PICTORIAL ESSAY | Abdominal Imaging

The spectrum of imaging features in small bowel pathology with CT-Enterography. A Pictorial Essay

Eleni Lazaridou, Sofia Athanasiou, Christina Aslanidi, Demetrios Exarhos
Department of CT/MRI, Evangelismos General Hospital, Athens, Greece

SUBMISSION: 5/7/2021 - ACCEPTANCE: 29/11/2021

ABSTRACT

CT-Enterography (CTE) is an established imaging modality for the investigation of small bowel disorders, including Crohn's disease (CD) and pathologies such as neoplastic, vascular and infectious entities. It is a non-invasive technique, which, besides exposure to radiation, has benefits due to many technical advances. It is available in an emergency setting and can be performed in uncooperative patients. CTE is essential in evaluating the affected mucosa and bowel wall, which is crucial in the diagnosis and follow up of suspected CD. It is also valuable in detecting extra-enteric pathology, the phase of the disease in CD and possible complications. This pictorial essay provides a thorough presentation of CTE in elucidating small bowel pathology.

KEY WORDS: CT enterography, small bowel pathology, Crohn's disease, vascular, neoplastic, infectious entities

Introduction

CT-Enterography (CTE) is a variation of CT with sufficient lumen distention that helps estimate the extension and severity of small bowel diseases [1]. It clearly demonstrates the small bowel lumen and extraluminal pathology, contrary to routine CT which is mainly used to detect extra-enteric complications such as fistulas, stenoses and abscesses. CTE and MR-Enterography (MRE) are the initial imaging methods performed in suspected Crohn's disease (CD) and are effective for evaluating acute exacerbation or complications, disease surveillance and monitoring therapy in patients with known CD [1]. CTE is also recommended for other suspected small bowel pathologies such as vascular and infectious conditions or neoplasms [2]. Moreover, it is useful in uncooperative patients in the acute setting due to a shorter scanning time compared to MRE [3]. However, the exposure to radiation remains the major disadvantage of CTE, thus MRE is usually preferable in paediatric and young adult patients [3].

CORRESPONDING AUTHOR, GUARANTOR
Christina Aslanidi
Department of CT/MRI, Evangelismos General Hospital,
45-47 Ipsilantou Str, 106 76, Athens, Greece,
Email: christina.aslanidi178@gmail.com

The purpose of this review is to highlight the utility of CTE in distinguishing intestinal pathology and establishing the correct diagnosis based on specific signs.

Technique

The procedure involves post-contrast abdominal CT in the enteric phase (45sec) after administration of 1.5-2 l of a neutral or low-density oral contrast in order to achieve small bowel distention. Additionally, these agents are useful in distinction between bowel wall and its lumen, improving the detection of the enhancement pattern of the wall. Neutral agents include water, combination of water and methylcellulose, polyethylene glycol, low concentration barium solution, milk, mannitol etc. Inadequate bowel distention results by only administering water. Contrary, milk, mannitol or low-density barium solution administration is associated with adequate luminal distention. Variable results are also reported concerning the recommended volume of the oral contrast media needed for adequate luminal distention without significant side effects, such as diarrhoea, vomiting and spasms. Our protocol included a 3-day liquid diet oral ingestion of 1500ml of mannitol solution 20% (250ml/7min) over 35-45min and if no contraindications were known, intravenous administration of an antispasmodic agent prior to the examination was administered. Scanning was performed on a 16 slice multi-detector scanner 45 seconds post- injection of a non-ionic iodinated contrast media (350-370mgI/ml) with a rate of 4ml/s in order to image the bowel (enteric phase). The total amount of non- ionic contrast media used was calculated according to body weight (1ml/kg) and ranged between 60ml and 120ml. In cases of suspected vascular pathology, scanning requires pre- and post-contrast enhancement in an arterial, portal venous and delayed phase. The post processing was carried out on a workstation in an axial plane with a slice thickness 1-2mm as well as MPR (multi-planar reformation) and MIP (maximum intensity projections). Our results were verified by biopsy and clinical results [4].

Crohn's Disease

CD is a life-long, idiopathic, inflammatory bowel disease characterised by widespread discontinuous gastrointestinal tract inflammation most commonly affecting the terminal ileum and proximal colon. CTE is useful in identifying disease involvement, activity, extent and possible complications [5].

Wall-thickening is usually divided into mild (3-5mm), moderate (5-9mm) and severe (>10mm). Segmental thickening is most frequently reported [5].

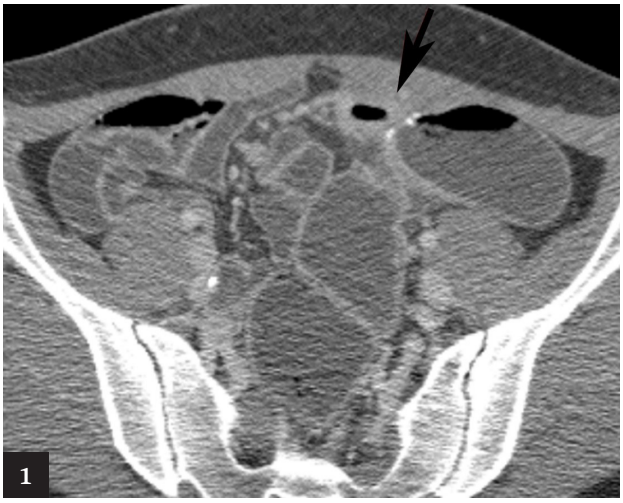


Fig. 1. *Acute CD with mural hyperenhancement. Axial CTE in a 27-year-old female depicts recurrent CD after bowel resection (black arrow).*

Mural hyperenhancement with associated wall thickening is the most specific finding of active CD and can be asymmetric, stratified or homogeneous (**Fig. 1**). It is important to compare bowel loops with the same degree of distention since collapsed loops may demonstrate regions of hyper-attenuation mimicking mural enhancement [1]. In cases of inadequate intestinal distention, secondary signs of activity are assessed, such as mesenteric fat stranding, vasa vasorum engorgement and complications [1].

Asymmetric mural hyperenhancement usually involves the mesenteric border and is the key imaging feature of active CD (**Fig. 2a**) [5].

Stratified mural enhancement (**Fig. 2b**) produces a "target" sign that originates from the bilaminar or trilaminar appearance of the oedematous bowel wall due to hyperenhancement of the inner and /or outer layers of the bowel wall along with low attenuation submucosal oedema [5, 6].

Homogeneous mural hyperenhancement (Fig. 2c), which is depicted by the bilaminar appearance, is a non-specific imaging feature for active CD and can be demonstrated in a variety of bowel disorders including fibrosis, ischemia and shock bowel [5].

Other features of active CD include prominent vasa recta ("comb sign"), mesenteric fat stranding and mesenteric lymphadenopathy (>10mm) (**Fig. 3**) [3, 6]. Additionally, the severity of CD can be classified according to increased fat density when compared to subcutaneous or other noninflamed fat, into severe (>60 HU) and mild (20-60HU) [7].

Furthermore, in the setting of active CD, CTE can detect

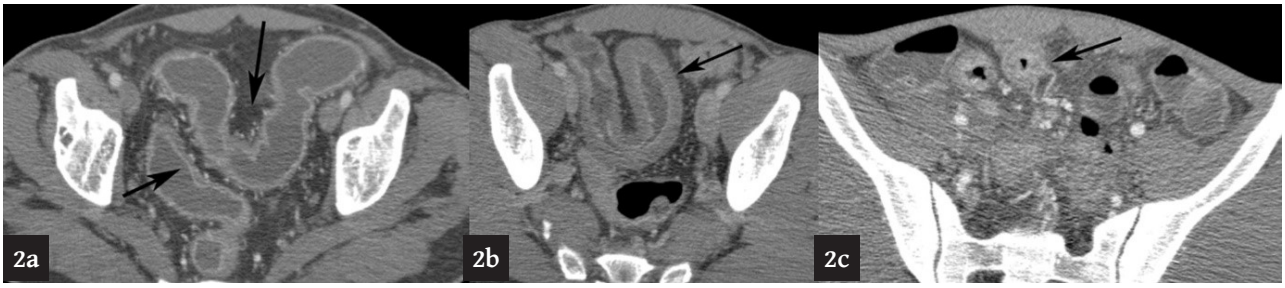


Fig. 2. *Spectrum of mural hyperenhancement in active CD.* ***(a)*** *asymmetrical pattern of moderate wall thickening of the sigmoid with ''comb sign" in a 62-year-old male (black arrows).* ***(b)*** *stratified pattern of enhancement of the inner aspect of the wall with intestinal wall thickening (black arrow) and luminal narrowing in 36-year-old male.* ***(c)*** *Homogenous symmetrical mural enhancement with severe thickness of the wall and luminal stenosis (black arrow) in 73-year-old male.*

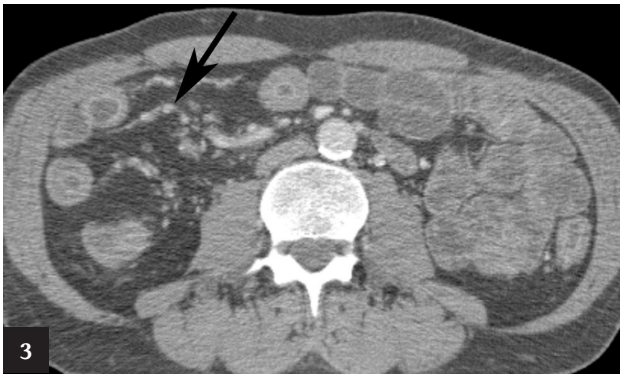


Fig. 3. *Complementary signs of active disease in a 54-year-old male with a known CD. Axial CTE shows acute disease with target appearance of the intestinal, "comb sign", fat stranding and lymph node enlargement (black arrow). Hypertrophy of the mesenteric fat is also depicted.*

complications such as fistulas (**Fig. 4a**) where the bowel lumen is connected with another epithelialised surface and abscess formation (**Fig. 4b**). In complex cases, inflamed converging bowel loops can give the appearance of an "asterisk shape" (**Fig. 5a**). Additionally, a sinus tract can be blind ended extending beyond the serosa but without communication with other structures (**Fig. 5b**). Inflammatory masses (**Fig. 5a**), ulceration (**Fig. 5c**), obstruction and free perforation may also be detected [3]. Sensitivity, specificity and accuracy of CTE for the diagnosis of abscess are 85.7%, 87.5% and 87.2% respectively. Sensitivity and specificity are 70% and 97% respectively, for fistula detection [3].

The chronic phase of CD is characterised by resolution of inflammation with the presence of residual features. Imaging findings in inactive CD include submucosal fat deposition, outpouchings along the antimesenteric border, surrounding fibrofatty proliferation, mild mural enhancement and fibrotic strictures [6]. The "fat halo sign" (**Fig. 6**) as a trilaminar intestinal appearance with intramural fat indicating past or chronic bowel inflammation [3]. Sacculations are outpouchings along the antimesenteric border and may be present mainly in chronic CD [5]. Fibrofatty proliferation refers to regional hypertrophy of the mesenteric fat, which separates the affected bowel loops (**Fig. 3**) [5]. It is also reported that mild mural enhancement similar to muscle attenuation can be a predictive but not a specific finding for chronic disease including CD, ischaemia, or radiation [8].

CTE is also used in differentiating active inflammatory strictures from fibrotic strictures, as these two entities differ in their management [6]. Strictures are defined as segmental small bowel wall thickenings with luminal narrowing and unequivocal dilatation (>3cm) which can be divided into fibrotic, inflammatory and mixed types. Inflammatory and fibrotic components frequently coexist due to repeated inflammation (**Fig 7a**) [5, 6]. A stricture based on upstream dilation is classified as mild (3-4cm) and severe (>4cm) [1]. In fibro-stenosing CD, mural hyperenhancement and stratification may be absent (Fig 7b). Contrary, in an acute phase of CD the oedema and bowel spasm may cause the inflammatory type of stricture that is determined by mural hyperenhancement and stratification with extensive intestinal wall thickness. A correlation between the presence of inflammatory strictures and penetrating disease has been reported [6].

Tuberculous (TB) enteritis

Given its low prevalence and often non-specific imaging findings, cases of TB enteritis are often difficult to diagnose and differentiate from entities including CD, typhlitis, infectious enteritis and lymphoma. Morphological types involve ul-

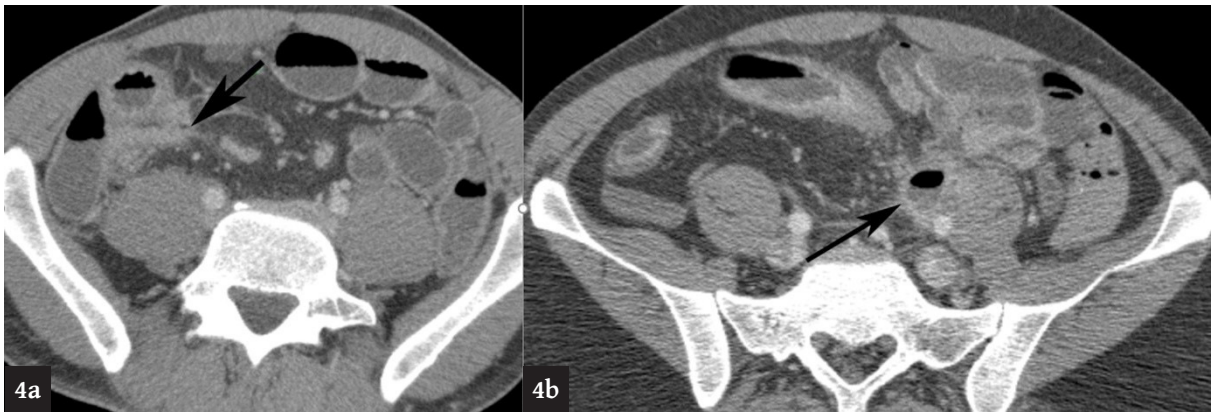


Fig. 4. *Extra intestinal complications in acute CD. (**a**) Axial CTE in a 36year-old male shows a fistula between the cecum and terminal ileum (black arrow). (**b**) Axial CTE in 29-year-old male reveals a small abscess in contact to the left psoas muscle (black arrow).*

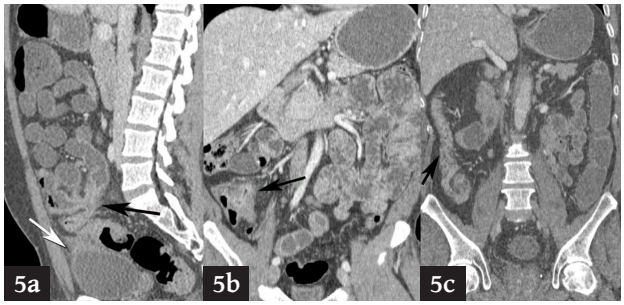


Fig. 5. *Extra intestinal complications in acute CD. (**a**) Sagittal CTE in a 33-year-old male with an ''asterisk shape'' appearance of the intestinal loops due to multiple enteroenteric and enterosigmoid fistulas (black arrow). Direct extension of the inflammatory mass into the adjacent wall of the bladder is also seen (white arrow). (**b**) Coronal CTE in 45-year-old male demonstrates a sinus tract that extends from the terminal ileum to the surrounding inflammatory mass (black arrow). (**c**) Coronal CTE in a 59-year-old male depicts cobblestone appearance due to deep ulcers of the caecum mucosa (black arrow).*

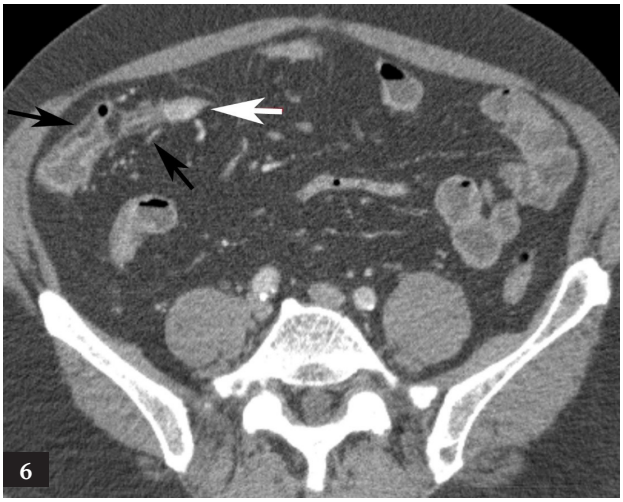
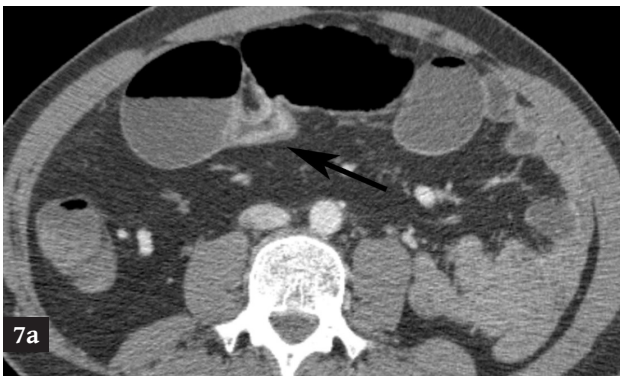


Fig. 6. *Acute and chronic lesions coexist in a 23-year-old male with CD. Axial CTE demonstrates the "fat halo sign" in the terminal ileum and cecum (black arrows) that indicates chronic phase of the disease. The proximal segment of the terminal ileum shows moderate wall thickening and mural hyperenhancement (white arrow) as in the acute phase of disease.*

cerative (60%), hypertrophic (30%) and ulcero-hypertrophic (10%) [9]. The ileocecal region is most commonly involved, followed by the jejunum [10]. Imaging findings include strictures and extensive circumferential mural thickening of the terminal ileum and cecum, which may appear as a mass-like lesion (**Fig. 8**). Asymmetric thickening of the ileocecal valve and a retracted conical and shrunken cecum constitutes a pathognomonic imaging sign. Massive mesenteric lymphadenopathy with central necrosis and peritoneal involvement are also included. Peritoneal involvement is identified in the form of peritoneal fluid collection, smooth homogenous peritoneal thickening and omental caking [10]. Differentiation between CD and TB enteritis can be challenging. Duration of symptoms, presence of ascites and peritoneal involvement, lymph node morphology, as well as extra-enteric manifestations are useful in order to differentiate between both entities [9].

Small bowel neoplasms

CTE plays an integral role in detecting small bowel neoplasms. Adenocarcinoma is the most common primary intestinal malignancy usually arising in the duodenum followed by the



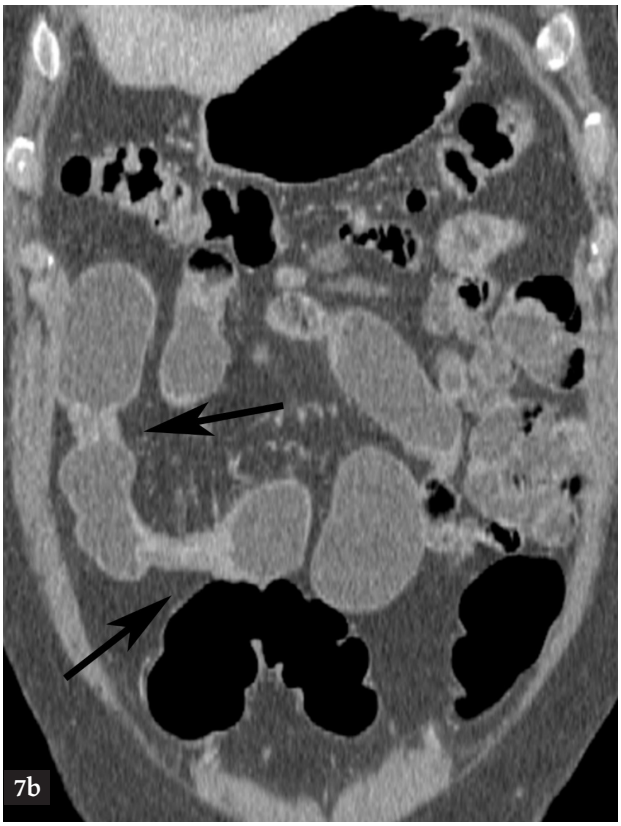


Fig. 7. *Spectrum of structuring skip-lesions in CD.* ***(a)*** *Axial CTE image in a 29-year-old male detect mixed type of strictures with severe upstream bowel dilation (black arrow).* ***(b)*** *Coronal CTE in a 59-year-old male shows intestinal fibrostenotic strictures with mild upstream intestinal dilatation. It is also depicted mild mural thickening without hyperenhancement (black arrows).*

jejunum and ileum. Contrary, the ileum is most commonly involved in patients with CD [11]. Pathologies associated with chronic inflammation and syndromes such as Peutz-Jeghers are predisposing factors (**Fig 9**). Small bowel neoplasms are demonstrated as a polypoid endoluminal lesion, irregular luminal narrowing with "apple core" appearances or as an ulcerative plaque in the mucosa with associated lymphadenopathy. Complications include obstruction or intussusceptions [12].

Carcinoids are usually located in the ileum, may be multifocal in 15-35% of cases and can be detected as hyper-enhancing polypoid tumours or as a sessile mass with segmental wall thickening [13]. Typically, a mesenteric calcified mass with desmoplastic mesenteric reaction prompts suspicion for carcinoid (Fig 10). Additionally, the presence of metastasis can help distinguish between benign and malignant disease [12].

Gastrointestinal stromal tumour (GIST) represents the most common mesenchymal malignancy arising anywhere from the gastrointestinal tract. The stomach is most commonly involved, followed by the small bowel [14]. They can vary widely in appearance on CTE, due to the size and aggressiveness of the mass. Small lesions tend to enhance homogeneously, while larger lesions tend to have an inhomogeneous appearance with necrosis, intratumoral haemorrhage, ulcers or cavities. CTE has benefits especially with small size lesion detection [12].

In intestinal lymphoma, the ileus is most typically affected owing to the greatest amount of lymphoid tissue. The jejunum is most commonly involved in patients with celiac disease [15]. Pathologies such as inflammatory bowel disease and immunodeficiency syndrome are predisposing factors. It is often depicted as an infiltrating enhancing small bowel mass with or without regional aneurysmal bowel dilatation (**Fig 11**) due to muscularis propria invasion and autonomic nerve plexus disruption. Patterns of intestinal lymphoma include a polypoid lesion, an extraluminal mass with perforation and/or ulceration resulting in fistulous tract and as a sterile abscess with associated splenomegaly and lymphadenopathy [16].

Sclerosing peritonitis

Sclerosing peritonitis is a complication of peritoneal dialysis and ventriculoperitoneal shunts and is characterised by thickened peritoneal membranes. Sarcoidosis, tuberculosis, gastrointestinal malignancy, ovarian thecoma along with abdominal surgery are also associated. CT findings include thickening and enhancement of the peritoneum in the early phases of the disease (**Fig. 12**), whilst in the advanced stages peritoneal calcification may appear as well as encapsulation of bowel loops. The inflammation may involve the antimesenteric border, causing fibrosis and wall thickening that may lead gradually to obstruction due to adhesions [17].

Myenteric ganglionitis

Myenteric ganglionitis is an inflammatory enteric neuropathy

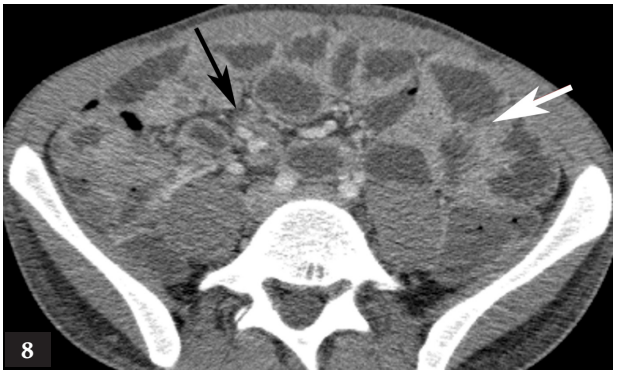


Fig. 8. *Hypertrophic form of tuberculous enteritis in a 23-year-old male. Axial CTE shows mural thickening of the intestinal wall as a mass-like lesion (white arrow) with an enlarged mesenteric lymph node (black arrow).*

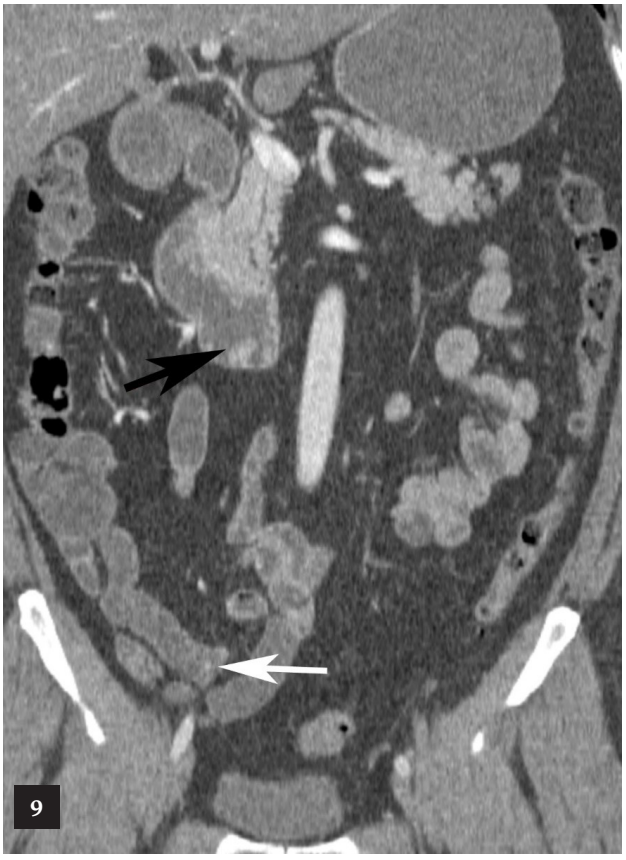


Fig. 9. *A duodenal polyp in 59-year-old male initially diagnosed endoscopically and confirmed by CTE. Coronal CTE demonstrates a well-defined mass (black arrow) arising from the wall of the second portion of the duodenum. In the terminal ileum another smaller polyp was depicted (white arrow).*

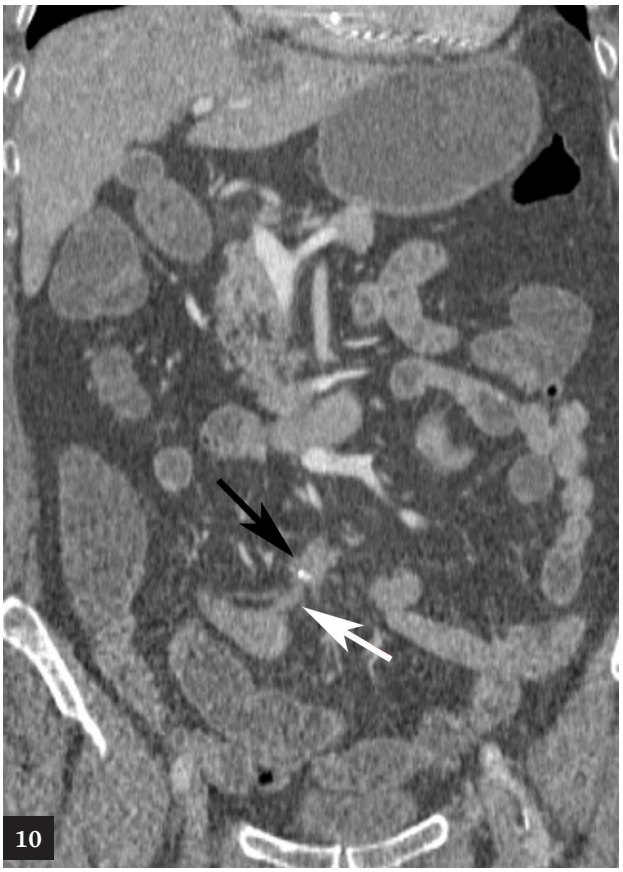


Fig. 10. *A mesenteric carcinoid tumour in an 81-year-old female who presents with ileum. Coronal CTE demonstrates a well-defined mesenteric mass with calcification (black arrow) and desmoplastic reaction (white arrow).*

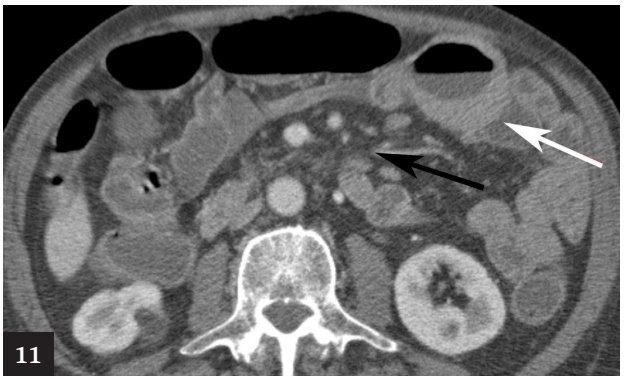


Fig. 11. *Small bowel lymphoma in a 90-year-old male. Axial CTE depicts focal aneurysmal dilation of the lumen in the proximal ileal loop with asymmetric wall thickness without obstruction (white arrow). Enlarged lymph nodes are present (black arrow).*

that may be correlated with paraneoplastic syndromes, infectious or neurological pathologies. Occasionally, idiopathic cases have been reported [18]. Para-neoplastic syndromes and idiopathic cases may be associated with the presence of anti-HU antineuronal antibodies that trigger an autoimmune reaction. Ganglionitis may present as bowel distention with-

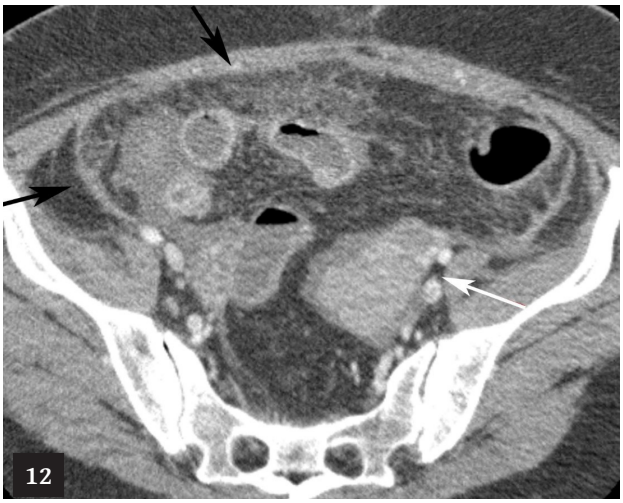


Fig. 12. *Early phase of sclerosing peritonitis with a left ovarian thecoma (white arrow) in 53-year-old female who suffered from recurrent abdominal pain. Axial CTE shows collections and peritoneal thickening with post contrast enhancement (black arrows).*

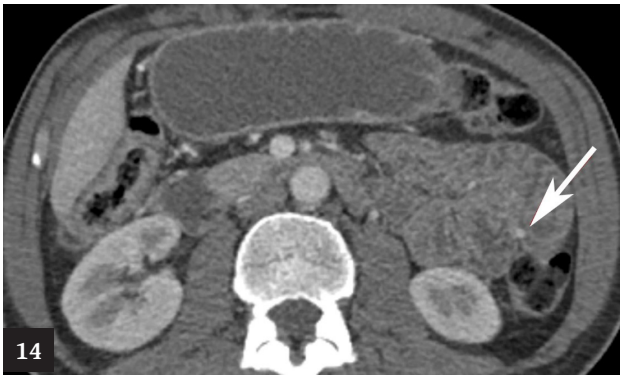


Fig. 14. *Angioectasia in 50-year-old man with anaemia and episodes of melena. Axial CTE in portal venous phase demonstrates a 2-3mm nodular area of enhancement in the wall of the jejunum that represents a focal bulbous of the vein (white arrow).*

out obstruction or stenosis appearing as a pseudo-obstruction (**Fig. 13**) [19].

Small-bowel vascular lesions

CTE is useful in detecting the cause of gastrointestinal tract bleeding. Vascular lesions of the small bowel represent a diverse group of abnormalities, which can cause haemorrhage. Vascular lesions are divided into three types: a) angioectasias, b) arterial and c) venous lesions (**Fig 14**). Each type is characterised by specific imaging features which are depicted by multiphase CTE [20].

On multiphase CTE, small-bowel angioectasias are depict-

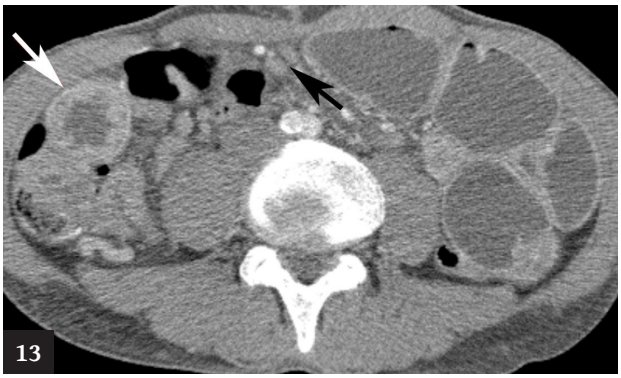


Fig. 13. *Chronic intestinal pseudo-obstruction in 45 -year-old male. Axial CTE detects lymphadenopathy (black arrow) and diffuse dilated intestinal loops with wall thickening due to smooth-muscle hypertrophy (white arrow).*

ed as punctate or discoid enhancements with a diameter less than 5mm. Bulbar swelling in the small bowel wall is also a finding usually located in the jejunum. Typically, angioectasias enhance in the enteric phase and gradually hypo-attenuate in the delayed post contrast phase. The differential diagnosis from an arterial lesion is usually easy. Rarely, angioectasias may enhance in the arterial phase making the diagnosis harder to reach.

Dieulafoy lesions, arteriovenous fistulas (AVFs) and arteriovenous malformations (AVMs) concern small bowel arterial pathologies. Dieulafoy lesions or calibre persistent arteries are normal arterial vessels, which are usually abnormally located in the submucosa of the stomach (70%) or less frequently in the small bowel (16%). Dieulafoy lesions increasingly enhance during the arterial phase and become indistinguishable in the latter post contrast phases.

AVFs and AVMs consist of a communicated feeding arterial and venous branch. Generally, bowel AVMs are usually large, solitary and congenital lesions. An early feeding venous filling in the arterial phase is the imaging key feature for the diagnosis.

The most common venous lesions are venous angiomas and small bowel venous varices. These lesions enhance in the enteric and delayed phase. Phleboliths are usually clearly depicted in haemangiomas in the arterial phase. The pattern of enhancement in haemangiomas is a progressively centrifugal filling of the lesion. Venous varices usually coexist with collateral veins in the abdomen [20].

Conclusion

The differential diagnosis of the small bowel pathology is extensive, including a variety of inflammatory, vascular and

neoplastic small bowel disorders. Optimal evaluation of the affected mucosa and the bowel wall is crucial in order to reach the correct diagnosis and ensure appropriate treatment. CTE is a valuable non-invasive imaging technique as it can be rapidly performed and can also detect extra-enteric pathology and possible complications. However, exposure to ionising radiation is the major negative concern of CTE, particularly in young patients with chronic disease requiring repeated studies. **R**

Conflict of interest

There are no conflicts of interest.

References

1. Paulsen S, Huprich J, Fletcher J, et al. CT Enterography as a Diagnostic Tool in Evaluating Small Bowel Disorders: Review of Clinical Experience with over 700 Cases. *Radiographics*. 2006; 26(3):641-57; discussion 657-62.
2. Kim DH, Chang KJ, Fowler KJ, et al.ACR Appropriateness Criteria® Crohn Disease. *J Am Coll Radiol*. 2020;17(5S):S81-S99.
3. Gauci J, Sammut L, Sciberras M, et al. Small bowel imaging in Crohn's disease patients. *Ann Gastroenterol.* 2018; 31(4):395-405.
4. Ilangovan R, Burling D, George A, et al. CT enterography: review of technique and practical tips. *Br J Radiol.* 2012;85(1015):876-8.
5. Guglielmo F, Anupindi S, Fletcher J, et al. Small Bowel Crohn Disease at CT and MR Enterography: Imaging Atlas and Glossary of Terms. *Radiographics*. 2020; 40(2):354-375.
6. Bruining DH, Zimmermann EM, Loftus EV Jr, et al. Consensus Recommendations for Evaluation, Interpretation, and Utilisation of Computed Tomography and Magnetic Resonance Enterography in Patients With Small Bowel Crohn's Disease. *Radiology*. 2018;286(3):776-799.
7. Lo Re G, Cappello M, Tudisca C, et al. CT enterography as a powerful tool for the evaluation of inflammatory activity in Crohn's disease: relationship of CT findings with CDAI and acute-phase reactants. *Radiol Med* 2014;119(9):658-666.
8. Macari M, Balthazar EJ. CT of bowel wall thickening: significance and pitfalls of interpretation. *AJR Am J Roentgenol*. 2001;176(5):1105-16.
9. Malikowskia Th, Mahmoodb M, Smyrkc Th, et al. Tuberculosis of gastrointestinal tract and associated viscera. *J Clin Tuberc Other Mycobact Dis*. 2018;14;12:1-8.
10. Debi U, Ravisankar V, Prasad KK, et al. Abdominal tuberculosis of the gastrointestinal tract: revisited. *World J Gastroenterol.* 2014; 20(40):14831-40.
11. Weber NK, Fletcher JG, Fidler JL, et al. Clinical characteristics and imaging features of small bowel adenocarcinomas in Crohn's disease. Abdom Imaging. 2015;40(5):1060-7.
12. Sokhandon F, Al-Katib S, Bahoura L, et al. Multidetector CT enterography of focal small bowel lesions: a radiological-pathological correlation. Abdom Radiol (NY). 2017;42(5):1319-1341.
13. Avcu S, Ozen O, Bulut MD, et al. Hepatic metastasis of primary jejunal carcinoid tumor: A case report with radiological findings. *N Am J Med Sci.* 2009;1(6): 305–308.
14. Zhao X, Yue C. Gastrointestinal stromal tumor. *J Gastrointest Oncol.* 2012;3(3):189-208.
15. Mendelson RM, Fermoyle S. Primary gastrointestinal lymphomas: a radiological-pathological review. Part 2: Small intestine. *Australas Radiol*. 2006;50(2):102-13.
16. Ghai S, Pattison J, Ghai S, et al. Primary gastrointestinal lymphoma: spectrum of imaging findings with pathologic correlation. *Radiographics*. 2007;27(5):1371-88.
17. George V, Tammisetti VS, Surabhi VR, et al. Chronic fibrosing conditions in abdominal imaging. *Radiographics*. 2013;33(4):1053-80.
18. De Giorgio R, Guerrini S, Barbara G et al. Inflammatory neuropathies of the enteric nervous system. *Gastroenterology*. 2004; 126:1872-83.
19. De Giorgio R, Barbara G, Stanghellini V, et al. Clinical and morphofunctional features of idiopathic myenteric ganglionitis underlying severe intestinal motor dysfunction: a study of three cases. *Am J Gastroenterol.* 2002;97(9):2454-9.
20. Huprich JE, Barlow JM, Hansel SL, et al. Multiphase CT enterography evaluation of small-bowel vascular lesions. *AJR Am J Roentgenol*. 2013;201(1):65-72.

READY - MADE CITATION

Lazaridou E, Athanasiou S, Aslanidi C, Exarhos D. The spectrum of imaging features in small bowel pathology with CT-Enterography. A Pictorial Essay. *Hell J Radiol* 2021; 6(4): 40-47.