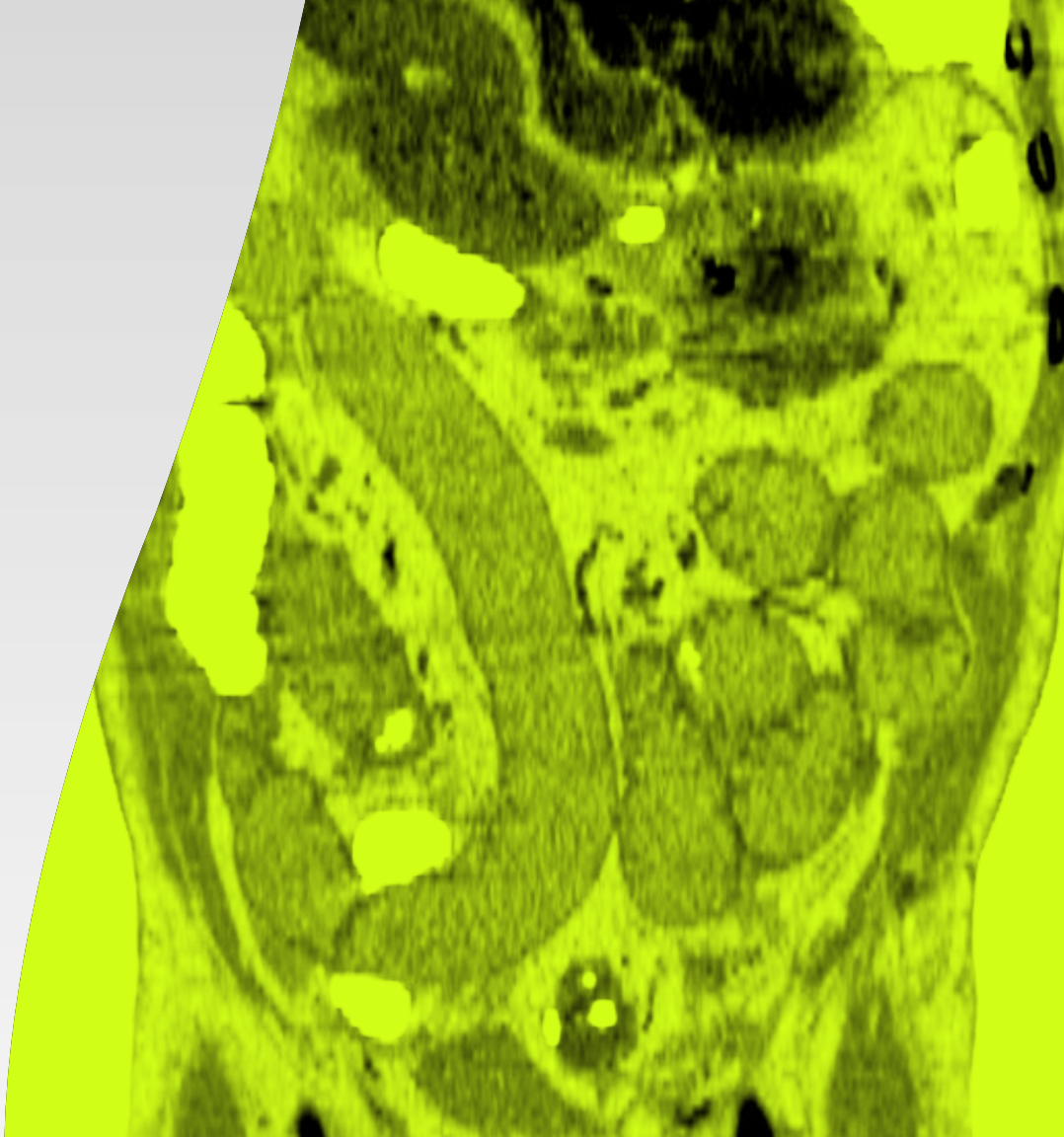
MODERN RADIOLOGY eBook

Small Bowel



ESR 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
Professor of Radiology, University of Geneva, Switzerland

Small Bowel

CHAPTER OUTLINE:

Copyright and Terms of Use

How to cite this work:

European Society of Radiology,
Kyra van Rijn, Jaap Stoker (2025)
ESR Modern Radiology eBook:

- Small Bowel.
  DOI 10.26044/esr-modern-radiology-15

Signage

CORE KNOWLEDGE

FURTHER KNOWLEDGE

ATTENTION

COMPARE

QUESTIONS

HYPERLINKS

REFERENCES

Small Bowel

CHAPTER OUTLINE:

MODERN RADIOLOGY eBook

Based on the ESR Curriculum for Radiological Education

Small Bowel

AUTHORS

Kyra van Rijn | Jaap Stoker

AFFILIATION

Amsterdam UMC, location University of Amsterdam, Department of Radiology and Nuclear Medicine, Meibergdreef 9, Amsterdam, The Netherlands

Amsterdam Gastroenterology Endocrinology Metabolism, Amsterdam, The Netherlands

<↑> HYPERLINK

k.l.vanrijn@amsterdamumc.nl
j.stoker@amsterdamumc.nl

CHAPTER OUTLINE:

Chapter Outline

Relevant Anatomy for Small Bowel Imaging

- Parts of the Small Bowel
- Normal Ultrasonography, Computed Tomography and Magnetic Resonance Imaging Anatomy
- Blood Supply

Strengths, Weaknesses and Role of Imaging Modalities

- Plain Abdominal Radiograph
- Ultrasonography
- Computed Tomography
- Magnetic Resonance Imaging
- Interventional Radiology

Main Indications to Small Bowel Imaging by Pathology

- Congenital
- Obstruction
- Perforation/Trauma
- Tumour
- Inflammatory/Infectious
- Ischaemia

Take-Home Messages

References

Test Your Knowledge

CHAPTER OUTLINE:

Relevant Anatomy for Small Bowel Imaging

CHAPTER OUTLINE:

/ Parts of the Small Bowel

For general anatomical, histological and physiological information about the **small bowel** (duodenum, jejunum, ileum) please refer to your knowledge obtained during your studies in the previous years.

Here we provide you only with some imaging-specific additions to the subject. This primarily concerns **ultrasonography** (US), **computed tomography** (CT), **magnetic resonance imaging** (MRI) and **interventional radiology**.

CHAPTER OUTLINE:

/ The Normal Small Bowel on US

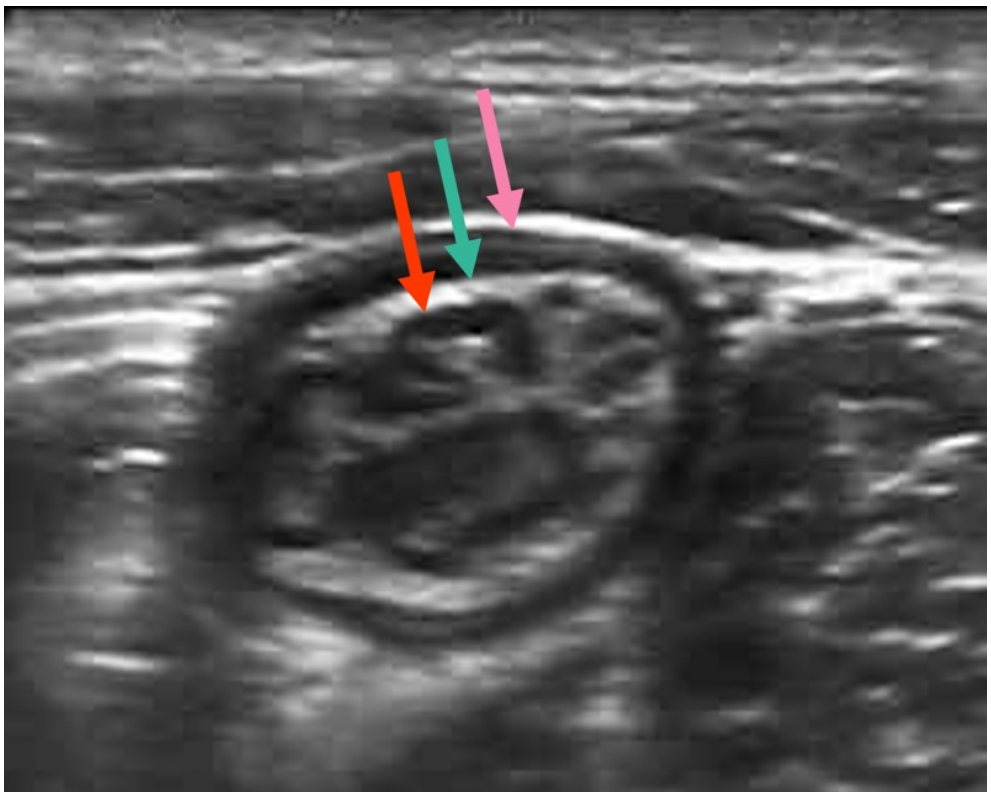


FIGURE 1

Ultrasonography of a normal small bowel loop in a transverse view. The different layers of the bowel wall can be distinguished, from inside out: lumen and superficial mucosal layer interface (echogenic, not pointed out), deep mucosa (hypoechoic, **red arrow**), submucosa (echogenic, **turquoise arrow**), muscularis propria (hypoechoic, **pink arrow**) and on the outside a thin layer of echogenic serosal surface (not pointed out because it is blended with the surrounding echogenic fat).

CHAPTER OUTLINE:

/ The Normal Small Bowel on CT

FIGURE 2

Normal small bowel loops on coronal CT after administration of an intravenous contrast medium. The bowel walls enhance normally and are relatively hyperintense compared to the lumen (red arrows).

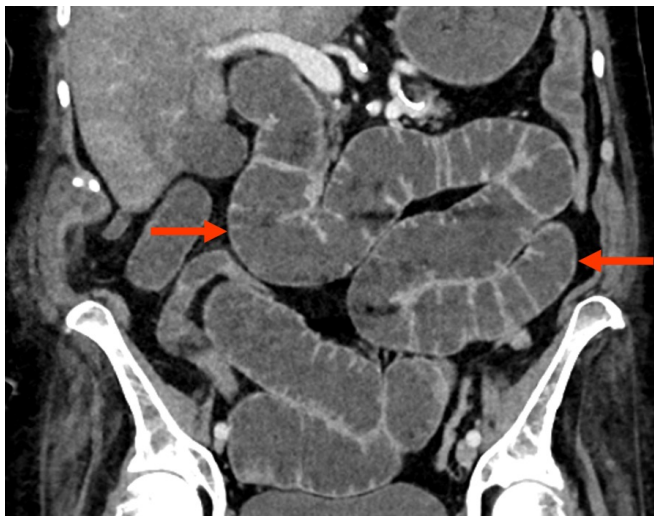


FIGURE 3

Coronal CT after intravenous contrast administration in a patient with dilated small bowel loops (arrows). The bowel loops have normal enhancement and normal thickness bowel walls. Also, the circular mucosal folds are well visualised in this patient due to the distended bowel loops.

CHAPTER OUTLINE:

/ The Normal Small Bowel on MRI

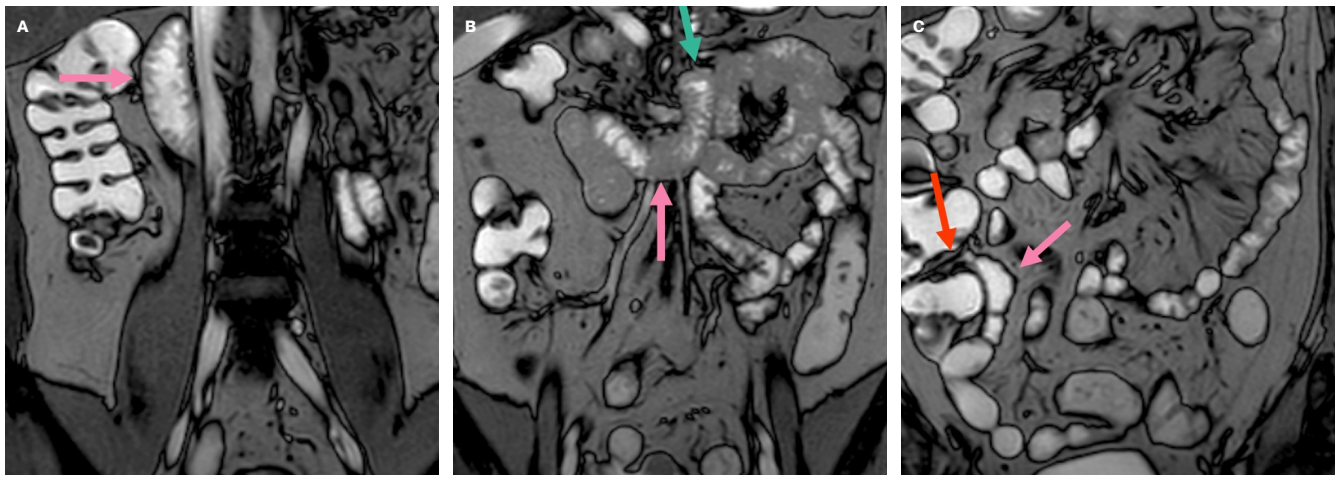


FIGURE 4 A–C

Normal small bowel on coronal MRI (T2-weighted sequences). Left to right: from posteriorly to anteriorly in the abdomen. On the left the descending part of the duodenum is pointed out (**pink arrow**), in the middle the transverse part of the duodenum (**pink arrow**) which continues (**turquoise arrow**) into the jejunum at the ligament of Treitz and on the right the terminal ileum (**pink arrow**) where it enters into the cecum (ileocecal valve, **red arrow**). The larger part of the small bowel (i.e., jejunum and ileum) lays in between the duodenum and terminal ileum. The lumen is variably filled in these images.

CHAPTER OUTLINE:

/ Anatomy for Small Bowel Imaging – **Blood Supply**

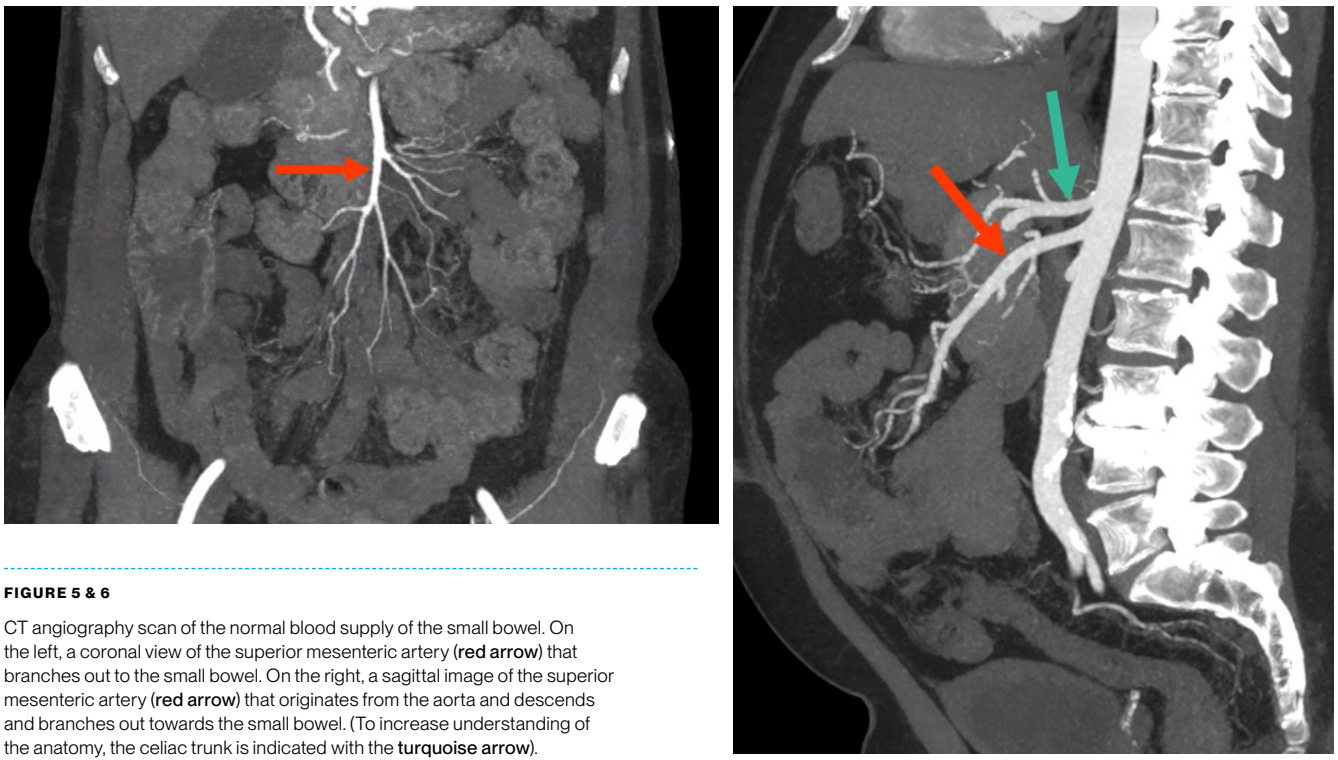


FIGURE 5 & 6

CT angiography scan of the normal blood supply of the small bowel. On the left, a coronal view of the superior mesenteric artery (**red arrow**) that branches out to the small bowel. On the right, a sagittal image of the superior mesenteric artery (**red arrow**) that originates from the aorta and descends and branches out towards the small bowel. (To increase understanding of the anatomy, the celiac trunk is indicated with the **turquoise arrow**).

CHAPTER OUTLINE:

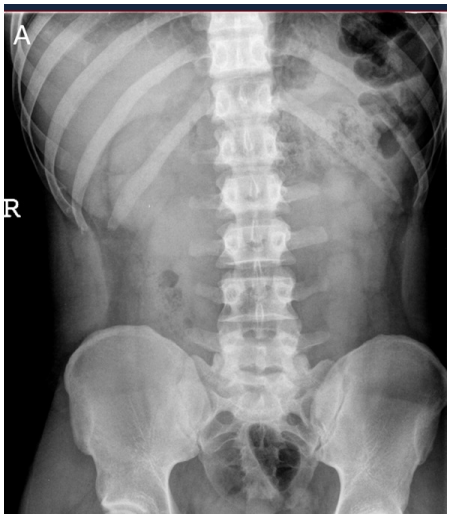
Strengths, Weaknesses and Role of Imaging Modalities

CHAPTER OUTLINE:

/ Strengths, Weaknesses and Role of Imaging Modalities – **Plain Abdominal Radiograph**

There is a very limited role, if any, for plain abdominal radiographs in visualising the small bowel. Bowel walls are generally not visible on plain X-rays and bowel content is only visualised when there is enough contrast with its surroundings, mostly due to gas. Furthermore, complications are not shown.

One of the abnormalities that can be visualised on plain X-rays are dilated bowel loops that are filled with gas, however, the cause of the dilation will need further evaluation using a different imaging modality. Also, free gas below the diaphragm caused by a gastrointestinal perforation can be seen on upright plain radiographs. However, CT has a substantially higher sensitivity and specificity for free peritoneal gas, it can show the cause of the perforation and possible complications.



>|< COMPARE

FIGURE 7

Normal plain abdominal radiograph in a patient with acute abdominal pain at the right lower quadrant. This patient had an appendicitis which was visualised on a CT-scan (distended appendix, periappendiceal infiltrate mesoappendix at **red arrow**).

/ Strengths, Weaknesses and Role of Imaging Modalities – **Ultrasonography**

Ultrasonography is often used in abdominal imaging including acute abdomen, inflammatory bowel diseases and in paediatric cases. One of the advantages of ultrasonography is the high resolution which makes it possible to visualise the different layers of the bowel wall. Motility can be assessed, which can be increased in bowel loops upstream of an obstruction or decreased such as in paralytic ileus. Compression can be applied which gives information on the compressibility of the small bowel which may be decreased (e.g., in Crohn's disease). Moreover, this modality is available in an outpatient clinic setting and the investigation is interactive with the patient, which may result in additional anamnestic information. Disadvantages are often the inability to give an overview of the entire small bowel, field of view can be limited by (bowel) gas and visualisation can be limited in obese patients.

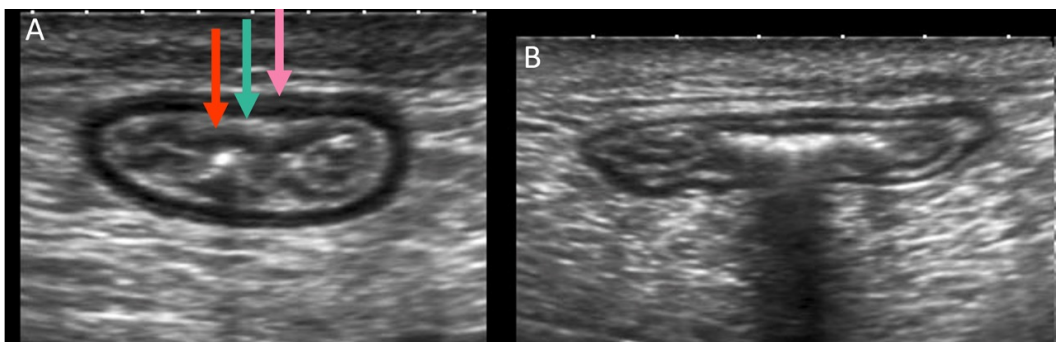


FIGURE 8 A&B

Normal small bowel ultrasonography. On the left, a transverse view of a normal small bowel loop. On the right, the same small bowel loop when it is compressed by the transducer. The **red arrow** shows the deep mucosa, the **turquoise arrow** the submucosa & the **pink arrow** the muscularis propria.

/ Strengths, Weaknesses and Role of Imaging Modalities – **CT**

CT is a widely and frequently used imaging modality to visualise the small bowel. Different protocols can be used, dependent on the indication.

The most important disadvantage is the use of ionising radiation, especially in children and (young) patients that need repeated imaging. State of the art CT-scanners have substantially decreased ionising radiation burden than earlier scanners, but the radiation dose of abdominal CT is not negligible.

/ CT Protocols

Intravenous contrast medium is routinely administered in CT of the bowel, as it improves visualisation of the bowel wall layers and facilitates detection of ischaemia or haemorrhage. A routine CT of the abdomen comprises a single phase CT obtained in the portal venous phase. For indications where there is a special interest in the vascularisation of the small bowel, biphasic CT can be performed in which intravenous contrast is administered in the arterial phase and venous phase.

Oral contrast medium or water can be used to distend the bowel loops and to highlight the contrast between bowel lumen and bowel wall in CT. Oral contrast media can be administered orally (CT enterography) or via a nasojejunal tube (CT enteroclysis). In acute situations no oral contrast medium is used routinely as it leads to time delay. In case of ischaemia or haemorrhage, oral contrast medium will decrease the conspicuity of bowel wall enhancement while intraluminal haemorrhage will be completely obscured by oral contrast medium. Therefore in these patients certainly no oral contrast medium should be used.

>|< COMPARE

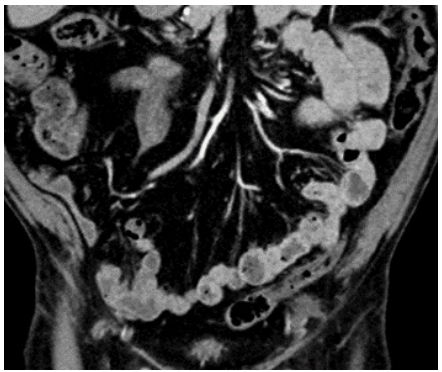


FIGURE 9

Normal coronal CT scan of a patient that received intravenous contrast in the portal venous phase but no oral contrast. A difference in contrast between the bowel wall and lumen can be visualised.

This protocol is used in most settings, indications are various but can for example consist of oncologic follow up, suspected small bowel obstruction or haemorrhage.

FIGURE 10

Normal coronal CT scan of a patient that received oral and intravenous contrast. The bowel lumen is filled with oral contrast so there is a large contrast difference between lumen and bowel wall.

Indications for this protocol consist mainly of disorders where there is an interest in bowel wall lesions, such tumours or Crohn's disease. Potential drawback is obscuring bowel wall or lesion enhancement.

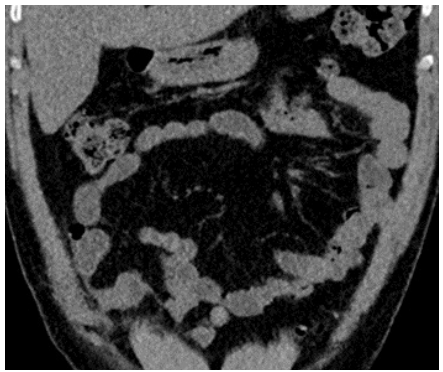


FIGURE 11

Normal coronal CT scan of a patient that did not receive oral preparation and no intravenous contrast. In some bowel loops there is a slight contrast between the bowel wall and lumen but circulation cannot be properly evaluated.

There are rare indications for this protocol, but for example ingested foreign bodies or in patients with an absolute contra indication for contrast medium.

/ Small Bowel

CHAPTER OUTLINE:

/ Strengths, Weaknesses and Role of Imaging Modalities – **MRI**

>|< COMPARE

MRI is another often used imaging modality for the small bowel, mostly in an elective setting.

A MRI examination comprises several sequences in different planes which will be optimised for certain diseases and/or areas in the abdomen. Indications for small bowel MRI mostly consist of an interest in lesions of the bowel wall; in daily practice Crohn's disease is a common indication.

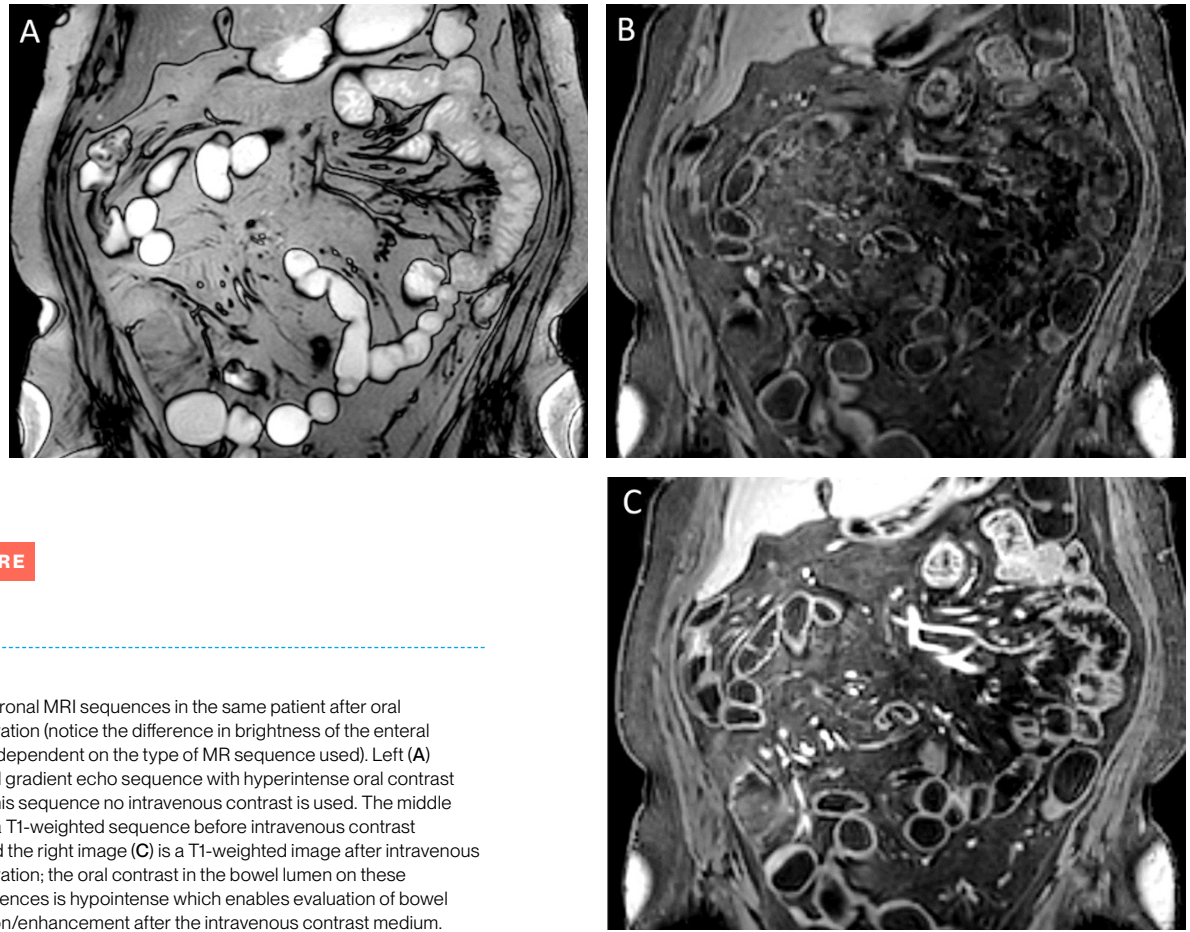
Its major advantages over CT are the inherent high contrast resolution, its versatility and lack of ionising radiation. The latter makes it especially suitable for a population that is young and/or needs repeated imaging. Disadvantage are that it is less widely available and takes more time than CT.

/ MRI Protocols

As with CT, different protocols including oral and intravenous contrast can be used.

Intravenous contrast is routinely administered for small bowel evaluation on MRI since it gives information on bowel wall layers, vascularisation of the bowel wall and of bowel lesions. Diffusion weighted imaging (based on differences in MRI-probed Brownian motion differences between tissue structures) can make intravenous contrast medium superfluous in some settings.

Oral contrast medium with a large volume, that is not well absorbed in the small bowel, is also routinely used in MRI of the small bowel (MR enterography or MR enteroclysis). This results in distended bowels and an increased contrast difference between lumen and bowel wall which enables adequate visualisation of the bowel wall and bowel wall lesions.



>|< COMPARE

FIGURE 12 A–C

Three different coronal MRI sequences in the same patient after oral contrast administration (notice the difference in brightness of the enteral contrast medium dependent on the type of MR sequence used). Left (**A**) shows a balanced gradient echo sequence with hyperintense oral contrast in the lumen, for this sequence no intravenous contrast is used. The middle image (**B**) shows a T1-weighted sequence before intravenous contrast administration and the right image (**C**) is a T1-weighted image after intravenous contrast administration; the oral contrast in the bowel lumen on these T1-weighted sequences is hypointense which enables evaluation of bowel wall vascularisation/enhancement after the intravenous contrast medium.

CHAPTER OUTLINE:

/ Strengths, Weaknesses and Role of Imaging Modalities – **Interventional Radiology**

Interventional radiology is used for the treatment of some small bowel diseases. In active gastrointestinal bleeding, an intravascular radiological intervention can be performed to block the vessel that is bleeding. Also, image-guided percutaneous drainage can be performed for fluid collections and abscesses.

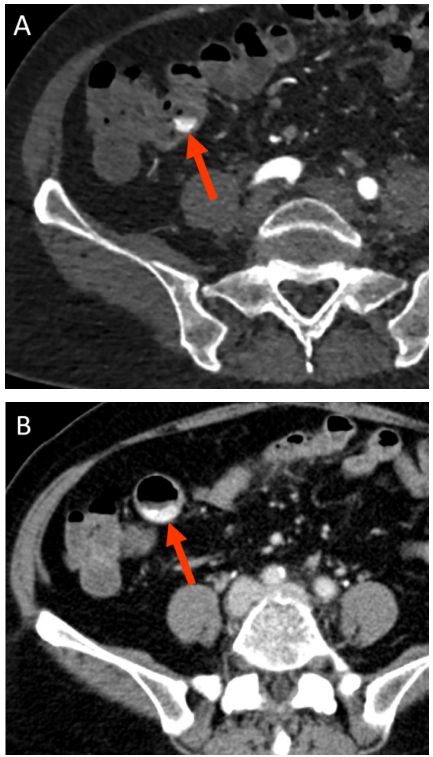


FIGURE 13

Transverse CT in the arterial phase (**A**) and portal venous phase (**B**) of a patient with arterial bleeding in the terminal ileum. The presence of contrast extravasation in the bowel lumen of the terminal ileum that increases in the portal venous phase indicates an active bleeding (**red arrow**).

FIGURE 14

An angiography was performed to treat the focus of the bleeding by intravascular embolisation but there was no contrast extravasation (blush) visualised. Bleeding can be intermittent. Therefore, no embolisation could be performed.

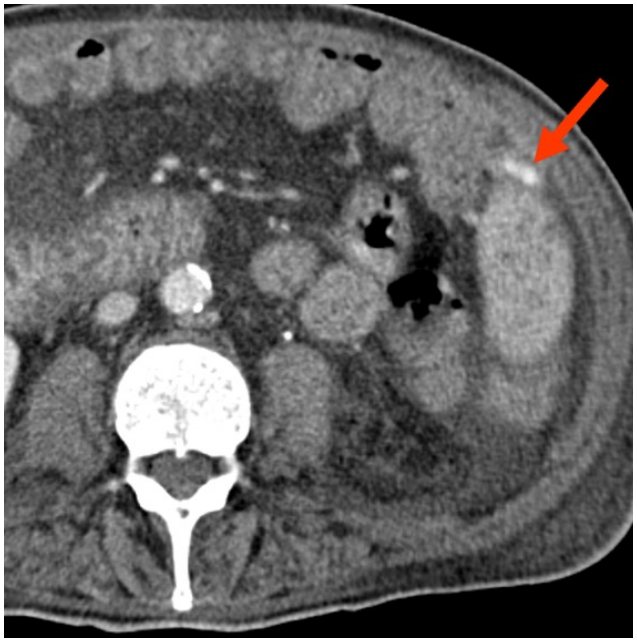


FIGURE 15

Transverse CT in the portal venous phase of a patient with an arterial bleeding in the jejunum. Contrast extravasation is present in the jejunum (**red arrow**) showing an active bleeding.

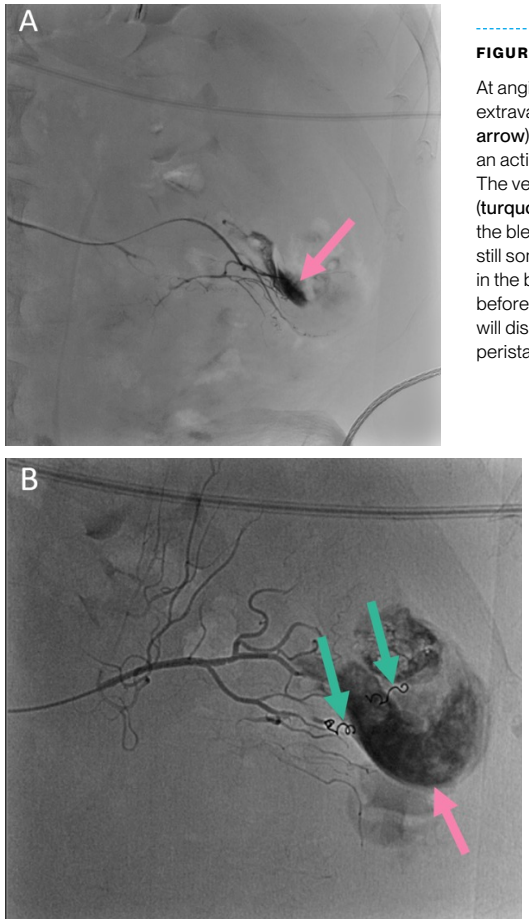


FIGURE 16 A&B

At angiography, contrast extravasation (blush, **pink arrow**) was seen indicating an active bleeding (**A**). The vessels were coiled (**turquoise arrows**) to stop the bleeding (**B**). There is still some contrast present in the bowel lumen from before the coiling, this will disappear due to peristalsis within minutes.

/ Small Bowel

CHAPTER OUTLINE:

Main Indications to Small Bowel Imaging by Pathology

CHAPTER OUTLINE:

/ Main Imaging Indications by Pathology

- / Congenital
- / Obstruction
- / Perforation/Trauma
- / Tumour
- / Inflammatory/Infectious
- / Ischaemia

/ Main Imaging Indications by Pathology – **Congenital**

- / Malrotation and volvulus
- / **Meckel's diverticulum:** see inflammation/infectious Perforation/trauma

/ Congenital: Malrotation & Volvulus

Intestinal malrotation is a congenital anomaly in which the intestines and its mesentery are rotated abnormally in the abdomen. In the abnormal situation, often the cecum lies in the right upper quadrant instead of the lower quadrant and the small bowel is localised mostly on the right side of the abdomen instead of the left side. The abnormal localisation can result in bowel twisting around itself leading to an obstruction of the blood flow and the bowel becoming ischaemic, which is called a volvulus. For a schematic overview please see (1).

Ultrasound is the recommended imaging modality for suspected volvulus in children.

<=> REFERENCE

(1) https://radiologyassistant.nl/pediatrics/abdominal-masses/acute-abdomen-in-neonates#congenital-high-obstruction

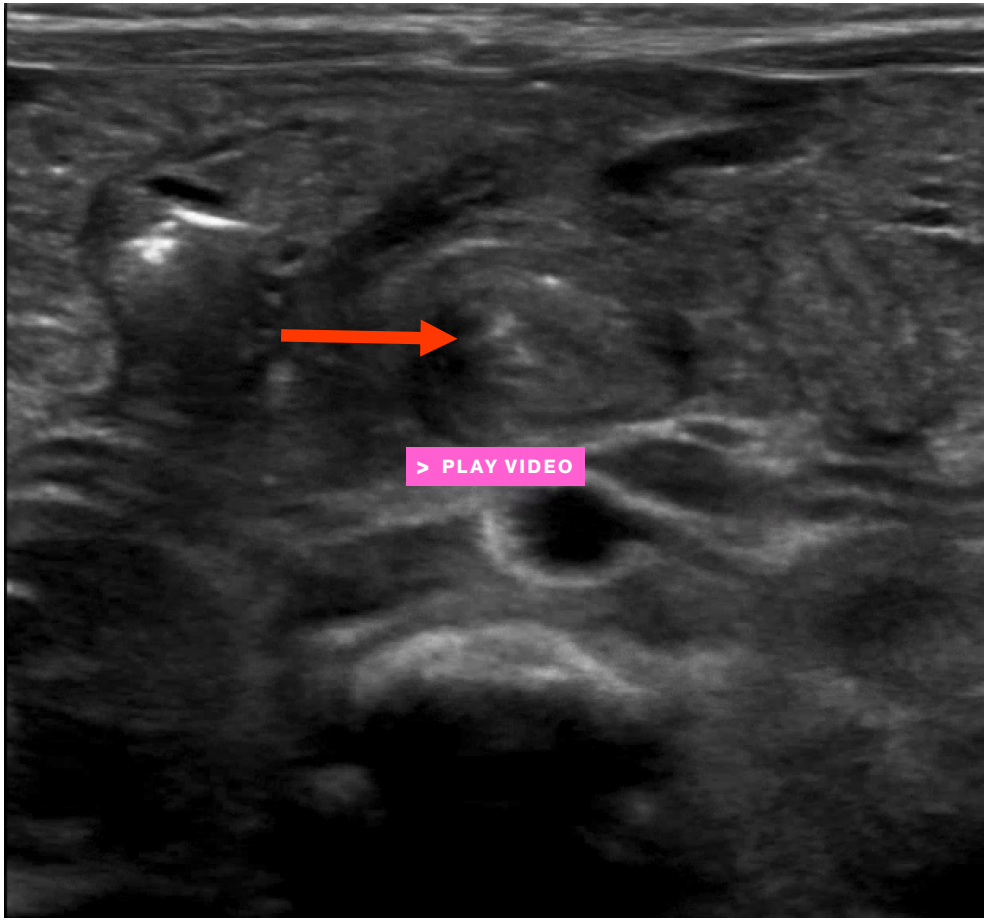
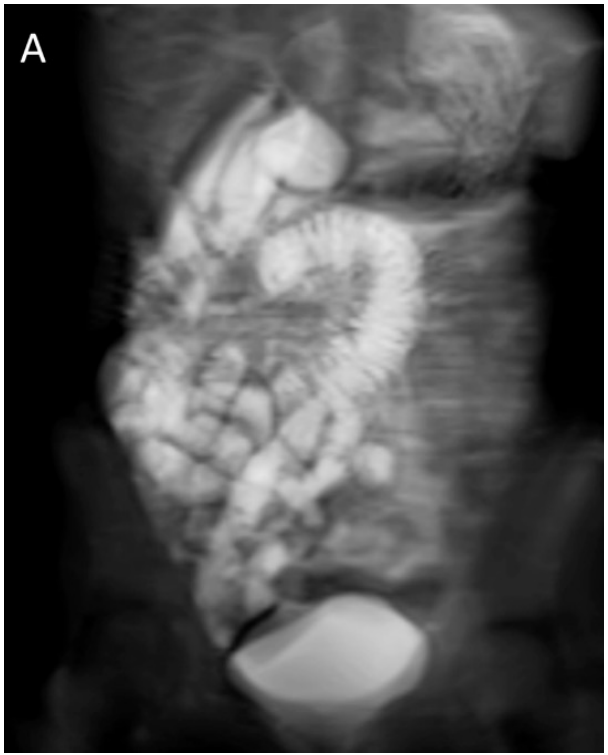


FIGURE 17

Ultrasonography of a child with a volvulus. The movie shows a transverse view with a circular, layered structure which is the small bowel with its mesentery, that twists around the superior mesenteric artery (**whirl sign, red arrow**).

Small Bowel

CHAPTER OUTLINE:



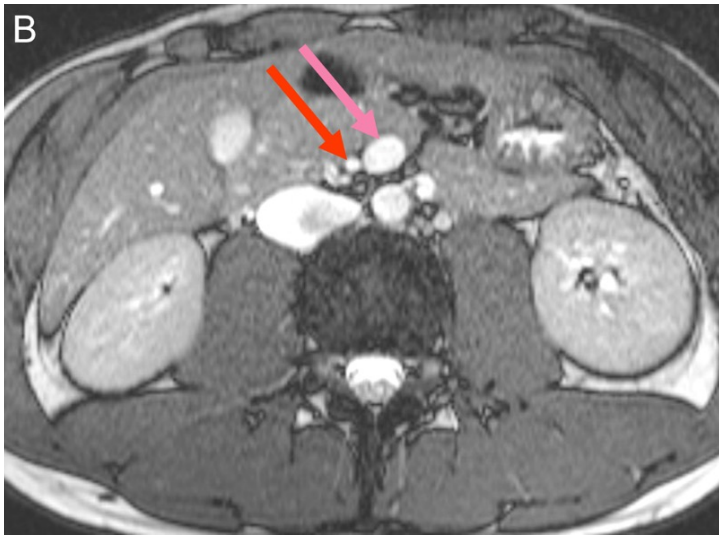


FIGURE 18 A&B

MRI of a 31-year old male with malrotation (midgut nonrotation). On the left (**A**), a coronal image showing that all small bowel loops are located on the right side of the abdomen. On the right image (**B**), a transverse view demonstrating reversed superior mesenteric artery (SMA) and superior mesenteric vein (SMV) relationships: SMV (**pink arrow**) on the left of the SMA (**red arrow**). It was an unexpected finding in this patient, MRI is usually not performed for this indication at this age. Images from Kavaliauskiene et al. Insights Imaging.2011;2:501–513.

Small Bowel

CHAPTER OUTLINE:

/ Main Imaging Indications by Pathology – **Obstruction**

- / Intussusception
- / Adhesions and internal herniation

<!> ATTENTION

/ Obstruction: Intussusception

Intussusception is a condition primarily occurring in children, in which a proximal small bowel loop is pulled into a more distal bowel loop. In some **cases** a lead point causing the invagination can be identified, such as a lymph node or a tumour. In most paediatric cases **however** there is no lead point identifiable, but in the small number of adults with an intussusception, there is almost always a lead point identified. It is an acute **diagnosis** and the bowel needs repositioning because it can lead to bowel ischaemia.

Ultrasonography is the first choice of imaging in paediatric cases. In young children often hydrostatic reposition will be attempted (i.e., the invaginated bowel is 'pushed back' by a fluid column introduced in the rectum) using ultrasound and/or fluoroscopic guidance before surgery will be considered.

<∞> REFERENCES

Del-Pozo G et al. Radiographics 1999. 19:299-319
Kim Y et a. Radiographics 2006. 26:733-744
Silva A et al. Radiographcs 2009. 29:423-439

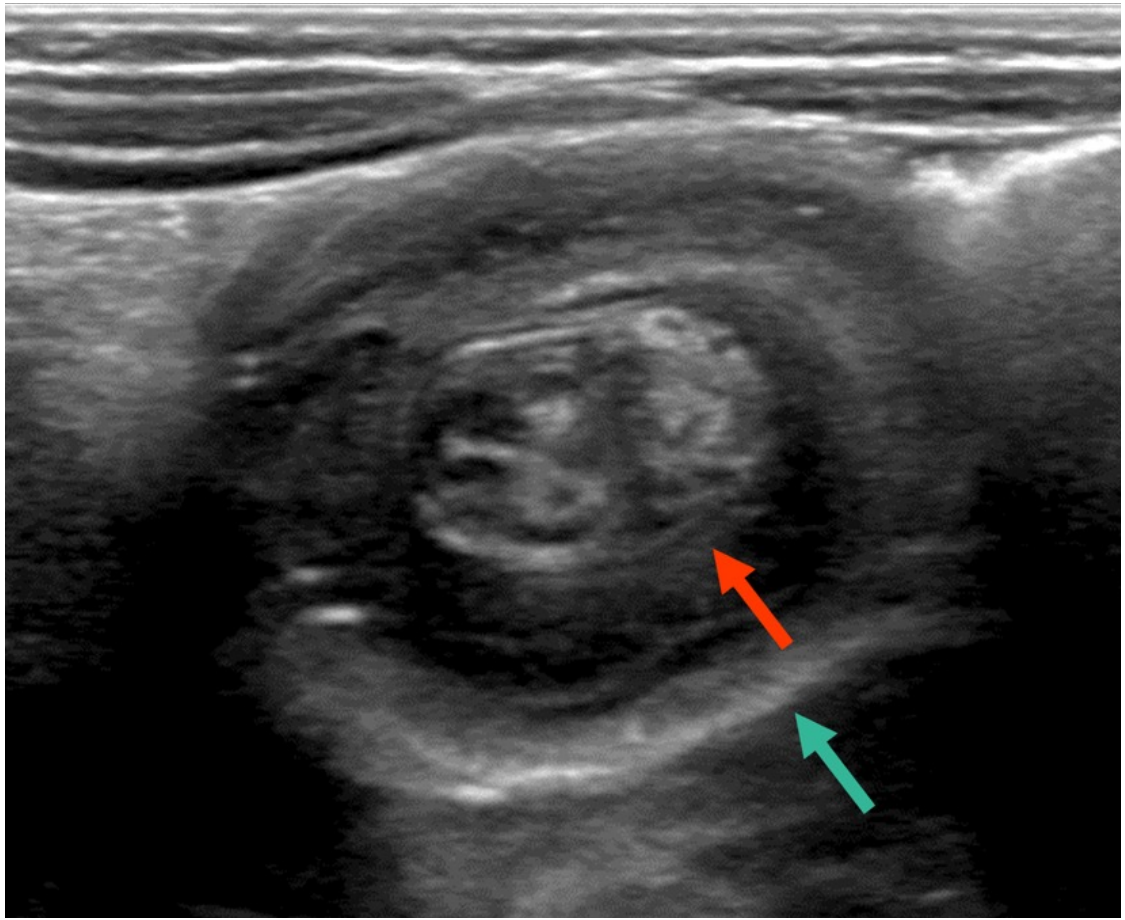
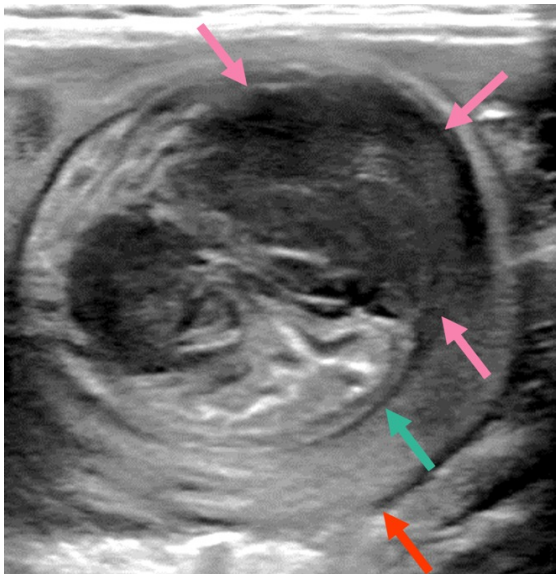


FIGURE 19

Ultrasonography in transverse view of a 22-month old child with an ileocecal intussusception. The **red arrow** points at the ileum that is inside the cecum (**turquoise arrow**) (doughnut sign).

Small Bowel

CHAPTER OUTLINE:



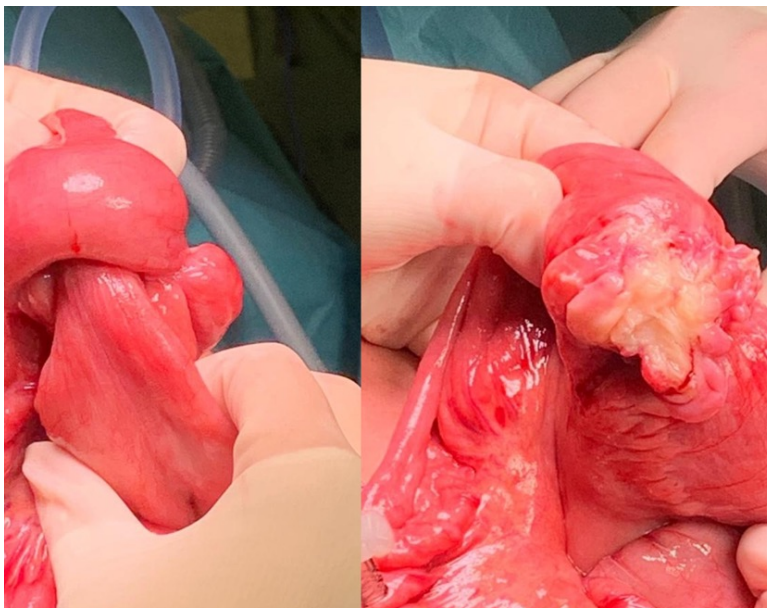


FIGURE 20 & 21

Ultrasonography in transverse view of a more rare case of a 5-year old child with an ileo-ileal intussusception due to a tumour. The **turquoise arrow** points at the ileum with mesentery that is invaginated inside another ileal loop, shown by the **red arrow**. The **pink arrows** point at the hypoechoic tumour that is the lead point in this case. On the right, the pictures at surgery with at the left the intussusception and at the right the tumour that had caused the intussusception (lead point) cut open. At histopathology a Burkitt lymphoma was found. Images from surgery, courtesy of C. de Raaff, MD.

/ Small **Bowel**

CHAPTER OUTLINE:

<!> ATTENTION

/ Obstruction: Adhesions, Internal Herniation and Closed Loop Obstruction

Small bowel obstruction is a relatively common diagnosis in adults and is often caused by adhesions. These fibrous bands in the abdominal cavity occur regularly in patients that underwent surgery or radiotherapy in the past and can cause blockage of the small bowel.

Another cause of small bowel obstruction is internal herniation, in which small bowel loops protrude through an entry point of the peritoneum or mesentery leading to obstruction.

A more serious complication that can be caused by adhesions and/or internal herniation is a closed loop obstruction. In this disorder, the small bowel is herniated and closed off at two separate bowel loops. This causes obstruction of the blood flow to the bowel loop in between, which can become ischaemic and necrotic, resulting in high mortality when not treated in time (for a schematic overview, see*).

In adult cases suspected of small bowel obstruction, CT with intravenous contrast administration is therefore recommended.

<∞> REFERENCES

* https://radiologyassistant.nl/abdomen/bowel/closed-loop-in-small-bowel-obstruction

Del-Pozo G et al. Radiographics 1999. 19:299-319
Kim Y et a. Radiographics 2006. 26:733-744
Silva A et al. Radiographics 2009. 29:423-439

/ Obstruction: Adhesion

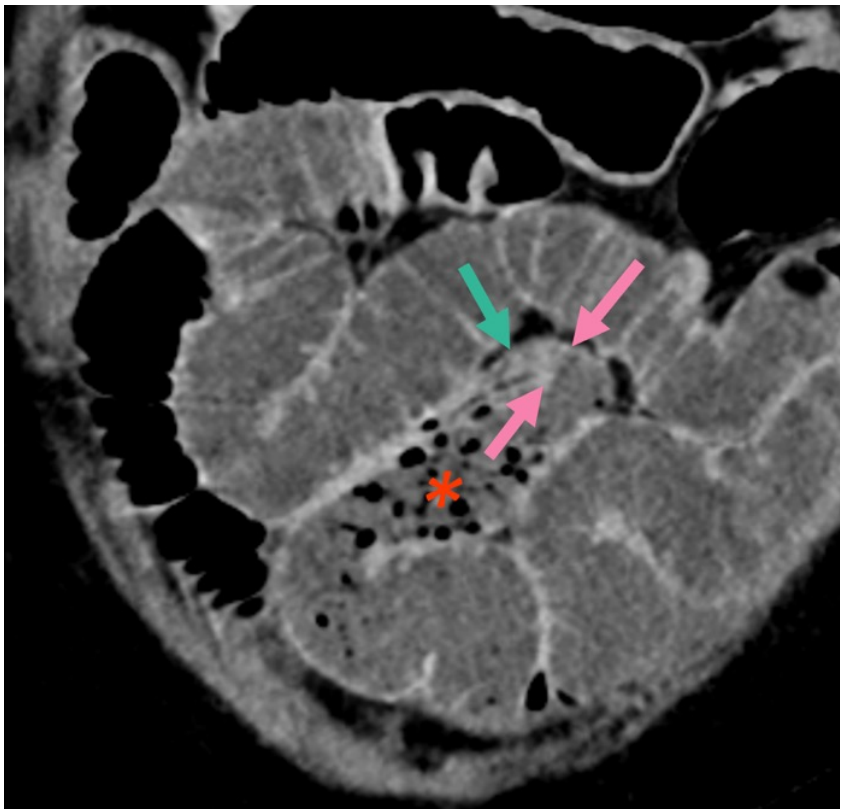


FIGURE 22

Coronal CT scan after intravenous contrast administration of a patient with a small bowel obstruction due to an adhesion. Several dilated small bowel loops are seen upstream of the obstruction, here a calibre change in the small bowel is seen indicating the adhesion (**pink arrows**). Proximal of the obstruction there is stasis leading to gas bubbles (faecal-like material in the small bowel, known as 'small bowel faeces sign' *) and distally to the obstruction the small bowel loop is collapsed (**turquoise arrow**). There is normal bowel wall enhancement.

CHAPTER OUTLINE:

/ Obstruction: Closed Loop Obstruction

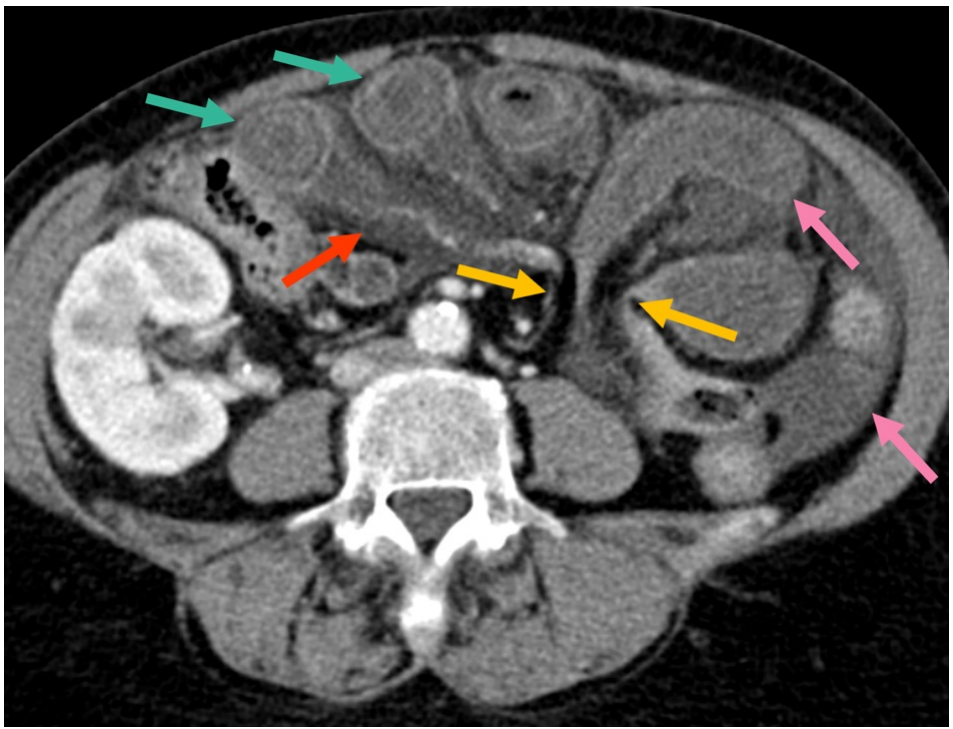


FIGURE 23

Transverse CT image after intravenous contrast administration in a patient with internal herniation of small bowel loops through a peritoneal or mesenteric orifice. The small bowel loops distend because of bowel obstruction leading the bowel to be trapped beyond the orifice, i.e. 'closed loop obstruction'.

The increased intraluminal pressure first will decrease venous outflow which will increase the pressure in the bowel wall and subsequently decrease arterial inflow, leading to bowel ischaemia and bowel necrosis.

At CT, the bowel loops have a thickened wall due to venous congestion in which you can see a layered pattern (water target sign, **turquoise arrows**), decreased enhancement and thinned walls due to arterial ischaemia (**pink arrows**) and there is mesenteric oedema (**red arrow**). Between the yellow arrows is the point of herniation.

This patient was operated on acutely. A necrotic small bowel loop of 60 cm was resected after which the patient had a good recovery.

CHAPTER OUTLINE:

/ Obstruction: Closed Loop Obstruction

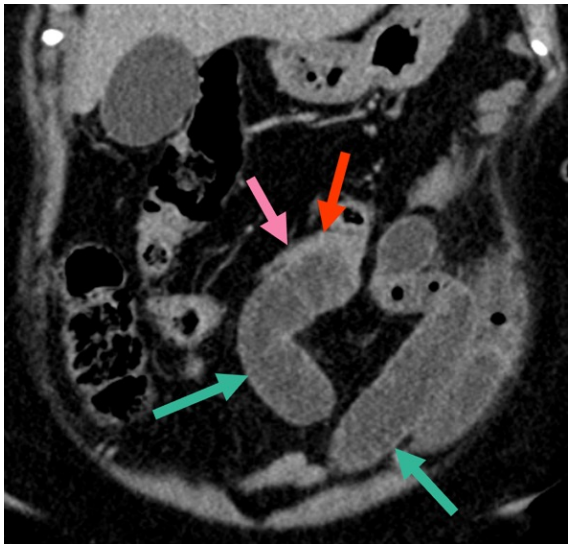


FIGURE 24

Coronal CT scan after intravenous contrast administration in a patient with a closed loop obstruction due an omental adhesion to the sigmoid. As in the previous case, the small bowel loops are distended (**turquoise arrows**). The bowel walls enhance showing that there is still arterial inflow. One point of internal herniation is shown by the **red arrow**, the **pink arrow** points at the collapsed small bowel loop before the distended bowel loop.

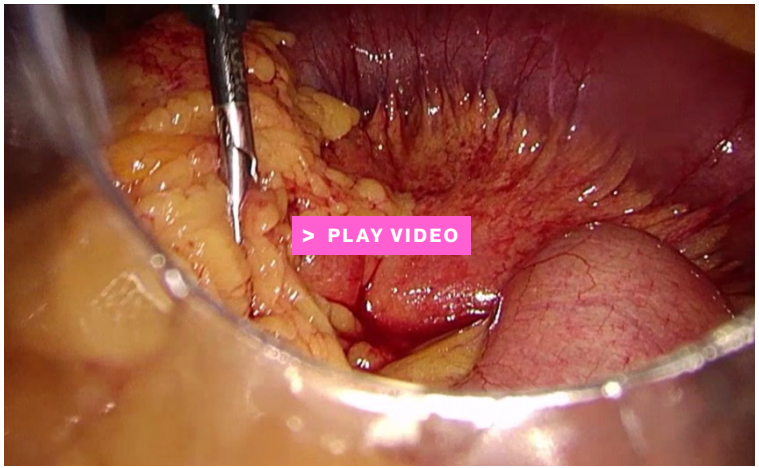


FIGURE 25

This patient was operated on acutely, a movie of the surgery is shown here. A discoloured, ischaemic bowel loop can be seen at the back and a vital bowel loop in front. The adhesion is cut, after which the bowel starts to gain back its normal colour. The patient had a full recovery after surgery. Video from surgery: courtesy of R.J. Swijnenburg, MD.

/ Main Imaging Indications by Pathology – **Perforation**

Perforation of the small bowel mostly occurs in the duodenum due to an ulcer. Other causes of small bowel perforation are sharp trauma, foreign body or perforation due to bowel ischaemia. In case of a suspected gastrointestinal perforation, a CT with intravenous contrast medium is indicated as it is the most accurate technique for detection of contained or free air, the location of the perforation and possible complications (e.g. abscess). Free intraperitoneal air and perforations can be identified at ultrasonography, but less readily and less accurate than at CT. Abdominal radiography (either supine or upright) have been surpassed by CT for the detection of a small bowel perforation while radiography does not give information on the site of the perforation or possible complications.

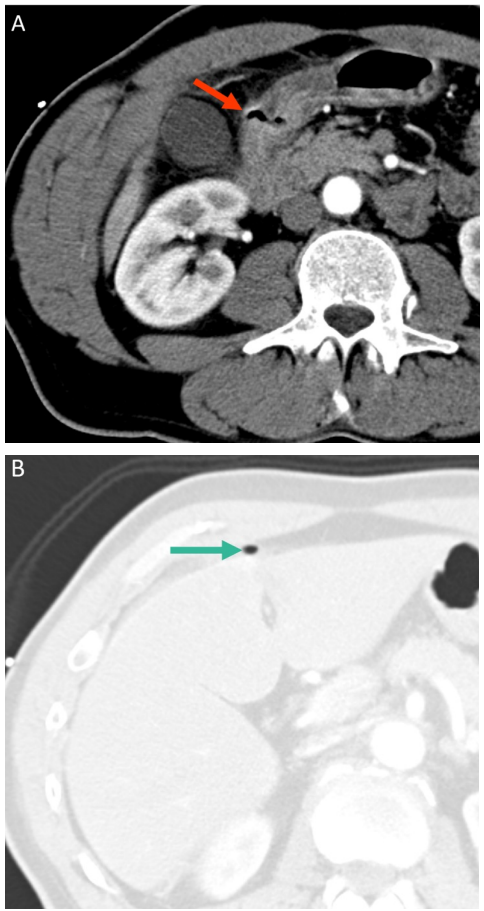


FIGURE 26 A&B

Transverse CT scan of a patient with a duodenal perforation. A perforated duodenal ulcer (**A**) is shown (**red arrow**). On the same CT scan, a small air bubble (**turquoise arrow**) corresponding to intraperitoneal free gas is seen on the lung window setting obtained at the level of the liver (**B**).

/ Duodenal Perforation

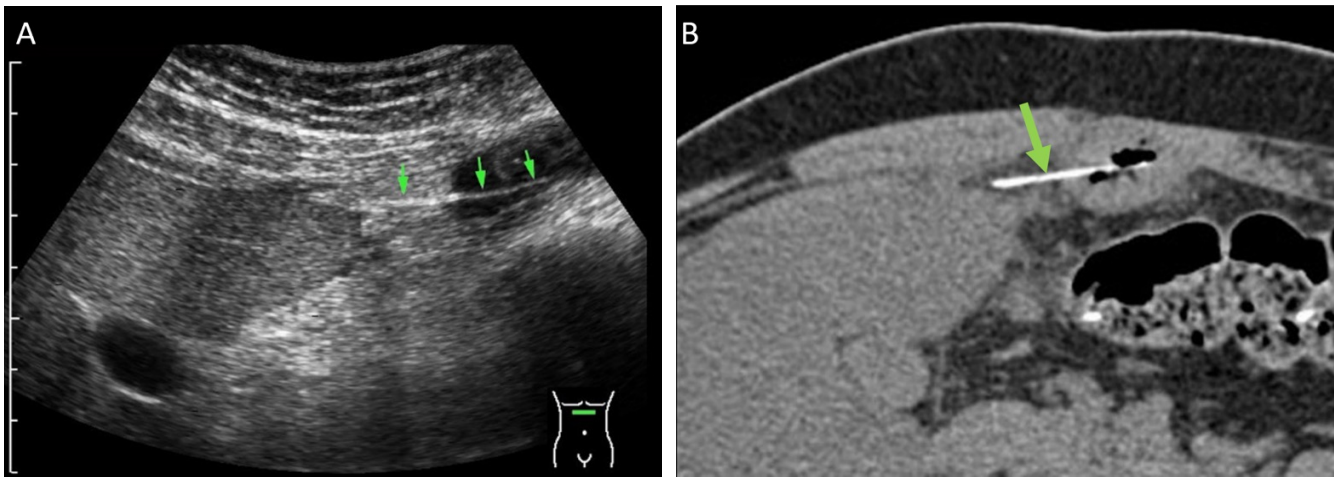


FIGURE 27 A&B

Ultrasonography and CT scan of a patient with a perforation due to a fishbone. On the left the ultrasonography in longitudinal view on which the fishbone is indicated with **green arrows**. On the right, the CT scan in transverse view reveals similar findings with the fishbone pointed out by the **green arrow**.

CHAPTER OUTLINE:

/ Main Imaging Indications by Pathology – **Tumour**

/ Polyps

/ Tumours

/ Tumour: Polyps

There is a limited indication to visualise polyps with radiological imaging; mostly endoscopy is used to diagnose and treat polyps. However, in syndromes with multiple polyps, such as Peutz-Jeghers syndrome, regular surveillance with video capsule enteroscopy or MR enterography is recommended.

/ Tumour: Polyps

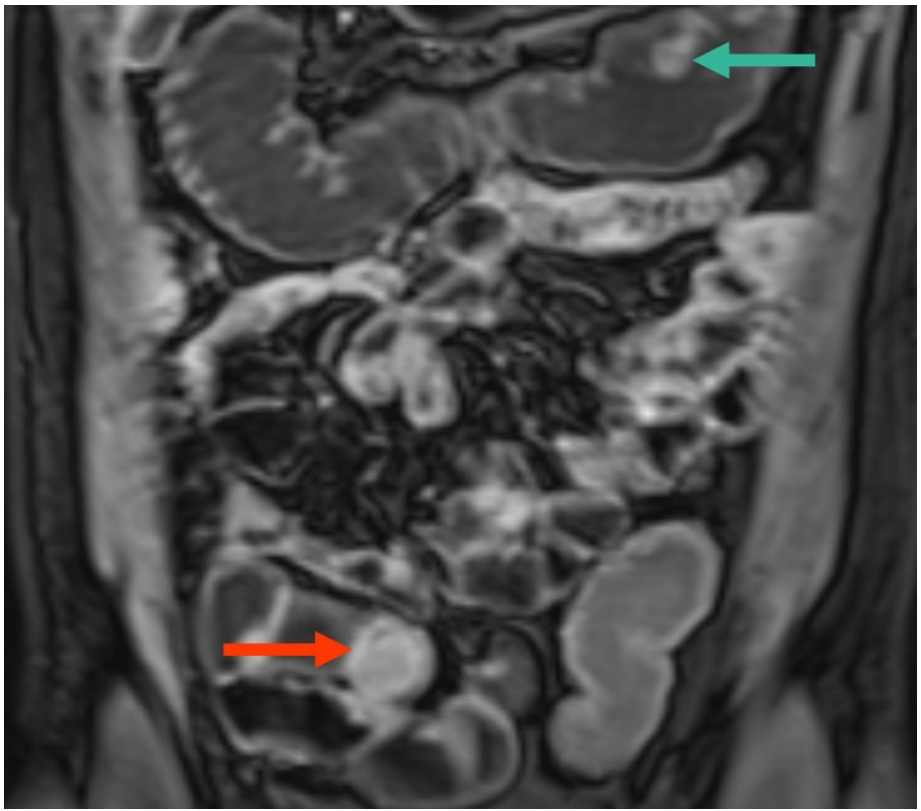


FIGURE 28

Coronal MR enterography after intravenous contrast administration in a patient with multiple polyps due to Peutz-Jeghers syndrome. The enhanced round lesion in the lumen of the ileum (**red arrow**) is a polyp and another polyp is present in the transverse colon (**turquoise arrow**).

CHAPTER OUTLINE:

/ Main Imaging Indicationy by Pathology – **Tumour**

Tumours rarely occur in the small bowel. Different subtypes can develop of which the most prevalent is adenocarcinoma, followed by neuroendocrine tumours, lymphomas and sarcomas.

CT or MR enterography with intravenous contrast media are indicated to visualise tumours of the bowel wall.

/ Tumour: Lymphoma

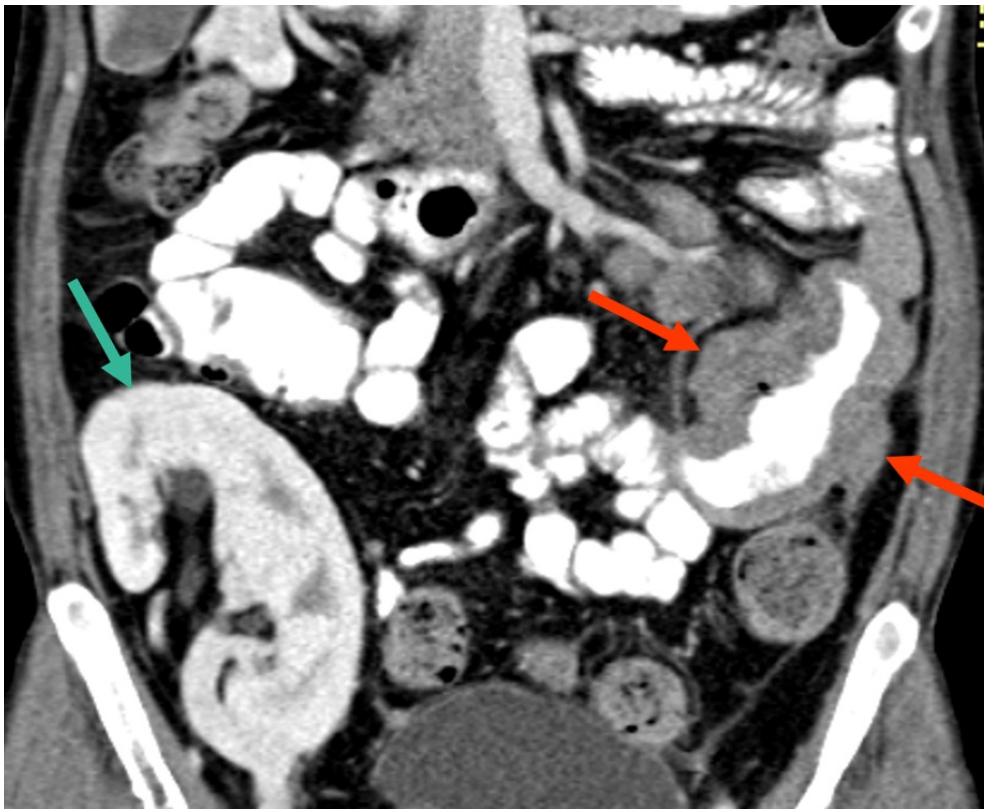


FIGURE 29

Coronal CT scan after oral and intravenous contrast administration of a patient with lymphoma (**red arrows**). Typical of lymphomas is that the tumour despite its size does not obstruct the bowel, the bowel wall is thickened but there is still patent lumen present. The cause of the lymphoma in this case is most likely immunosuppressant therapy after a kidney transplant (abnormal kidney localisation in the right iliac fossa; **turquoise arrow**).

/ Tumour: Neuroendocrine Tumour

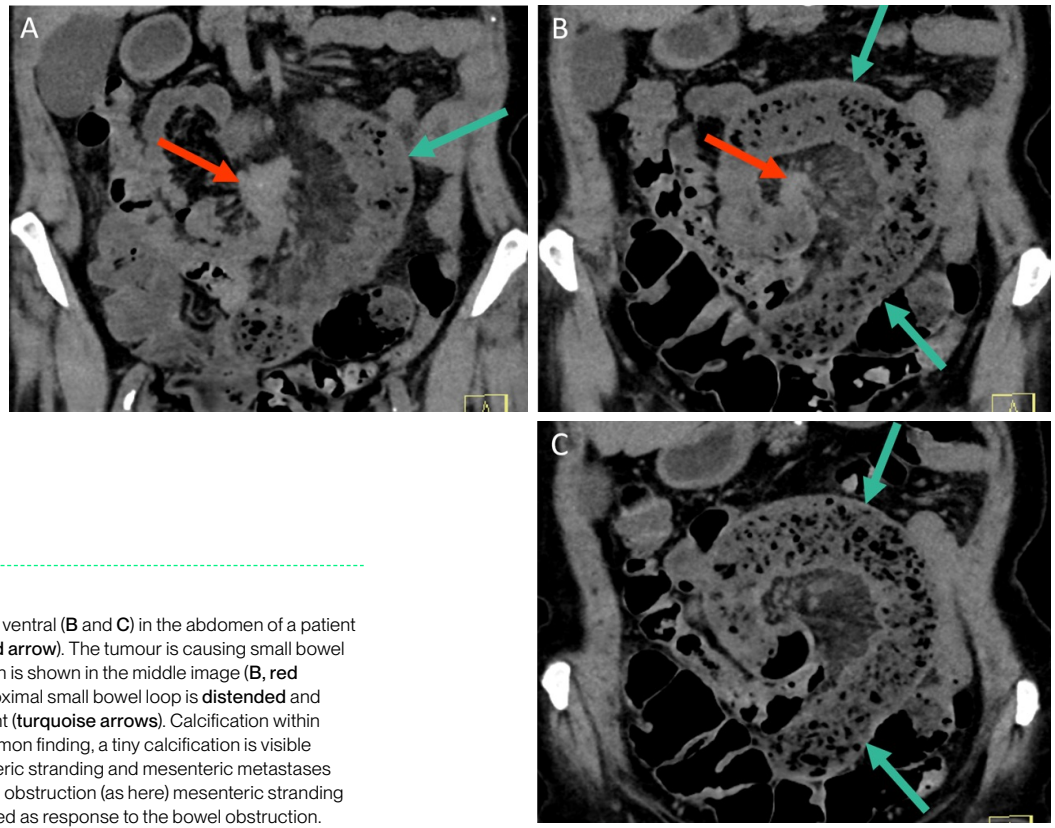


FIGURE 30

Coronal CT scan from dorsal (**A**) to ventral (**B** and **C**) in the abdomen of a patient with a neuroendocrine tumour (**red arrow**). The tumour is causing small bowel obstruction, the point of obstruction is shown in the middle image (**B, red arrow**). Due the obstruction the proximal small bowel loop is **distended** and a small bowel faeces sign is present (**turquoise arrows**). Calcification within a neuroendocrine tumour is a common finding, a tiny calcification is visible centrally in the tumour (**A**). Mesenteric stranding and mesenteric metastases can be seen, but in a case of bowel obstruction (as here) mesenteric stranding and small nodules ca also be caused as response to the bowel obstruction.

/ Main Imaging Indications by Pathology – **Inflammation/Infection**

- / Meckel's Diverticulum
- / Crohn's disease

/ Inflammation/ Infection: Meckel's Diverticulum

Meckel's diverticulum is a congenital remnant resulting from failed closure of the embryological connection between the umbilicus and the small bowel. It is visible as a bulge in the ileum of the small bowel at the anti-mesenterial site. It is a true diverticulum (i.e., has all bowel wall layers) and the most common congenital defect of the gastrointestinal tract (about 2-3% of the general population). The diverticulum can get inflamed (diverticulitis) which requires treatment; it can also bleed.

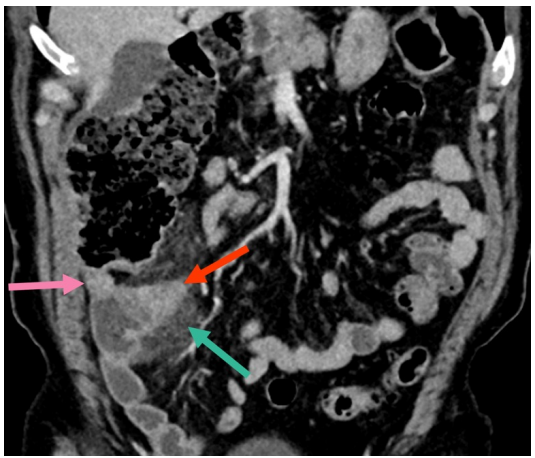


FIGURE 31

Coronal CT scan after intravenous contrast administration of a patient with an inflamed Meckel's diverticulum, seen as a bulge in the ileum (**red arrow**); the ileum continues at the **pink arrow**. Induration in the surrounding tissue is seen due to inflammation (**turquoise arrow**).

/ Inflammation/Infection: Crohn's Disease

Crohn's disease is a chronic inflammatory bowel disease. Patients are of all ages but often are diagnosed at an adolescent age. Most patients require several therapies throughout their lives, including medication and surgery, and they often need repeated imaging. The disease presents with inflammation of the bowel wall, which is typically seen as bowel wall thickening and increased vascularisation on imaging. Over time, complications such as fistulas (connections from one bowel loop to another bowel loop, to adjacent organs or the skin), abscesses and strictures of the bowel can occur.

Ultrasound, CT and MR enterography can be used for these type of patients, MRI is preferred over CT in young patients since repeated imaging is often required. In an acute setting often US and CT are performed over MRI as they are more easily accessible and available.

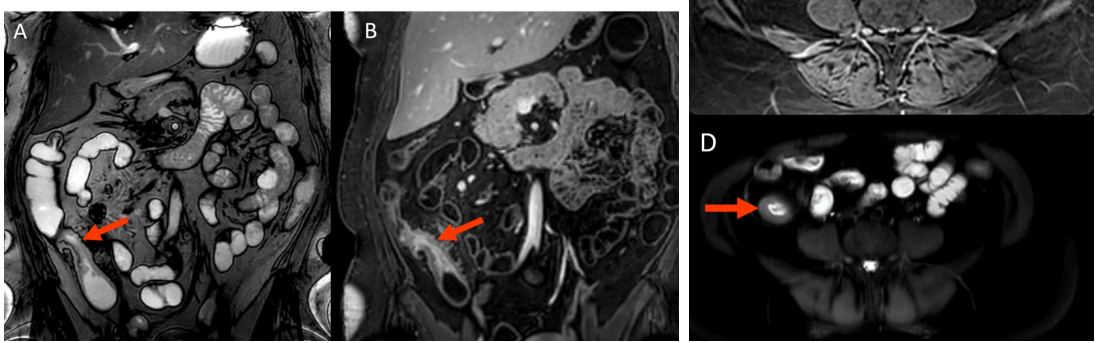
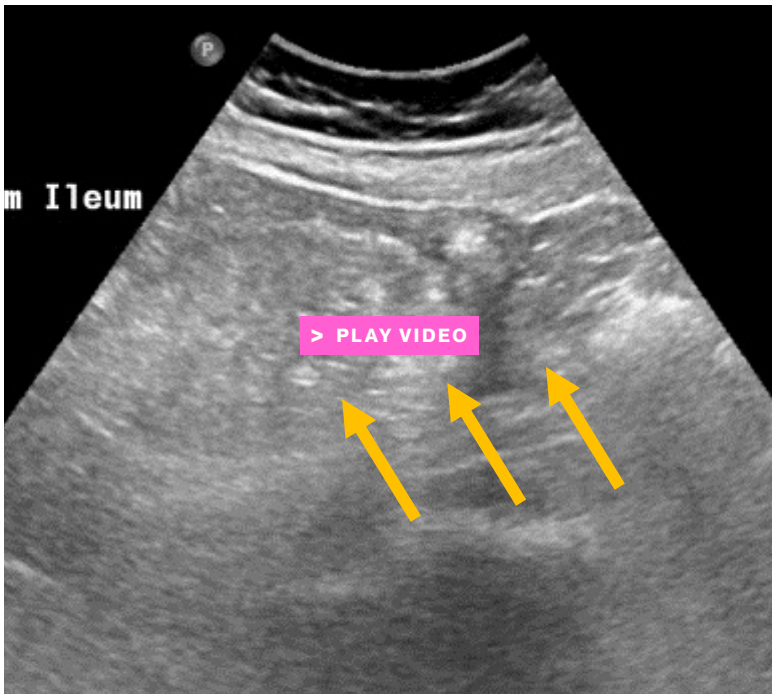


FIGURE 32

MR enterography of a patient with Crohn's disease. On the left, two different coronal sequences and on the right two different transverse sequences. The **red arrow** points at the terminal ileum with thickened bowel wall and stenosis, the area proximal to the thickened bowel wall is somewhat dilated (pre-stenotic dilation) because the downstream terminal ileum lumen is narrowed. B and C show increased enhancement after intravenous contrast administration due to increased vascularisation and D shows bowel wall oedema, caused by inflammation, on a T2-weighted sequence with fat suppression. There is a growing interest in differentiating between bowel wall inflammation and fibrosis (which develops over time), but at this time point imaging is not accurate in this differentiation yet.

CHAPTER OUTLINE:

/ Inflammation/Infection: Crohn's Disease



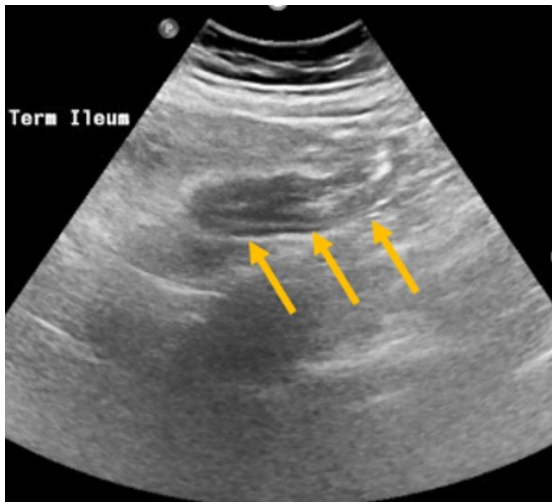


FIGURE 33

Ultrasonography of the same Crohn's disease patient as on the previous slide. On the left, a movie in the longitudinal view of the terminal ileum with a thickened wall at the ileocecal valve. On the right, a still frame of this movie with the terminal ileum pointed out.

/ Inflammation/Infection: Crohn's Disease

>|< COMPARE

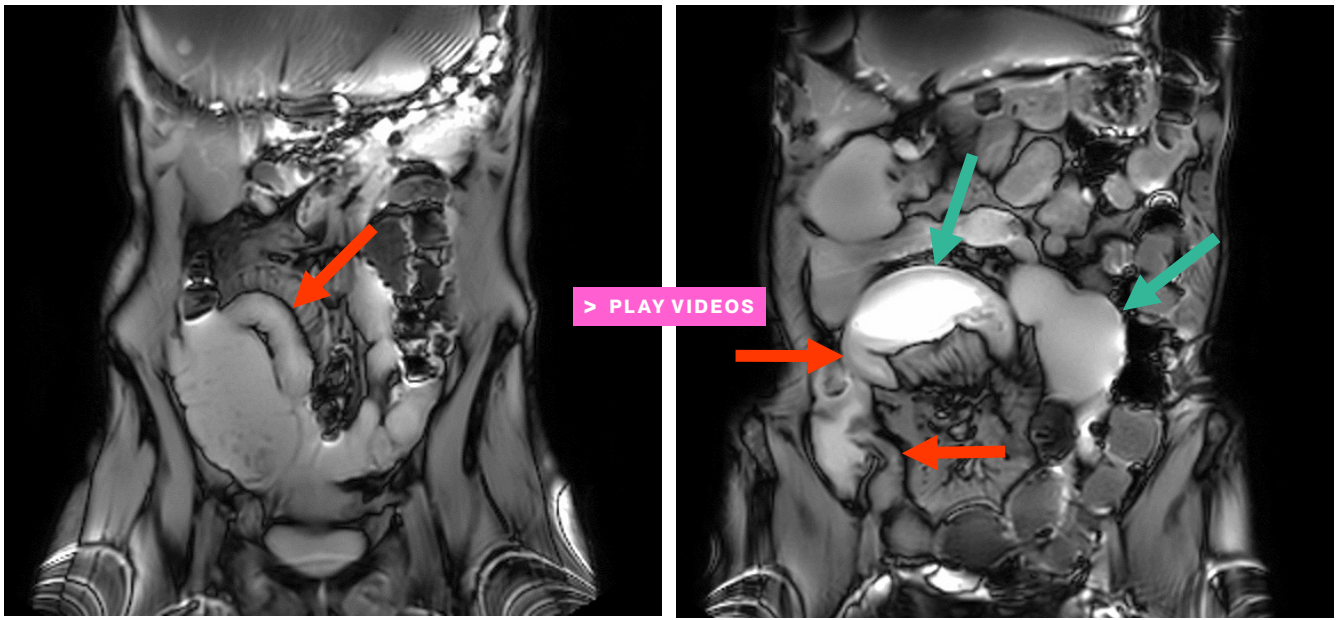


FIGURE 34 & 35

Movies of coronal cine-MRI scans of two patients with Crohn's disease. This sequence can be performed to obtain information about the functionality of the small bowel. In Crohn's disease, motility is decreased in the diseased segment (**red arrows**). In some patients, due to stenosis, the prestenotic segment is dilated and can have increased motility, shown in two separate bowel loops in the right image (**turquoise arrows**).

/ Inflammation/Infection: Crohn's Disease

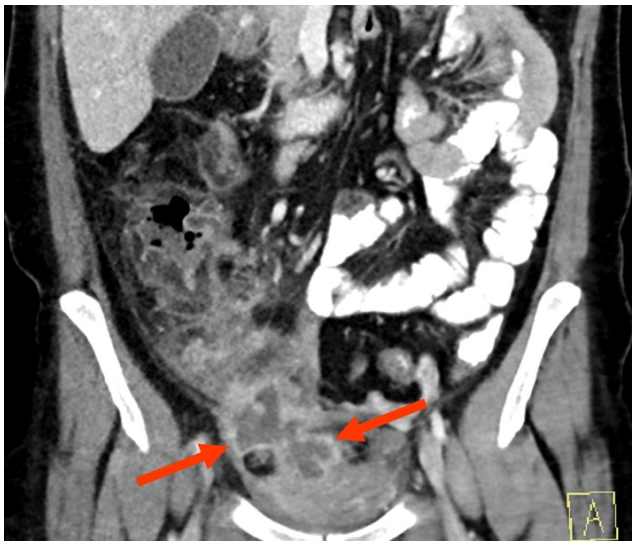


FIGURE 36

Coronal CT scan after oral and intravenous contrast administration of a patient with fistulas and an abscess due to Crohn's disease. Complications of Crohn's disease include fistulas and abscesses (**red arrows**). This patient required abscess drainage.

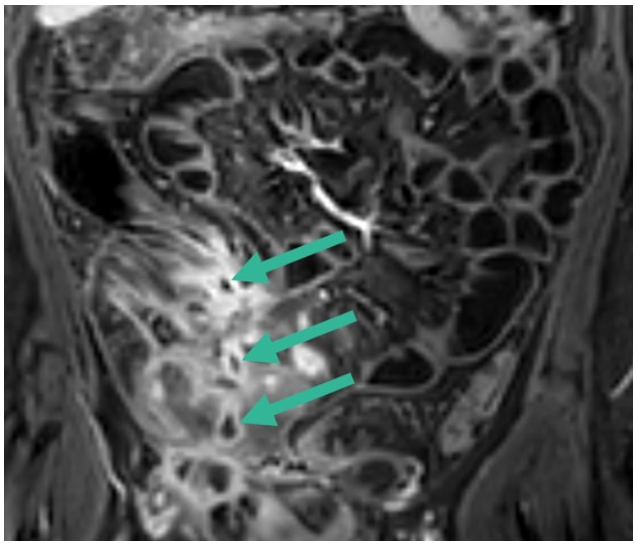


FIGURE 37

Coronal MRI scan after oral and intravenous contrast administration of the same patient. The patient required resection of the inflamed bowel segment and the fistula complex; the MRI scan was performed for surgical guidance. The **turquoise arrows** show different parts of the fistula tracts.

/ Inflammation/Infection: Crohn's Disease

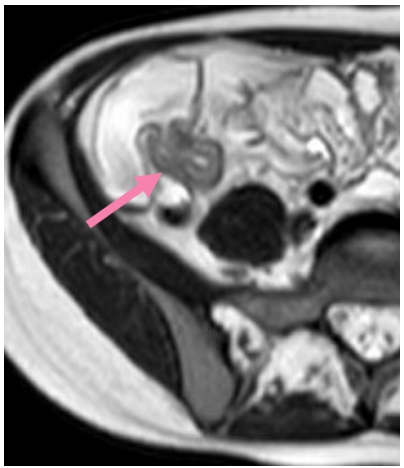


FIGURE 38

Transverse MRI scan of an inflamed terminal ileum (**pink arrow**) in a patient with Crohn's disease for which an ileocecal resection was performed.

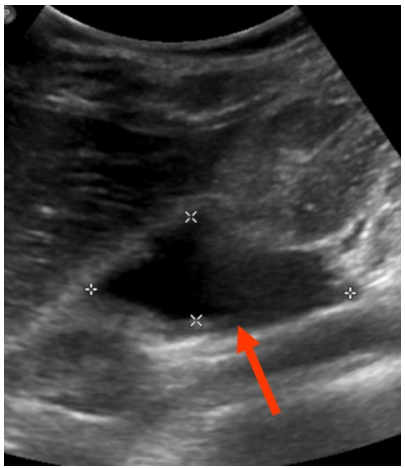


FIGURE 39

Ultrasound 10 days postoperatively at which a fluid collection is seen (**red arrow**), most likely due to an anastomotic leakage.

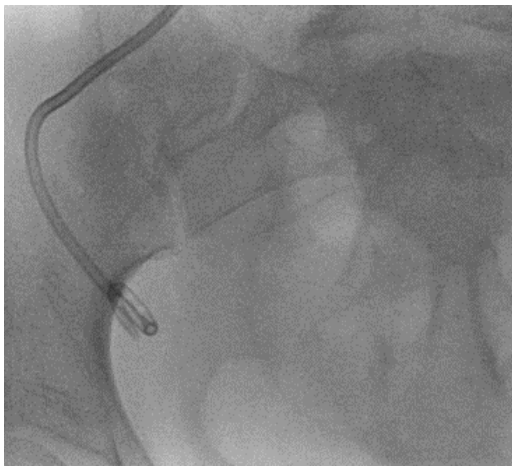


FIGURE 40

Using fluoroscopic guidance, a drain was inserted in the fluid collection in the pelvis after which the patient had a good recovery.

/ Main Imaging Indications by Pathology – **Ischaemia**

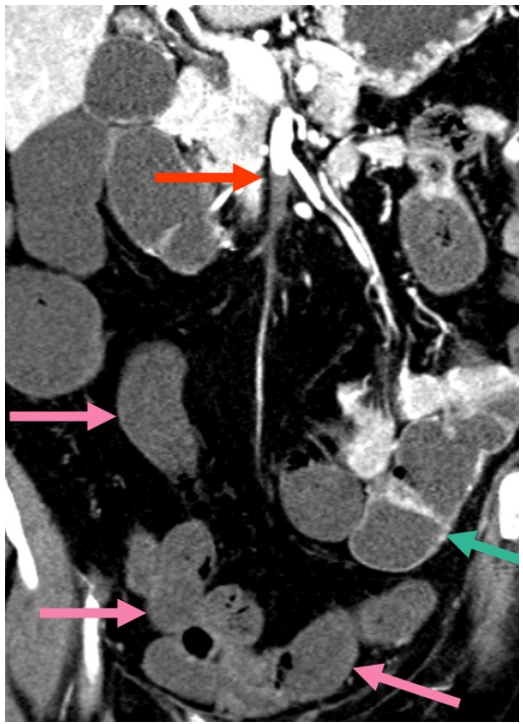
Ischaemia can be caused by an arterial obstruction due to thrombosis or an embolus resulting in a reduced or absent blood supply to the downstream small bowel. Also, a dissection can occur in the superior mesenteric artery (often as continuation of an aortic dissection) and results in a decreased or absent blood flow to the small bowel causing bowel ischaemia. Also, venous outflow obstruction can lead to bowel ischaemia.

Non-occlusive mesenteric ischaemia (NOMI) causes bowel ischaemia by a systemic hypoperfusion (e.g. shock due to sepsis or hypovolemia) which results in an inadequate blood supply to the bowel in the absence of an occlusion.

CT angiography can be performed in cases that have suspected abnormalities in vascularisation of the small bowel.

FIGURE 41

Coronal CT scan after intravenous contrast administration of a patient with bowel ischemia due to a dissection of the superior mesenteric artery. The **red arrow** points out the dissection at the point of transition from hyperintense (contrast medium) to hypointense (lack of contrast medium) in the vessel. A part of the small bowel enhances (**turquoise arrow**) where there is still patent vascularisation and a part of the small bowel shows no enhancement (**pink arrows**) which is a sign of ischemia.



/ Ischaemia

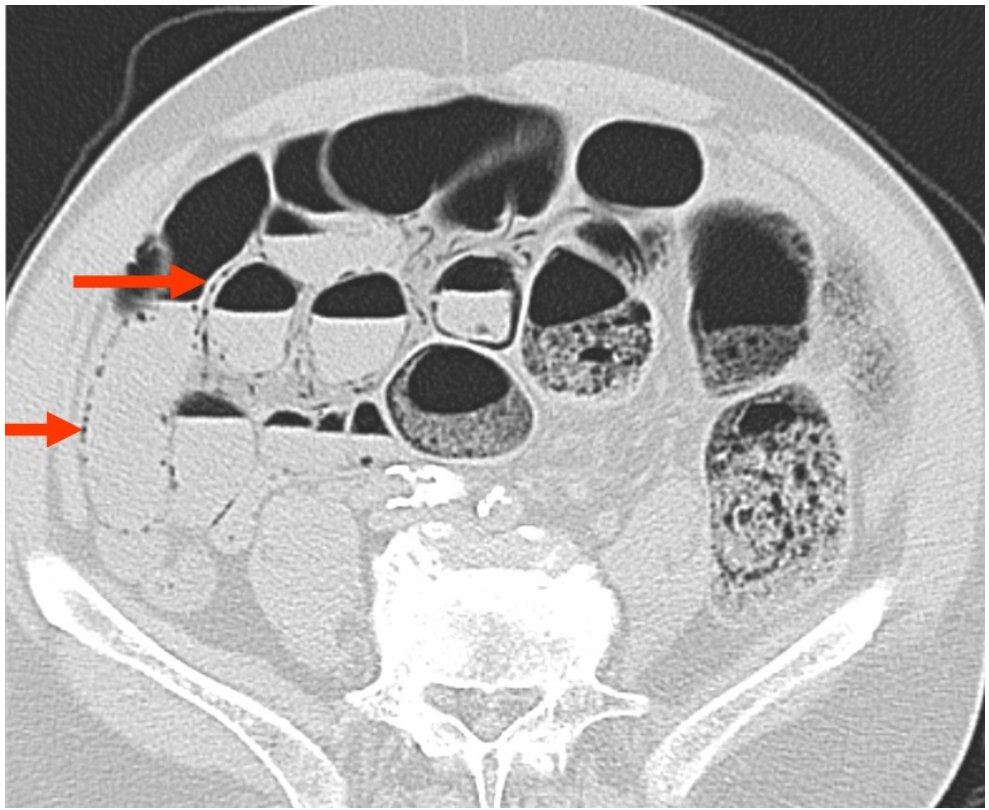


FIGURE 42

Transverse CT scan in lung window setting of a patient with bowel ischaemia. The bowel loops are distended and within the bowel wall there is gas present (pneumatosis intestinalis) which is seen as small hypodense spots (black spots) following the bowel wall (**red arrows**). Pneumatosis intestinalis can be caused by many conditions and is not a pathognomonic sign for bowel ischaemia.

/ Take-Home Messages

- Plain abdominal radiographs has no role in visualising the small bowel.
- Ultrasonography is the first-line imaging technique of the small bowel in the paediatric population.
- CT is widely used for visualising the small bowel as it is a fast, readily available technique with a large field of view; the CT acquisition protocol is adapted to the clinical setting.
- Ionising radiation exposure is the main limitation of CT.
- MRI has inherent high contrast resolution, is versatile and lacks ionising radiation.
- For MRI availability/access are often limited and the examination takes more time than CT.
- Small bowel diseases are a common cause of acute abdominal pain and ultrasonography and CT play an important role in management of these diseases.
- The overview and better assessment of complications favours CT over ultrasonography in bowel obstruction; CT is crucial for the timely diagnosis of bowel ischaemia.
- MRI and ultrasonography are preferred for small bowel Crohn's disease, with MRI having the advantage of high inherent contrast resolution and a large field of view while ultrasonography is an easily assessable, interactive, high spatial resolution technique.

/ Take-Home Messages

- CT is most commonly used in patients with oncologic diseases of the small bowel; MRI (and in some cases ultrasonography) are alternatives.
- Imaging has a limited role in diagnosing intraluminal small bowel diseases (e.g., polyps); CT or MRI are mostly used, CT having higher spatial resolution and MRI lacking ionising radiation exposure (especially relevant when surveillance is needed, necessitating multiple examinations over time).

/ References

Websites

/ https://radiologyassistant.nl/pediatrics/acute-abdomen/acute-abdomen-in-neonates#congenital-high-obstruction-mal-rotation

/ https://radiologyassistant.nl/abdomen/bowel/closed-loop-in-small-bowel-obstruction

/ https://radiologyassistant.nl/abdomen/bowel/crohn-s-disease

Articles

/ Kavaliauskiene et al. Insights Imaging.2011;2:501–513

/ Del-Pozo G et al. Radiographics 1999. 19:299-319

/ Kim Y et a. Radiographics 2006. 26:733-744

/ Silva A et al. Radiographcs 2009. 29:423-439

/ Gosangi et al. Radiogaphics 2020. 40:1441-1457

/ Jasti et al. Radiographics 2020. 40:1020-1038

/ Van Leerdam et al. 2019 Endoscopy. 51:877-895

/ Bruining et al. Radiology 2020. 286:776-799

/ Sugi et al. Radiographics 2018. 38:1352-1369

/ Kanasaki et al. Radiographics 2018. 38:945-961

/ Zins et al. Radiology 2020. 296:480-492.

/ Paulson et al. Radiology 2015. 275(2):332-42.

Test Your Knowledge

CHAPTER OUTLINE:

/ Test Your Knowledge

<?> QUESTION

1 **The CT protocol in small bowel obstruction includes**

- ☐ Intravenous contrast medium
- ☐ Oral contrast medium
- ☐ Oral water
- ☐ Rectal contrast medium

/ Test Your Knowledge

<?> ANSWER

1 **The CT protocol in small bowel obstruction includes**

- ■ Intravenous contrast medium
- ☐ Oral contrast medium
- ☐ Oral water
- ☐ Rectal contrast medium

/ Test Your Knowledge

<?> QUESTION

2 In intussusception

- ☐ A lead point can always be identified
- ☐ A lead point is almost always visible in children, but rarely in adults
- ☐ No rectal contrast medium is needed
- ☐ CT should be performed

/ Test Your Knowledge

<?> ANSWER

2 In intussusception

- ☐ A lead point can always be identified
- ☐ A lead point is almost always visible in children, but rarely in adults
- ■ No rectal contrast medium is needed
- ☐ CT should be performed

/ Test Your Knowledge

<?> QUESTION

3 In closed loop obstruction

- ☐ The cause is mostly a large obstructive small bowel polyp
- ☐ The complete small bowel is dilated
- ☐ Ischaemia is a rare complication
- ☐ The bowel wall can be thickened or thinned

/ Test Your Knowledge

<?> ANSWER

3

In closed loop obstruction

- ☐ The cause is mostly a large obstructive small bowel polyp
- ☐ The complete small bowel is dilated
- ☐ Ischaemia is a rare complication
- ■ The bowel wall can be thickened or thinned

/ Test Your Knowledge

<?> QUESTION

4 Perforation of the small bowel

- ☐ Is mostly diagnosed by identifying contained or free intrabdominal gas
- ☐ Can often be diagnosed at supine plain radiography
- ☐ Can best be examined at CT as it outperforms ultrasonography for detecting small bowel perforation, the perforation site and possible complications
- ☐ Can be best examined by ultrasonography as it outperforms CT for detecting small bowel perforation, the perforation site and possible complications

/ Test Your Knowledge

<?> ANSWER

4 Perforation of the small bowel

- [x] Is mostly diagnosed by identifying contained or free intrabdominal gas
- [ ] Can often be diagnosed at supine plain radiography
- [x] Can best be examined at CT as it outperforms ultrasonography for detecting small bowel perforation, the perforation site and possible complications
- [ ] Can be best examined by ultrasonography as it outperforms CT for detecting small bowel perforation, the perforation site and possible complications

/ Test Your Knowledge

<?> QUESTION

5 **Small bowel polyps are**

- ☐ A common cause of closed loop obstruction
- ☐ More common than colon polyps
- ☐ Possible incidental findings
- ☐ Often enhancing to a variable extent

/ Test Your Knowledge

<?> ANSWER

5 **Small bowel polyps are**

- ☐ A common cause of closed loop obstruction
- ☐ More common than colon polyps
- ■ Possible incidental findings
- ■ Often enhancing to a variable extent

/ Test Your Knowledge

<?> QUESTION

6 In small bowel tumours

- ☐ Small bowel adenocarcinoma, lymphoma and neuroendocrine tumours have certain differentiating features at CT
- ☐ Even when large, small bowel adenocarcinoma does not obstruct the bowel lumen
- ☐ Lymphoma are often more bulky than small bowel adenocarcinoma or neuroendocrine tumours
- ☐ Neuroendocrine tumours often have calcifications

/ Test Your Knowledge

<?> ANSWER

6 In small bowel tumours

- ■ Small bowel adenocarcinoma, lymphoma and neuroendocrine tumours have certain differentiating features at CT
- ☐ Even when large, small bowel adenocarcinoma does not obstruct the bowel lumen
- ■ Lymphoma are often more bulky than small bowel adenocarcinoma or neuroendocrine tumours
- ■ Neuroendocrine tumours often have calcifications

/ Test Your Knowledge

<?> QUESTION

7 In small bowel Crohn's disease

- ☐ Radiography is commonly used in acute situations
- ☐ The first presentation is with enteral fistulas
- ☐ Ultrasonography and CT are the preferred imaging techniques in daily practice
- ☐ Bowel wall enhancement at CT and MRI are common findings

/ Test Your Knowledge

<?> ANSWER

7 In small bowel Crohn's disease

- ☐ Radiography is commonly used in acute situations
- ☐ The first presentation is with enteral fistulas
- ☐ Ultrasonography and CT are the preferred imaging techniques in daily practice
- ■ Bowel wall enhancement at CT and MRI are common findings

/ Test Your Knowledge

<?> QUESTION

8 In small bowel Crohn's disease

- ☐ Bowel wall thickening is a common finding
- ☐ Bowel wall oedema can be identified at CT
- ☐ Inflammation and fibrosis can be accurately differentiated at imaging
- ☐ Complications such as fistulas are often missed

/ Test Your Knowledge

<?> ANSWER

8 In small bowel Crohn's disease

- ■ Bowel wall thickening is a common finding
- ☐ Bowel wall oedema can be identified at CT
- ☐ Inflammation and fibrosis can be accurately differentiated at imaging
- ☐ Complications such as fistulas are often missed

/ Test Your Knowledge

<?> QUESTION

9

A Meckel's diverticulum

- ☐ Originates from the embryological front gut.
- ☐ It is a false diverticulum
- ☐ Is visible at the mesenterial site of the ileum
- ☐ Can become inflamed or bleed

/ Test Your Knowledge

<?> ANSWER

9

A Meckel's diverticulum

- ☐ Originates from the embryological front gut.
- ☐ It is a false diverticulum
- ☐ Is visible at the mesenterial site of the ileum
- ■ Can become inflamed or bleed

/ Test Your Knowledge

<?> QUESTION

10 In small bowel ischaemia

- ☐ Arterial or a venous occlusion can be present
- ☐ There can be no occlusive cause while ischaemia is present
- ☐ CT is the preferred imaging technique as radiation exposure is not important in these patients
- ☐ Pneumatosis intestinalis is a pathognomonic finding

/ Test Your Knowledge

<?> ANSWER

10 In small bowel ischaemia

- ■ Arterial or a venous occlusion can be present
- ■ There can be no occlusive cause while ischaemia is present
- ☐ CT is the preferred imaging technique as radiation exposure is not important in these patients
- ☐ Pneumatosis intestinalis is a pathognomonic finding