Radiology in Intensive care: What the radiology residents need to know

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Learning objectives

1. To educate junior radiology trainees in the interpretation of imaging in critically ill patients.
2. To describe and illustrate pertinent radiological examinations in the evaluation of the intensive care unit patient.
3. To discuss the advantages and limitations of various modalities in this scenario.

Background

Radiological imaging is an intrinsic part of the everyday management of the intensive care unit (ICU) patient.

Because of the highly dependent nature of most ICU patients, radiological imaging is generally limited to techniques which can be carried out at the bedside (such as plain radiography and ultrasound scanning (US)), or computed tomography (CT), where transfer is necessary to the radiology department, but where monitoring of the patient is relatively straightforward.

We will describe the indications and typical radiological findings encountered in the ICU setting for the three principal radiological modalities, plain chest radiography, US and CT.

Imaging findings OR Procedure details

Chest radiographs in the intensive care unit patient

It is essential to be able to recognize common pathological appearances on portable chest radiographs in the postoperative or medically ill patient.

Various life-support and monitoring devices may be used in the care of patients in the ICU.

Endotracheal tube:
In an adult, the tip of the tube should be situated approximately 5 cm above the tracheal carina.

The most common serious malpositioning of the ET tube is accidental right main bronchus (Figure 1) intubation.

**Tracheostomy tube**

A chest radiograph should always be performed after tracheostomy to check the correct position of the tracheal cannula.

**Nasogastric tube**

Complications of malpositioned nasogastric tubes include tracheopulmonary intubation, bronchial perforation and pleural cavity penetration leading to pneumothorax. Tube kinking (Figure 2), tube breakage and enteric perforation are other complications.

**Central venous catheters**

Pneumothorax is a common complication of unsuccessful attempts at subclavian or low jugular catheter insertion.

**Atelectasis and consolidation**

Atelectasis (Fig 3) is frequently seen in the postoperative phase. A common cause of consolidation in the postoperative period is acute inflammatory exudate associated with pneumonia.

**Adult respiratory distress syndrome (ARDS)**

Radiographic manifestations include opacification in the lungs, nearly always bilateral, usually diffusely scattered, which may be both central and peripheral in the lungs. Air bronchograms and the absence of pleural fluid are other findings. (Figure 4)

**Pleural fluid**

The classical signs of pleural effusion on erect chest X-ray are blunting of the costophrenic angle (Figure 5), homogeneous opacification of the lung fields with no air bronchograms, meniscus sign and accentuation of the right minor fissure.

**Pneumothorax**
On an erect chest radiograph, free air within the pleural space usually collects at the apex. The sharp white line of the displaced visceral pleura separates the retracted lung from the radiolucent pleural space, which is devoid of lung markings (Figure 6).

Signs of tension pneumothorax include mediastinal and hilar displacement and depression of the ipsilateral hemidiaphragm.

**Ultrasound in the intensive care unit patient**

**Thoracic Ultrasound**

A pleural effusion is depicted as an anechoic or hypoechoic layer between two pleural layers (Figure 7). US can be utilized at the bedside as a real-time imaging technique for thoracocentesis and the placement of pleural drainage catheters.

**Abdominal ultrasound**

US is the first-line investigation to diagnose disorders of the gallbladder and biliary tree. Gallstones are typically echogenic lesions with posterior acoustic shadowing. In acute cholecystitis, findings may include gallbladder wall thickening, mural oedema, pericholecystic fluid and the sonographic Murphy's sign. Acalculous cholecystitis shows similar findings in the absence of gallstones (Figure 8). US is a good tool for differentiation of obstructive from non-obstructive jaundice, with prediction of the level of biliary obstruction in 80% of cases.

Both diffuse or focal liver diseases can be detected on US. US reveals an irregular surface, coarsened echotexture and decrease in size in cirrhosis. In fatty liver, the parenchyma appears brighter (hyperechoic) than the adjacent right kidney. A liver abscess may appear as a faint hypoechoic solid mass in the initial stages, developing a more mixed echogenicity picture with a central collection of anechoic pus with liquefaction.

An US examination in the ITU setting may be required for assessment of acute pancreatitis with complications, follow-up of pancreatic pseudocysts, suspected rupture of a pseudocyst, vascular complications including superior mesenteric or portal vein thrombosis and arterial pseudoaneurysms.

The spleen can be evaluated for splenomegaly. Splenic abscesses are similar in appearance to hepatic abscesses. Multiple hypoechoic nodules in the immunocompromised patient may indicate microabscesses.
Other common indications for US in the ITU include identification and assessment of abdominal and pelvic fluid collections, differentiating subphrenic from pleural fluid, identification of the cause of abdominal distension, e.g., fluid, small bowel ileus, bladder distension and masses (Figure 9).

Ultrasound-guided paracentesis can provide a diagnosis when abdominal fluid has an unclear cause.

**Renal ultrasonography in the ICU patient**

US is often used as the initial imaging procedure to identify the cause of acute renal impairment, particularly hydrenephrosis.

Hyperechogenicity of the renal parenchyma, compared to the adjacent hepatic and splenic parenchyma indicates a diffuse parenchymal pathology. In the present of hydrenephrosis, the collecting system becomes visible. Calculi are detected as echogenic structures with characteristic acoustic shadowing.

Renal pathology is frequently associated with changes in parenchymal perfusion. The most significant semi-quantitative variable to evaluate is the resistive index (RI). Values >0.70 are considered abnormal, although major clinical significance is associated with values >0.80. Acute tubular necrosis, the most common cause of ARF results in an increase in the RI.

**Central line placement**

Central venous catheterization is frequently performed in critically ill patients. The use of US guidance during central venous catheterization has been well demonstrated to minimize complications and decrease the number of failed attempts.

**Cranial CT in the intensive care unit patient**

**Stroke**

An urgent CT is needed to differentiate between those who have had an ischaemic stroke and those who have had a stroke due to primary intracerebral haemorrhage.

Early CT signs of ischaemic stroke include hyperattenuation of an artery which represents acute thrombus within a segment of a cerebral vessel, hypoattenuation in the involved territory, loss of grey-white matter differentiation, loss of the insular ribbon, obscuration of the lentiform nucleus, hypoattenuation of basal ganglia and cortical sulcal effacement.
**Hypertensive bleed**

Hypertensive haemorrhage (Fig 10) is the most common cause of nontraumatic intracerebral haemorrhage in adults. Typical hypertensive haemorrhages are found in the basal ganglia and appear as hyperdense foci with surrounding hypodense oedema.

**Subarachnoid haemorrhage (SAH)**

Hyperdensity representing acute haemorrhage is visualised in the sulci overlying the cerebral convexities, in the Sylvian fissures, basal cisterns and interhemispheric fissure.

**Venous thrombosis**

The most frequent cerebral vein to thrombose is the sagittal sinus. Unenhanced CT may show a strongly hyperdense triangle in the area of the sinus (dense triangle sign). The empty delta sign (an unenhanced central portion of the affected sinus after administration of contrast material) is the best and most frequently seen CT sign of sagittal sinus thrombosis.

**Intracranial infection**

The role of neuroimaging in meningitis is in the detection of complications such as hydrocephalus, subdural effusion, brain abscess or cerebral infarction.

CT is usually normal in uncomplicated meningitis. Unenhanced CT may show obliteration of basal cisterns. Contrast-enhanced CT may show meningeal enhancement in the basal cisterns and sylvian fissures.

On CT, a subdural empyema appears as a hypodense or isodense crescentic area adjacent to the inner table of the skull. Enhancement of the medial rim may be seen on contrast-enhanced scan.

Epidural empyema is seen as a lentiform hypodense or isodense collection. Contrast enhanced CT or MRI show the inflamed dura in an epidural empyema as a well-demarcated rim of enhancement.

The distinctive feature of a brain abscess is the presence of smooth, thin, uniform capsule which shows enhancement with intravenous contrast with a moderate amount of surrounding cerebral oedema. The enhancement pattern is similar on CT and MRI.

**CT of the chest in the intensive care unit patient**
Clinical indications for CT in this setting include characterisation of pulmonary parenchymal and pleural disease, mediastinal abnormalities including mediastinitis, mediastinal abscess, abnormal or unusual fluid or air collections, pulmonary embolism and tube-malpositioning. CT may also be used for increased precision in percutaneous drainage and aspiration for loculated or otherwise difficult pneumothoraces or fluid collections.

Another form of thoracic infection that should be considered in ICU patients is septic pulmonary emboli. ICU patients are at risk due to indwelling vascular catheters. CT findings include patchy subpleural alveolar or nodular opacities with a tendency for cavitation (Figure 11, the "feeding vessel sign" and pleural effusions.

Chest trauma

Injuries to the thoracic cage may be complicated by pulmonary contusion, pneumomediastinum (Figure 12), pneumothorax (Figure 13), mediastinal emphysema, pneumopericardium or mediastinal haemorrhage.

CT-guided percutaneous catheter drainage provides accurate, safe and effective treatment for loculated thoracic air collections and obviates surgical intervention in critically ill, high-surgical-risk patients.

Pulmonary embolism

Acute PE is principally diagnosed by visualising a low attenuation filling defect within a well-opacified pulmonary artery (Figure 14). Other CT findings include the "railway track sign", the vessel cut-off sign and the rim sign, where there is a filling defect due to thrombus with a rim of contrast around it.

Adult respiratory distress syndrome

Ground glass opacity, consolidation and a reticular pattern are hallmarks of ARDS on CT. A ventral to dorsal gradient of lung attenuation is typical (Figure 15).

CT of the abdomen in the intensive care unit patient

CT is widely used for the evaluation and follow-up of a variety of intra-abdominal conditions and complications that may be encountered in the intensive care unit setting.
Acute pancreatitis

CT findings in uncomplicated acute pancreatitis include a generalised or focal increase in the size of the pancreas, and an irregular contour with peripancreatic inflammatory fat stranding. Fluid collections can accumulate within the pancreas or around the gland. Many collections spontaneously resolve, but some develop into pseudocysts. CT is valuable in helping determine the optimal pathway for pseudocyst drainage where appropriate.

Biliary tract sepsis

Imaging studies, such as US or CT, are used for evaluation of the site and cause of biliary obstruction, the degree of biliary dilatation and the presence or absence of hepatic abscess (Figure 16) to plan precise treatment.

Acute pyelonephritis

In severe pyelonephritis, CT may show a diffuse or focal enlargement of the kidney with abnormal enhancement, with a striated nephrogram (Figure 17) seen as wedge and band shaped areas of reduced enhancement.

Emphysematous pyelonephritis (EPN) may be seen with gas in the collecting system only or gas in the renal parenchyma (Figure 18).

Bowel obstruction

CT diagnosis of obstruction (Figure 19) is based on dilated small bowel and a corresponding transition point where calibre abruptly decreases.

Pseudomembranous colitis

Common CT findings in pseudomembranous colitis include wall thickening, low-attenuation mural thickening corresponding to mucosal and submucosal oedema (Figure 20).

Abdominopelvic abscess and perforation

Abscesses appear as non-tubular fluid collections with an enhancing rim, which are distinguished from adjacent bowel by their focal, non-continuous nature.
The majority of abdominopelvic abscesses can be accessed with CT guidance for percutaneous drainage, if clinically appropriate.

**Acute mesenteric ischaemia**

Biphasic CT with mesenteric CT angiography is effective in the diagnosis of acute mesenteric ischaemia. Diagnostic criteria include pneumatosis intestinalis (Figure 21), venous gas, SMA occlusion, celiac and IMA arterial occlusion with distal SMA disease, or arterial embolism, or, alternatively, bowel wall thickening combined with any one finding of focal lack of bowel wall enhancement, solid organ infarction, or venous thrombosis.

**Images for this section:**

![Fig. 1: ET tube in RLL bronchus on CXR](image-url)
Fig. 2: NG tube coiled in oesophagus
Fig. 3: Complete collapse of the left lung with mediastinal shift
Fig. 4: ARDS
Fig. 5: Small left pleural effusion
Fig. 6: Right pneumothorax
Fig. 7: Pleural effusion on US
Fig. 8: Acalculous cholecystitis

Fig. 9: Ascitic fluid
Fig. 10: Hypertensive intraparenchymal bleed with intraventricular extension
Fig. 11: Septic emboli
Fig. 12: Pneumomediastinum
Fig. 13: Tension pneumothorax
Fig. 14: Acute pulmonary embolism

Fig. 15: ARDS
**Fig. 16:** Pneumobilia and liver abscess
Fig. 17: Striated nephrogram in acute pyelonephritis
Fig. 18: Emphysematous pyelonephritis
Fig. 19: Small bowel obstruction
Fig. 20: Pseudomembranous colitis
Fig. 21: Pneumatosis intestinalis in mesenteric ischaemia
Conclusion

1. Imaging is increasingly being used in diagnosis and therapeutic procedures in the care of the critically ill patient.

2. It is essential to be able to recognize common pathological appearances on imaging in the postoperative or medical intensive care unit patient.

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References


