Identifying emergency pathology on abdominopelvic CT for non-radiologists

ABSTRACT

Abdominal and pelvic computed tomography (CT) scans can be complex to interpret but sometimes significant abnormalities are relatively easy to recognize. In emergencies it is beneficial if physicians and surgeons can identify significant pathology that may immediately change patient management. Early image interpretation will allow clinicians to alert radiologists to provide prompt urgent reports, facilitate early referral to other specialities or expedite emergency surgery.

This article provides non-radiologists with a systematic approach to identifying emergency pathology on abdominal and pelvic CT scans. It reviews the relevant cross-sectional anatomy and discusses the CT appearances of bowel perforation, bowel obstruction, bowel ischaemia (gangrene), bleeding, appendicitis and hydronephrosis using illustrative examples from the authors' clinical practice. Underlying causes for these conditions and the importance of interpreting the radiological appearances in conjunction with the patient's clinical condition and history are discussed. The authors hope that by using the POGBAH acronym and a systematic approach readers will be able to identify emergency pathology on abdominal and pelvic CT which may improve patient care.

Abdominopelvic computed tomography (CT) scans can be complex to interpret, and a final report should always be completed by a radiologist who has the relevant knowledge and training. However, in emergencies it is beneficial if surgeons and physicians can identify significant pathology that may immediately change patient management.

This article provides tips for non-radiologists to identify emergency pathology on a CT scan of the abdomen and pelvis. Findings are often subtle and difficult to perceive, and this article is not a complete guide.

CT images are formed by a patient lying flat on a table and an X-ray tube rotating at right angles to the patient. A computer then produces cross-sectional axial images which can be reformatted in the coronal or sagittal plane. The density of tissues penetrated by the X-ray beam can be measured by calculating the attenuation coefficient (a measure of how easily a material can be penetrated by an X-ray beam). The average linear attenuation coefficient of the tissues within a voxel is calculated in Hounsfield units (HU) and the nature of a structure can be worked out by measuring these values (Allisy-Roberts and Williams, 2008) (*Table 1*).

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Anatomy

Understanding anatomy is an obvious prerequisite to interpretation. Normal positions of intra-abdominal organs are shown in *Figure 1*.

Systematic approach

When interpreting any radiological study, it is important to have a robust reproducible system, so abnormalities are not missed. Start by briefly scrolling up and down the scan to look for gross abnormalities then examine each organ in turn.

Use a cranial to caudal approach assessing the oesophagus, stomach and duodenum, then examine the liver, gallbladder, bile ducts, pancreas, spleen, adrenal glands, both kidneys, ureters and the urinary bladder. Then start at the rectum and trace the large bowel proximally assessing the sigmoid colon, descending colon, transverse colon, ascending colon and then identify the ileocaecal valve.

Table 1. Approximate Hounsfield unit (HU) ranges for different tissues

Tissue	Range
Bone	500–1500 HU
Soft tissue	40–80 HU
Liver	56–60 HU
Water	0 HU
Fat	-60 – -100 HU
Air	-1000 HU

The ileocaecal valve is often identified by fat surrounding the valve (although fat is not always present) and by identifying the terminal ileum entering the caecum. The caecum is mobile and distal to the ileocaecal valve. The appendix is a small blind-ended tube which originates from the caecal pole. Trace the loops of ileum and jejunum proximally until they join the distal duodenum. Successfully tracing small bowel is time consuming and takes significant practice. Therefore, the authors recommend splitting the abdomen into four quadrants and then examining the small bowel separately in each quadrant.

To complete interpretation examine the mesentery, abdominal aorta and its main branches, portal vein and its tributaries and hernial orifices. Use lung windows to assess the lung bases and to identify free intraperitoneal gas. Check for free fluid within the abdomen and pelvis. Examine the bones using bone windows with sagittal and coronal reformats.

There are many specific review areas and features to positively identify or exclude depending on the suspected diagnosis.

This article uses the acronym 'POGBAH', invented by Dr Anthony Blakeborough, a consultant gastrointestinal radiologist at the authors' institution, to help identify six findings which may require emergency surgery:

P Perforation
O Obstruction
G Gangrene (bowel Ischaemia)
B Bleeding
A Appendicitis
H Hydronephrosis.

Gynaecological causes of an acute abdomen are not included in this article.

Patients with atraumatic acute abdominal pain with no evidence or suspicion of active bleeding should be scanned with intravenous contrast in the portal venous phase as this generally gives the most diagnostic information.

Perforation

Gastrointestinal tract perforation requires prompt diagnosis and often emergency surgery to prevent peritonitis, sepsis and mortality. CT is the most reliable modality to identify the site of perforation with an accuracy of 82–90% (Kothari et al, 2017). The most important sign to identify is extraluminal gas. Switching to lung windows will help gas stand out from the surrounding structures and allows detection of small locules of gas in the peritoneum (*Table 2*).

Gastrointestinal tract perforation has a wide aetiology, but the most common cause is peptic ulcer disease causing gastric or duodenal perforation followed by diverticular disease (Kothari et al, 2017). Other causes include malignancy (gastric, oesophageal and colorectal), trauma, foreign body aspiration, colitis, ischaemia, bowel obstruction and appendix rupture. Rarer causes include small bowel malignancy, intussusception and volvulus (Kothari et al, 2017) (*Figure 2*).

The exact site of a perforation can be identified by locating a focal defect within the bowel wall (cleft sign) (*Figure 3*). This may not always be possible but is often easier to locate in colonic perforation than small bowel perforation.

Table 2. Computed tomography signs of perforation

Direct signs of perforation	Extraluminal gas or contrast (oral contrast)
	Discontinuity along the bowel wall
Indirect signs of perforation	Pericolic fat stranding
	Abnormal bowel wall enhancement
	Abscess
	Inflammatory mass (phlegmon) adjacent to the bowel wall

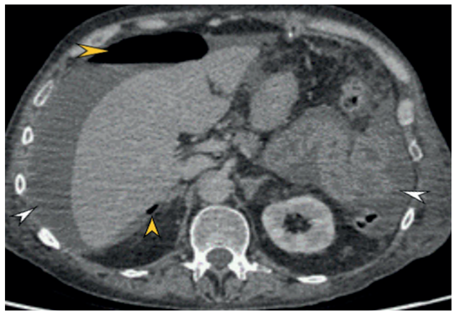


Figure 2. Axial slice of abdominopelvic contrast-enhanced computed tomography from a 62-year-old patient with acute abdominal pain. Yellow arrowheads show a large locule of free intraperitoneal gas anterior to the liver and a smaller locule posterior to the right lobe of liver. White arrow heads show free fluid surrounding the liver and loops of small bowel in the left side of the abdomen. Exploratory laparotomy revealed perforated duodenal ulcer.

Other causes of extraluminal gas include recent surgery, intraperitoneal instrumentation, barotrauma and bladder perforation (Kothari et al, 2017). Considering these causes will help prevent misdiagnosis.

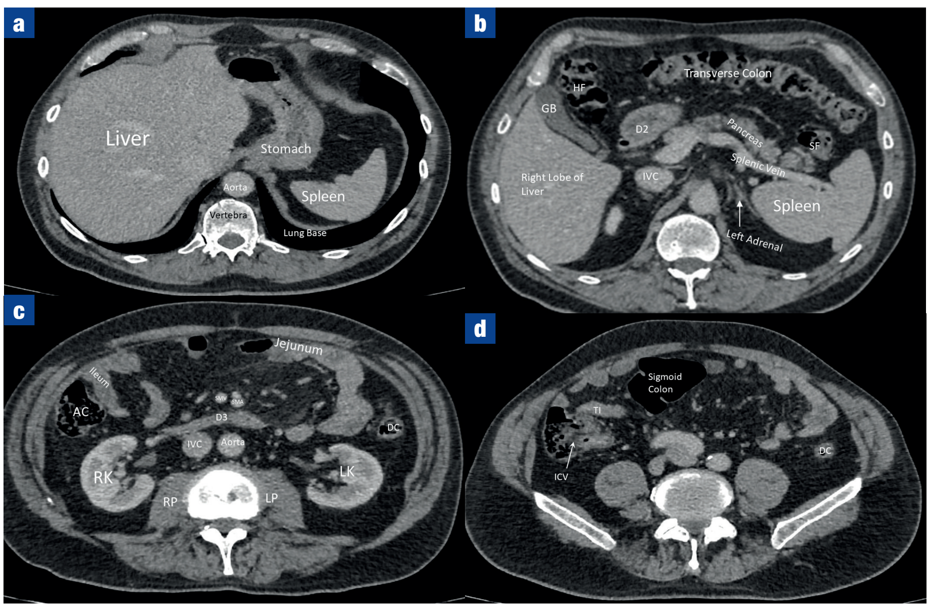
Bowel obstruction

Depending on the cause, most patients with small bowel obstruction are managed conservatively with nasogastric tube decompression and fluids, but high grade small bowel obstruction is a surgical emergency with mortality ranging from 2–8% (Paulson and Thompson, 2015).

Small bowel should be <3 cm in diameter, large bowel <6 cm and the caecum <9 cm. Small bowel obstruction is most frequently caused by adhesions, hernias or malignancy (80%) (Paulson and Thompson, 2015) (*Figure 4*; *Tables 3* and *4*). The small bowel is dilated proximally and collapsed distal to the point of obstruction. The site where bowel changes from dilated to collapsed is called the transition point which may be obvious (e.g. at the site of an inguinal hernia in the groin) but is often subtle and occasionally not identified. Bands of adhesions are rarely visible so if there is a history of multiple operations and no other cause present, adhesions will be the most likely underlying cause.

Sometimes the small bowel contains faeces just proximal to the point of obstruction which is known as the small bowel faeces sign. However, the presence of faeces in the terminal ileum without small

Figure 1. Annotated axial slices of abdominopelvic contrast-enhanced computed tomography at the level of the **(a)** gastro-oesophageal junction, **(b)** splenic vein, **(c)** third part of the duodenum, and **(d)** ileocaecal valve. AC = ascending colon; DC = descending colon; D2 = second part of the duodenum; D3 = third part of the duodenum; GB = gallbladder; HF = hepatic flexure; ICV = ileocaecal valve; IVC = inferior vena cava; LK = left kidney; LP = left psoas major muscle; RK = right kidney; RP = right psoas major muscle; SF = splenic flexure; SMA = superior mesenteric artery; SMV = superior mesenteric vein; TC = transverse colon; TI = terminal ileum.



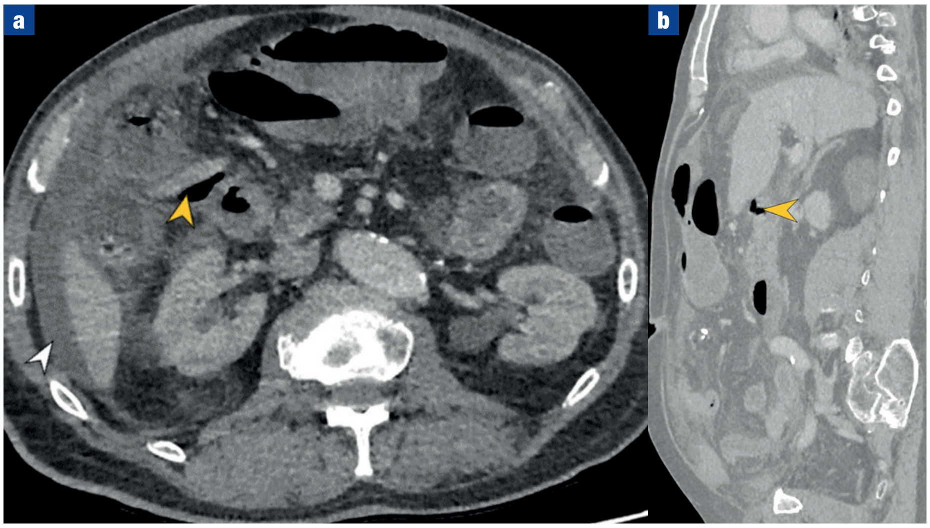


Figure 3. **a.** Axial slice of abdominopelvic contrast-enhanced computed tomography from an 82-year-old man with lower abdominal pain. Yellow arrowhead demonstrates a locule of extraluminal gas adjacent to the second part of the duodenum. White arrowhead shows free fluid surrounding the liver. **b.** Sagittal reformat from the same patient using lung windows to highlight the free gas. The yellow arrowhead demonstrates a defect (cleft sign) in the wall of the second part of the duodenum with free gas entering the peritoneal cavity.

bowel dilatation is not clinically significant. Complete obstruction is where no fluid or gas passes beyond the transition point, in contrast to partial obstruction where a small quantity of fluid and gas may travel beyond the obstruction (Paulson and Thompson, 2015). If the small bowel obstruction is complete, the large bowel and rectum may be collapsed, although this depends on how long the patient has been obstructed. Complications of small bowel obstruction are perforation, ischaemia and infarction. As the bowel dilates or becomes twisted the blood supply becomes compromised (Malhotra and Rabouhans, 2013).

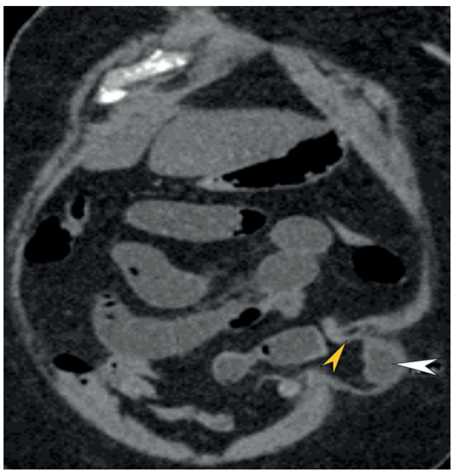


Figure 4. Coronal abdominopelvic contrast-enhanced computed tomography from a patient with small bowel obstruction as a result of a left-sided parastomal hernia. Dilated loops of small bowel can be seen proximal to the hernia. White arrowhead demonstrates a dilated loop of small bowel within the hernia. Yellow arrowhead demonstrates the transition point and a collapsed loop of small bowel distal to the hernia.

Table 3. Causes of small and large bowel obstruction

Causes of small bowel obstruction	Adhesions
	Hernias
	Malignancy (including extra-luminal tumours)
	Crohn's disease strictures
	Appendix abscess
	Foreign bodies
	Volvulus
	Gall stones
	Intussusception
Causes of large bowel obstruction	Colorectal cancer
	Faecal impaction
	Volvulus
	Inflammation
	Crohn's disease or ulcerative colitis
	Diverticulitis

Large bowel obstruction is rarer than small bowel obstruction, but more often requires emergency surgery (Jaffe and Thompson, 2015). Findings on CT are dilatation proximal to the point of obstruction, with collapse distally. The transition point and underlying cause of large bowel obstruction, e.g. colonic cancer or diverticular stricture, are usually visible. Large bowel obstruction often occurs at the caecum, hepatic and splenic flexures or the recto-sigmoid junction. The most common cause of large bowel obstruction is colorectal cancer (60%) which appears as a segment of colonic wall thickening or an enhancing mass (Jaffe and Thompson, 2015). Just proximal to the malignancy the colon often becomes filled with fluid which can help identify the transition point and the tumour.

An important feature of large bowel obstruction is whether the ileocaecal valve is competent or incompetent. A competent ileocaecal valve will stop fluid decompressing into the distal small bowel, resulting in rapid increase in pressure within the large bowel. An incompetent ileocaecal valve will allow some decompression of the large bowel, but appearances can then mimic small bowel obstruction as a result of proximal dilatation of the small bowel.

Table 4. Computed tomography signs of small and large bowel obstruction

Signs of small bowel obstruction	Dilated loops of small bowel (>3 cm)
	Transition point with distal collapsed loops of small bowel
	Solid small bowel faeces proximal to the obstruction
	Large bowel is usually collapsed
Signs of large bowel obstruction	Dilated loops of large bowel (gas, fluid or stool filled)
	Collapsed colon distal to the obstruction
	If the transverse colon is >5.5 cm diameter and the caecum is greater than 9 cm diameter, there is a significant chance of perforation
	Identification of an underlying cause, e.g. large bowel tumour or stricture

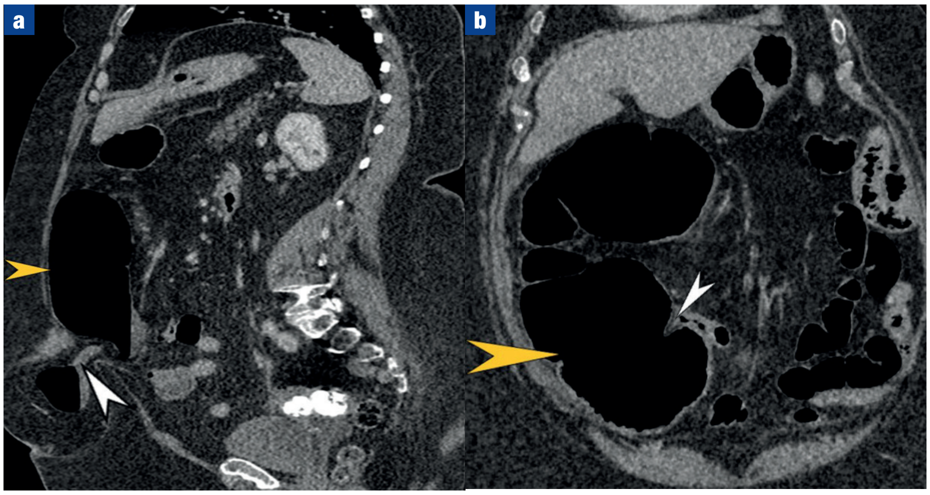


Figure 5. Abdominopelvic contrast-enhanced computed tomography from a patient with large bowel obstruction. **a.** Sagittal slice. White arrowhead shows the transition point within the ventral hernia. Yellow arrowhead shows dilated loop of large bowel proximal to the hernia. **b.** Coronal slice. White arrowhead shows a second transition point at the competent ileocaecal valve with a normal calibre terminal ileum proximally and dilated large bowel distally (yellow arrowhead) implying a closed loop large bowel obstruction.

Closed loop obstruction occurs when the bowel is obstructed at two points along its course and can occur with small and large bowel. The length of bowel involved within the closed loop is variable, but the transition points are often adjacent to each other. Because the involved bowel is obstructed at both ends, it cannot decompress proximally or distally. Consequently, this isolated section of obstructed bowel continues to secrete fluid and rapidly dilates, impairing venous return and resulting in ischaemia (Paulson and Thompson, 2015). It is imperative to identify this condition early, as patients with closed loop obstruction require surgery because of the increased risk of bowel infarction and perforation (*Figure 5*).

Gangrene (ischaemia)

Bowel ischaemia is a true emergency that is potentially fatal, but if diagnosed early is potentially reversible (Brant, 2019b). Clinical signs of ischaemia are often non-specific and vary with aetiology, therefore CT plays a crucial role in diagnosis. For simplicity, it is useful to subdivide causes of bowel ischaemia into three broad categories – arterial, venous and non-occlusive causes – however, practically a combination of causes may occur (Dhatt et al, 2015). For example, malignancy and volvulus can cause arterial or venous ischaemia, or a combination of both, and processes that cause profound hypotension may result in non-occlusive bowel ischaemia (e.g. heart failure, sepsis, trauma). Causes and CT signs of bowel ischaemia are listed in *Tables 5* and *6*.

Patients with suspected bowel ischaemia at the authors' institution have a triple phase abdominopelvic CT. A non-contrast scan is performed initially to act as a baseline scan and assess for haemorrhage in the bowel wall. Arterial phase CT is then performed to examine the mesenteric arteries, and to specifically look for arterial thrombosis, atherosclerotic plaques and evidence of vasculitis. Finally, portal venous phase imaging is performed to assess for bowel wall enhancement, patency of the portal venous system and for general assessment of the abdomen and pelvis. The density of bowel wall on the portal venous scan is also compared with the baseline non-contrast scan, to ensure any increase in attenuation is secondary to true enhancement and not to haemorrhage within the bowel wall.

Many radiological signs associated with bowel ischaemia are non-specific so it is vital to interpret them in the context of the clinical history, vital signs and laboratory findings, and to confirm findings with a radiologist. For example, pneumatosis intestinalis is an imaging finding strongly associated with bowel wall ischaemia, but rarely it can occur secondary to non-ischaemic causes. Mucosal disruption secondary to ulcers, inflammatory bowel disease and biopsy procedures can all cause pneumatosis intestinalis, as can many chemotherapy agents which increase mucosal permeability (Brant, 2019b). Patients with inflammatory bowel disease can occasionally have gas in the portal venous system which is unrelated to ischaemia (*Figure 6*).

Table 5. Causes of bowel ischaemia

Arterial ischaemia	Embolus (most common cause of acute ischaemia, 60–70% of cases)
	Volvus
	Vasculitis (polyarteritis nodosa most common)
	External compression
Venous ischaemia	Venous thrombosis
	Bowel strangulation (secondary to obstruction, volvulus or intussusception)
	Tumours
Non-occlusive	Heart failure
	Sepsis
	Trauma
	Chemotherapy
	Corrosive injury (e.g. from alkali)
	Vasoconstrictive medications (e.g. ergotamine, digitalis, noradrenaline)

Table 6. Computed tomography findings in bowel ischaemia

Arterial occlusion (low attenuation arterial filling defect)
Venous thromboembolism (low attenuation venous filling defects)
Circumferential or nodular bowel wall thickening (most common but non-specific)
Pneumatosis intestinalis (intraluminal gas enters the bowel wall as a result of muscosal damage)
Mesenteric or portal venous gas
Reduced or absent enhancement of the bowel wall
Haemorrhage within the bowel wall (as a result of mucosal damage seen as high attenuation within the bowel wall)
Inflammatory fat stranding in the mesentery (caused by venous congestion)
Bowel dilatation (non-specific)
Ascites (non-specific)

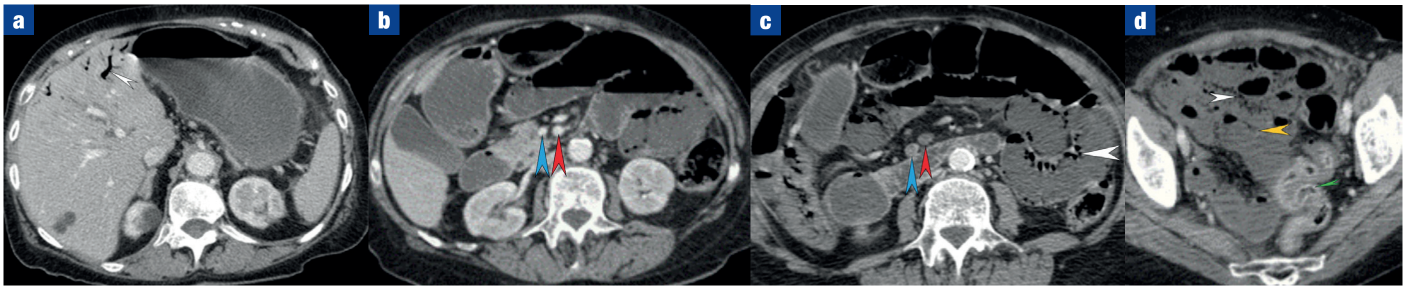
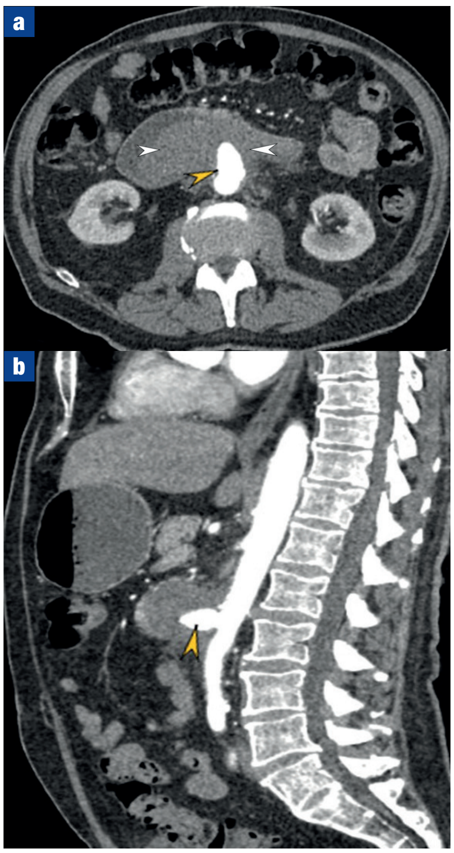


Figure 6. **a–d.** Axial slices of abdominopelvic contrast-enhanced computed tomography (portal venous phase) from the same patient with metastatic pancreatic cancer presenting with abdominal pain.

Bleeding

If active gastrointestinal haemorrhage is suspected a triple phase abdominopelvic CT should be performed. Each phase of the scan is performed for a reason. A non-contrast scan before intravenous contrast administration is performed to identify haemoperitoneum and acute haematoma, as contrast may obscure the high attenuation blood and mask bleeding. Haemoperitoneum or haemoretroperitoneum is seen as a spontaneous fluid collection of high attenuation whereas haematoma appears as a round or oval collection of blood (both should measure >40 HU) (Tasu et al, 2015). A small clot of blood may be present at the site of active bleeding which is known as the sentinel clot sign. If the patient is unstable, abdominopelvic CT in the arterial phase can potentially identify the site of active arterial bleeding as a result of contrast extravasation (contrast leaving the vessel). A portal venous phase scan may help identify contrast extravasation as a result of venous bleeding or confirm arterial bleeding by the pooling of contrast (*Figure 7, Table 7*).

Figure 7. **a.** Axial and **(b)** sagittal slices from an arterial phase abdominopelvic contrast-enhanced computed tomography. The yellow arrowhead shows a focal aortic aneurysm adjacent to the third part of the duodenum. No active contrast extravasation is present, but the white arrowheads show high attenuation consistent with haemorrhage within the second and third parts of the duodenum. Appearances are consistent with an aorto-duodenal fistula and unfortunately the patient died before emergency surgery could be undertaken.



Appendicitis

Acute appendicitis is the commonest cause of emergency surgery in the UK and the USA (Ramsay et al, 2018; Quadri et al, 2019). The normal appendix is a blind ending tube originating at the caecal pole, which is usually 8–10 cm in length but can be up to 30 cm. To locate the appendix, start by finding the ileocaecal valve and then scroll through the caecum to identify a blind ended tube connecting to the lumen. The appendix may not be visualized in 5–10% of CT examinations (Brant, 2019a; Quadri et al, 2019). Appendicitis is most commonly caused by obstruction of the lumen by an appendicolith (calcium deposition around a nidus of firm faeces) in adults or lymphoid hyperplasia in children. Appendicoliths are not diagnostic in themselves and can occur in asymptomatic patients with a normal appendix. In older patients, appendicitis can also be caused by an obstructing appendicular or caecal tumour, which is an important differential (*Table 8*).

Complications include perforation which may be localized or generalized, abscess formation and phlegmon formation (inflammatory soft tissue mass). Phlegmons measure >20 HU whereas abscesses are fluid filled and measure <20 HU (Quadri et al, 2019) (*Figures 8* and *9*).

Table 7. Common causes of intra-abdominal bleeding

Upper gastrointestinal haemorrhage	Peptic ulcer disease
	Oesophageal or gastric varices
	Mallory–Weiss tears
	Tumour
	Aortoduodenal fistula
Lower gastrointestinal bleeding	Diverticulitis
	Inflammatory bowel disease
	Postoperative (especially postpolypectomy)
	Haemorrhoids
	Traumatic vascular injury

Hydronephrosis

Hydronephrosis is dilatation of the renal pelvis and calyceal system with urine caused by an obstruction of the urinary tract. This finding

Table 8. Computed tomography findings in acute appendicitis

Diagnostic	Abnormal dilated appendix (>6 mm diameter outer wall to outer wall) with luminal distention, wall thickening or both
	Enhancing appendix with periappendiceal fat stranding, haziness or fluid (abscess)
Supporting signs	Lymph node enlargement in right iliac fossa
	Obstructing calcified appendicolith

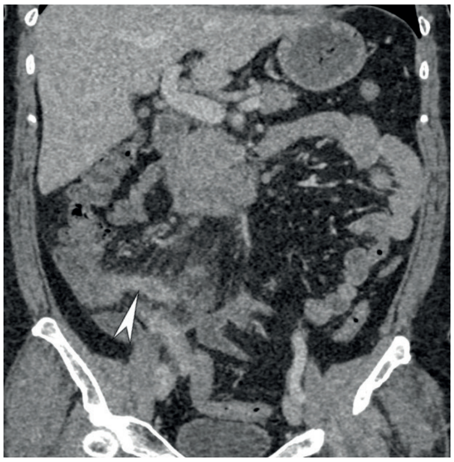


Figure 8. Coronal slice of abdominopelvic contrast-enhanced computed tomography. White arrowhead shows an inflamed appendix with surrounding inflammatory fat stranding in the mesentery.

has a wide aetiology and is relatively easy to identify on an abdominopelvic CT. Although hydronephrosis can be longstanding, such as when caused by chronic urinary outflow obstruction, it is important to identify in patients who may require an urgent nephrostomy. Emergency nephrostomies are typically performed to relieve pyonephrosis, which is an obstructed and infected urinary system. Pyonephrosis classically presents with the triad of fever, flank pain and hydronephrosis, or more simply hydronephrosis with sepsis (Li and Regalado, 2012). Therefore, the referring clinician is best placed to determine whether the hydronephrosis observed is secondary to infection (*Figure 10*).

Conclusions

This article has provided an introduction for non-radiologists to interpreting abdominopelvic CT scans by reviewing important anatomy and providing a systematic approach for interpretation. By using the POGBAH acronym readers should be able to identify emergency pathology on abdominal and pelvic CT scans which may expedite emergency management of patients. **BJHM**

Conflict of interest: none.

CURRICULUM CHECKLIST

This article addresses the following requirement from the general internal medicine training curriculum

- Appropriately selects, manages and interprets investigations

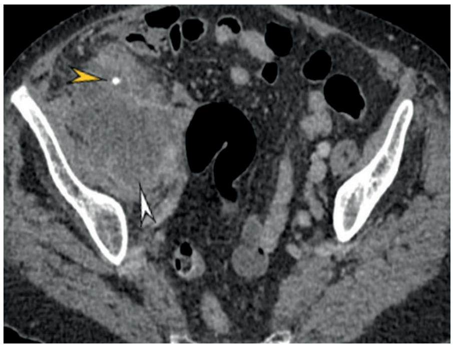


Figure 9. Axial slice of abdominopelvic contrast-enhanced computed tomography. White arrowhead shows peri-appendiceal abscess in the right iliac fossa. Yellow arrowhead shows a calcified appendicolith which was the likely cause of acute appendicitis.

KEY POINTS

- Learn the relevant cross-sectional anatomy.
- Use a systematic approach and always review previous imaging.
- Use the POGBAH acronym to assess for emergency pathology.
- Perforation is associated with free intraperitoneal gas.
- Bowel obstruction is associated with dilated bowel proximally and collapsed bowel distally.
- Bleeding is associated with high attenuation fluid or contrast extravasation.
- Use the ileocaecal valve to help identify the appendix and assess its calibre, enhancement and the surrounding mesentery.
- If you identify hydronephrosis consider whether this could this be a pyonephrosis.

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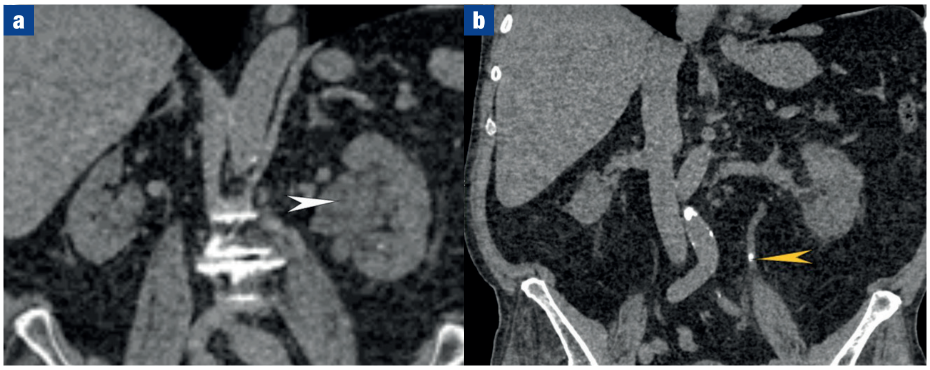

Figure 10. **a, b**. Coronal slices of a non-contrast abdominal computed tomography of the kidneys, ureters and bladder from the same patient. The white arrowhead shows moderate hydronephrosis of the left kidney and the yellow arrowhead shows the underlying cause of urinary obstruction, which is an obstructing calculus in the left mid-ureter.