aortic diameter.
- ☐ A ruptured abdominal aortic aneurysm is a likely diagnosis. Ultrasound ca be used to measure the abdominal aortic diameter und to look for free fluid, while he is undergoing resuscitation.
- ☐ A ruptured abdominal aortic aneurysm is a likely diagnosis. A monophasic CT scan in portal venous phase is the protocol of choice to look for an active bleeding.
- ☐ A ruptured abdominal aortic aneurysm is not a likely diagnosis in this case.

/ Test Your Knowledge

<?> ANSWER

4

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- ☐ A ruptured abdominal aortic aneurysm is not a likely diagnosis in this case.

/ Test Your Knowledge

<?> QUESTION

5 **In a CT scan of a polytrauma patient we want to look for acute life-threatening injuries first. What kind of injury would classify as potentially life-threatening and needs your attention in the initial review of the images?**
(Multiple answers might be correct)

- ☐ Displaced rib fracture with consecutive haemothorax in a patient who was found unconsciousness on the street.
- ☐ Displaced distal radial fracture in a bicycle accident.
- ☐ Abdominal periaortic haematoma in a car accident.
- ☐ Subcutaneous haematoma of the right flank in a patient who fell from a ladder.

/ Test Your Knowledge

<?> ANSWER

5 **In a CT scan of a polytrauma patient we want to look for acute life-threatening injuries first. What kind of injury would classify as potentially life-threatening and needs your attention in the initial review of the images?**
(Multiple answers might be correct)

- [x] Displaced rib fracture with consecutive haemothorax in a patient who was found unconsciousness on the street.
- [ ] Displaced distal radial fracture in a bicycle accident.
- [x] Abdominal periaortic haematoma in a car accident.
- [ ] Subcutaneous haematoma of the right flank in a patient who fell from a ladder.

> see slide 49 for further information

/ Test Your Knowledge

<?> QUESTION

6 Which statement regarding a stroke is correct?

(Multiple answers might be correct)

- ☐ Stroke imaging can be performed using MRI.
- ☐ A non-enhanced CT scan is not necessary if a CT scan with arterial contrast is performed.
- ☐ The clinical symptoms of a stroke can be caused by an intracranial haemorrhage.
- ☐ A CT angiography of the arteries supplying the brain is used to look for arterial vessel occlusions.

/ Test Your Knowledge

<?> ANSWER

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> see page 19 & 20 for further information

/ Test Your Knowledge

<?> QUESTION

7 Which statement regarding spondylodiscitis is correct?

- ☐ All patients are febrile.
- ☐ Back pain is an uncommon symptom.
- ☐ Can be caused by haematogenous spread.
- ☐ Staphylococcus aureus in an uncommon pathogen to cause spondylodiscitis.

/ Test Your Knowledge

<?> ANSWER

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> see page 47 for further information

/ Test Your Knowledge

<?> QUESTION

8 Which is not a common indication for an unenhanced CT scan?

- ☐ Intracranial haemorrhage
- ☐ Sinusitis
- ☐ Active abdominal bleeding
- ☐ Spinal fracture
- ☐ Renal colic

/ Test Your Knowledge

<?> ANSWER

8 Which is not a common indication for an unenhanced CT scan?

- ☐ Intracranial haemorrhage
- ☐ Sinusitis
- ■ Active abdominal bleeding
- ☐ Spinal fracture
- ☐ Renal colic

> see page 16 for further information

/ Test Your Knowledge

<?> QUESTION

9 A patient with sudden onset of a severe headache was admitted to the emergency room. What is the most likely diagnosis in the non-enhanced CT scan of the head shown here?

- ☐ Tumour-related haemorrhage
- ☐ Subarachnoid haemorrhage caused by the rupture of an arterial aneurysm
- ☐ Epidural haematoma caused by a traumatic injury
- ☐ Intraparenchymal haemorrhage caused by hypertension

/ Test Your Knowledge

<?> ANSWER

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> see page 22 for further information

/ Test Your Knowledge

<?> QUESTION

10 What is an advantage of CT imaging?

- ☐ Higher costs compared to ultrasound and X-ray
- ☐ Radiation exposure
- ☐ Potential allergic reactions to contrast medium
- ☐ Contrast medium allows the evaluation of pathologies of vascular structures, parenchyma and soft tissue

/ Test Your Knowledge

<?> ANSWER

10 What is an advantage of CT imaging?

- ☐ Higher costs compared to ultrasound and X-ray
- ☐ Radiation exposure
- ☐ Potential allergic reactions to contrast medium
- ■ Contrast medium allows the evaluation of pathologies of vascular structures, parenchyma and soft tissue

> see page 14 for further information