

The wall enhancement of bowel diseases observed on MDCT and MRI: a pictorial essay

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Authors: F. Roccasalva, M. Piccoli, S. Palmucci, L. A. Mauro, G. Cappello, G. C. Ettore; Catania/IT
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Learning objectives

To describe different contrast enhancement patterns in bowel wall and to correlate them with the most common intestinal diseases.

Background

Many classifications have been proposed by radiologists to describe intestinal diseases; they are focused on clinical onset (acute or chronic disease), localization (small or large bowel) and causes (non neoplastic diseases and neoplastic diseases).

Bowel wall thickening showed on MDCT and MRI can be observed as normal variants, inflammatory conditions and gastrointestinal neoplasm; so imaging findings of abnormal bowel tract should be accurately analysed. The normal thickness of small bowel and colonic wall is less than 3 mm, when the lumen is well distended. A lot of bowel diseases show a wall thickening (>3 mm) on MDCT and MRI.

According to Macari et al. [1], criteria to easily evaluate bowel disease using MDCT are:

- Pattern of attenuation
- Degree of thickening
- Symmetric versus asymmetric thickening
- Focal, segmental, or diffuse involvement
- Associated perienteric abnormalities:
 1. Lymph nodes
 2. Mesenteric stranding and calcification
 3. Abscess, sinus tract, and fistulas
 4. Proliferation of fat
 5. Vascular occlusion
 6. Solid organ abnormalities

To make an accurate differential diagnosis, radiologist should be familiar with the different imaging criteria reported; among them, the wall contrast enhancement pattern seems to be a valid diagnostic tool in the differentiating bowel diseases.

After administration of contrast material, normal bowel wall enhances. The enhancement is usually greater on the mucosal layer of the bowel wall and it is more easily identified in patients who have been given water as an oral contrast agent [1].

The presence or absence of enhancement is evaluated comparing:

1. The attenuation of the thickened segment with other adjacent segments
2. Contrast-enhanced scans with unenhanced or delayed images

Technique: MDCT

Patients undergoing routine CT exam should abstain from food for 4 hours before the examination.

According to Macari et al. [2], to detect an abnormal bowel wall requires:

- Adequate luminal distension, using positive contrast materials, such as diluted barium or water-soluble iodinated solutions, or better with oral ingestion of a large volume of neutral enteric contrast agents such as water; defectively distended loops can simulate or hide disease;
- Administration of intra-venous contrast, 100-150 mL of non-ionic iodinated contrast material at a rate of 2-5 mL/s;
- Thin-section (#1 mm) CT scan.

Helical scanning is performed from diaphragm to the lower margin of the symphysis pubis during a single breath-hold. The acquisition started approximately 25-30 seconds after injection for the arterial phase and 60 seconds for portal venous phase [3].

In cases of mesenteric ischemia and gastrointestinal bleeding, the addition of unenhanced scanning to the CT enterography protocol is useful [3].

Data sets from the arterial phase of enhancement may be used for various types of post-processing.

Post-processing techniques include:

- Reformatting of axial image data for coronal and bilateral oblique (30° angulation) maximum intensity projections
- Volume rendering.

Sagittal, coronal, and curved multi-planar reformatted (MPR) of axial images, created at a workstation by using the acquired volume data sets, allow for excellent demonstration and characterization of enteric and extra-enteric abnormalities.

Maximum intensity projection images are particularly useful for visualizing the mesenteric vasculature [3].

Technique: MRI

MRI is a valid alternative to CT in the assessment of bowel disease in young patients, in pregnant women and in patients with inflammatory bowel disease (IBD) and polyposis syndromes (usually requiring multiple studies to follow-up).

In addition, MRI has various advantages: lack of ionizing radiation exposure, better soft tissue contrast resolution and the ability to acquire multiplanar images and to perform real time functional images; it is also used in patients with contraindications to contrast-enhanced CT (iodinate contrast agent allergy).

The cost of the exams, the quality (patient cooperation and breath-holding ability) and lower spatial and temporal resolution than CT examinations are the limitations of MRI [4].

The bowel study is performed using single-shot fast spin-echo sequences and steady-state-free precession images, in order to better visualize not only the intestinal wall but also the mesenteric fat planes around the intestinal loops.

Enhanced acquisition are generally in a multi-phases modality, using three dimensional T1-weighted fast spoiled gradient echo acquisitions; intravenous contrast material is used to detect the enhancement pattern and to do a correct diagnosis (arterial phase usually starts 45 seconds after injection, whereas the portal phase is generally acquired after 70-80 seconds).

In this essay, we explain different attenuation types observed in our Radiology Department between August 2006 and November 2012.

Imaging findings OR Procedure details

Wall attenuation, as suggested by Macari et al. [1], can be described in the following different patterns:

- Homogeneous:
 - Marked
 - Moderate
 - Decreased
 - Absent
- Heterogeneous:
 - Stratified
 - Mixed

Contrast Enhancement Pattern		Common Diagnosis
Homogeneous	Marked/Moderate	<ul style="list-style-type: none"> - Crohn's disease (Active or Chronic) - Chronic radiation enteritis - Lymphoma / Small adenocarcinoma
	Decreased/Absent	<ul style="list-style-type: none"> - Intestinal Ischemia
Heterogeneous	Stratified	<ul style="list-style-type: none"> - Crohn's disease and ulcerative colitis - Infectious enterocolitis - Radiation enteritis - Vasculitis - Ischemia
	Mixed	<ul style="list-style-type: none"> - Adenocarcinoma - Gastrointestinal stromal tumors (GISTs) - Metastasis

Table 1: Scheme of contrast enhancement patterns according to Macari classification.

References: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

A homogeneous moderate enhancement, similar to muscle, is common in chronic inflammatory conditions, such as chronic Crohn's disease and chronic radiation enteritis, because of transmural fibrosis development. Crohn's disease will show also a homogeneous marked enhancement, because of the hyperemia correlated with acute inflammation. The acute phase of disease it is also accompanied by mesenteric changes of vascular dilation and tortuosity: this leads to the development of the so called "comb sign" - due to the prominence and increased separation of vasa recta in the ileum [1] [Fig. 1](#) on page 11 [Fig. 2](#) on page 16 [Fig. 3](#) on page 11 .

Rarely, homogeneous enhancement occurs in malignancy, especially in smaller tumors and in gastrointestinal lymphoma. Gastrointestinal lymphoma is the most common extra-nodal lymphoma of non-Hodgkin type [5].

The ileum and the cecum are the most common sites where lymphoma develops. It usually is observed on CT scan as a solitary or multiple segmental areas of circumferential thickening, often symmetric and marked (1.5-7 cm), with homogeneous attenuation and low enhancement. In comparison with adenocarcinoma, lymphoma involves a longer

segment of the bowel, the transition to normal bowel is more gradual and usually is associated with bulky mesenteric and retroperitoneal lymph nodes [1, 6] [Fig. 4](#) on page 12 [Fig. 5](#) on page 13.

A decreased enhancement is pathognomonic for intestinal ischemia, caused by arterial or venous occlusion, strangulating obstruction and hypoperfusion associated with non-occlusive vascular disease. The imaging findings vary as the bowel wall progresses from ischemia to infarction. Initially, bowel ischemia shows mild thickening with a target appearance correlate to edema and intramural bleeding [Fig. 6](#) on page 14. Progressing to infarction, the bowel becomes thin and shows decreased enhancement; finally, when mucosal integrity is broken, bowel infarction is diagnosed by the detection of pneumatosis (air in the wall of bowel with black attenuation) and also air in the regional mesenteric venous branches and/or intrahepatic portal veins [7] [Fig. 7](#) on page 15.

As suggested by Furukama et al [7], in arterial occlusion, emboli and thrombi can be seen as defects in the superior mesenteric artery and its branches; the diameter of the superior mesenteric artery is often larger than that of the superior mesenteric vein; in venous occlusion or strangulating obstruction, with C- or U- shaped distended loops, we also observe engorgement of mesenteric veins, reflecting venous congestion secondary to stasis; in non-occlusive mesenteric ischemia or infarction, arterial constriction may also be seen. The ischemic segment may also show increased enhancement caused by reperfusion after arterial occlusion or non-occlusive ischemia, hyperemia (venous occlusion), or prolonged enhancement because of reduction of arterial perfusion and venous outflow (strangulating obstruction, non-occlusive ischemia and shock bowel).

Characteristic	Arterial occlusion	Venous occlusion
Bowel Wall	Thickening	Thickening
Contrast-enhancement of bowel wall	Diminished/absent Target sign Increased	Diminished/absent Target sign Increased
Other findings	Defect in arteries Arterial Diameter > Vein Diameter	Defect in veins Venous Engorgement

Table 2: Scheme of differential diagnosis between arterial and venous bowel ischemia based on Furukama classification.

References: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

A heterogeneous stratified enhancement, showing the double halo sign or the target sign, is common in inflammatory disease, infection and radiation enteritis.

The double halo sign consists of either an inner low/grey-attenuation ring surrounded by a higher attenuation outer one (muscularis propria) or an inner higher-attenuation layer and an outer grey attenuation one.

The target sign consists of inner (mucosal) and outer (serosal) enhanced layers surrounding a middle (submucosal) low-attenuation ring. The lower-attenuation (grey) layer is related to edema and the higher one to hyperemia.

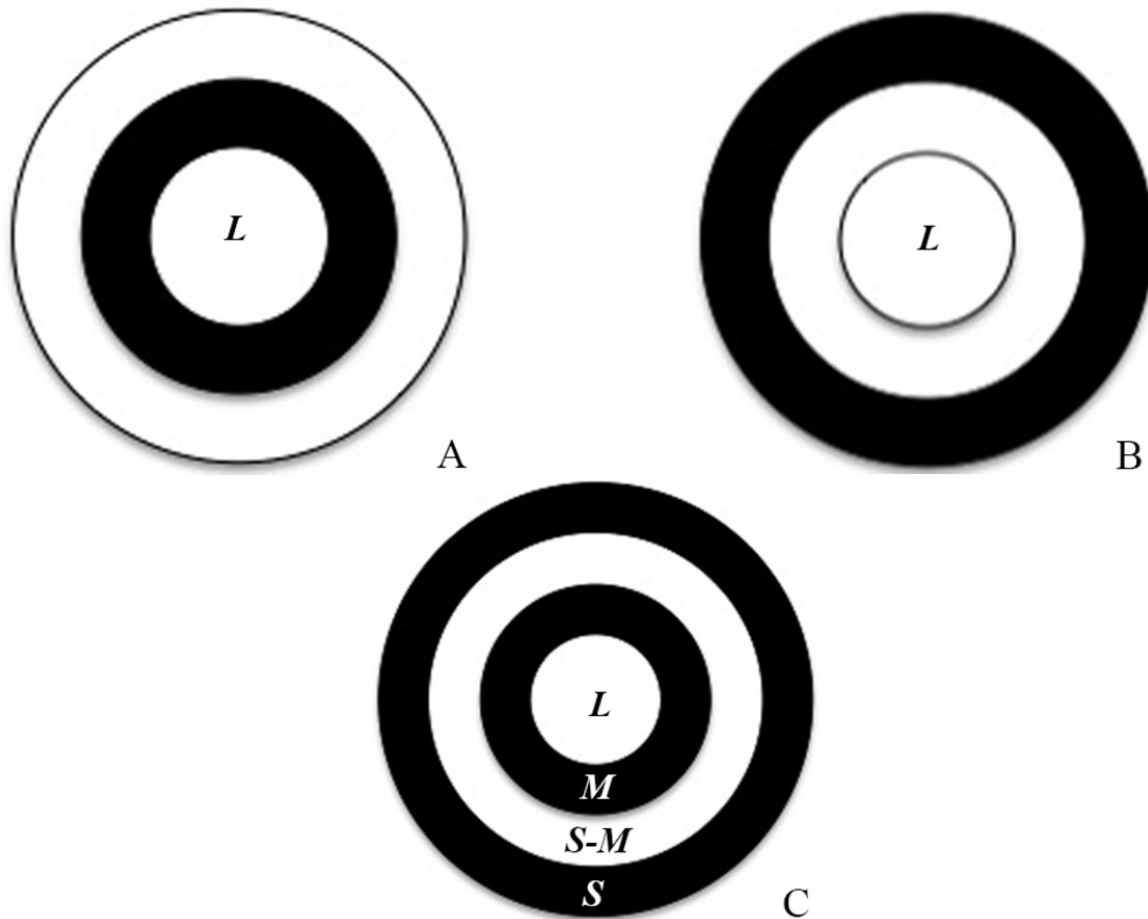


Fig. 8: Schematic drawings of the "double halo sign" and the "target sign". Figure 8A depicts inverted double halo sign with inner higher attenuation layer (white circle) and outer low attenuation ring (black circle). Figure 8B describes double halo sign with inner low attenuation ring (black circle) surrounded by a outer higher attenuation ring (white circle). Figure 8C shows the target sign: it consists of inner mucosal (M) and outer serosal (S) enhanced layers surrounding a middle submucosal (S-M) low-attenuation ring. L: lumen.

References: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

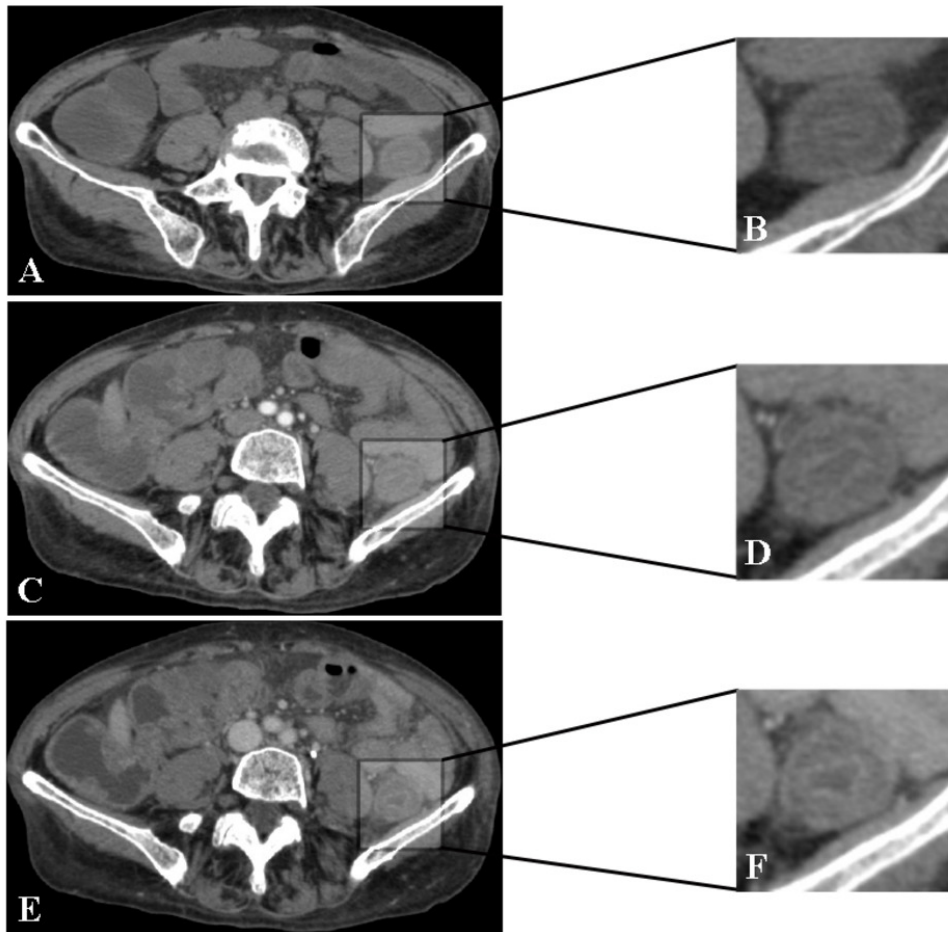


Fig. 9: A typical example of target sign in a 72 year-old female. Figure 9A and magnification (figure 9B) show bowel wall thickening in unenhanced axial MDCT scan. Arterial (figure 9C and 9D -magnification) and venous phase (figure 9E and 9F - magnification) images depict the target sign: inner mucosal and outer serosal higher attenuation layers, correlated to hyperemia, and middle submucosal lower attenuation ring, related to edema.

References: Radiodiagnostic and Oncological Radiotherapy Unit, University Hospital "Policlinico-Vittorio Emanuele" - Catania/IT

These signs are best visualized during the arterial phase of enhancement.

To make an accurate differential diagnosis of all disease showing these signs (Crohn's disease and ulcerative colitis, infection, radiation enteritis, lupus erythematosus, vasculitis and ischemia) it is useful to correlate them with clinical history and other CT findings.

The association of these signs with fibro-fatty proliferation, hyperemia of the vasa recta adjacent to inflamed loop of bowel (the comb sign, seen as hyper-enhanced parallel lines), sinus and fistula formation, and abscess suggests Crohn's disease.

If we suspect an ischemia, mesenteric arteries and veins (caliber and occlusion) should always be evaluated.

This enhancement pattern is also observed in pseudo-membranous colitis, a potentially life-threatening acute infectious colitis, caused by toxins of *Clostridium Difficile*. Common CT findings of this entity are: circumferential and irregular wall thickening (3-32 mm) with "thumb-printing", target sign or double halo sign (submucosal edema) in enhanced acquisition, peri-colonic stranding, ascites and "accordion sign", highly suggestive of pseudo-membranous colitis, caused by trapping of positive contrast material between thickened haustral folds, with the appearance of alternating area of high attenuation (contrast material) and low attenuation (edematous haustra) [8] [Fig. 10](#) on page 17.

Rarely, this pattern occurs in neoplastic diseases, mainly in infiltrating scirrhous carcinoma of the stomach and colon.

The middle low-attenuation ring of target sign can be a fatty attenuation (<10 HU), common in long-standing inflammation of Crohn disease and ulcerative colitis because of fat deposition within submucosal layer. The differentiation with the "typical target sign" is based on the Hounsfield attenuation characteristics of fat. Sometimes, it is observed in cytoreductive therapy exposure and chronic radiation enteritis [9].

Mixed heterogeneous enhancement pattern is typical of malignant tumor, such as adenocarcinoma, gastrointestinal stromal tumors or metastasis.

This pattern consists of some irregular areas of lower and higher attenuation mixed together [Fig. 11](#) on page 18 .

It is common in high-grade, poorly differentiated neoplasms, such as adenocarcinoma and malignant gastrointestinal stromal tumors (GISTs), which usually have central necrosis related to rapid growth, ischemia, and necrosis.

In tumors, the attenuation pattern correlates with size: it is heterogeneous in large, irregular and ulcerate tumors, and homogeneous in small, well-circumscribed ones.

Often, it is difficult to differentiate between benign and malignant GISTs; Ulasan et al [3, 10] reported several CT findings correlated with malignant GISTs with a high mitotic index. These criteria are: lesion larger than 5 cm, heterogeneous enhancement, tumor location (gastric), associated metastasis and cystic-necrotic component.

Metastasis may show heterogeneous or homogeneous enhancement.

A single disease, such as Crohn's disease or intestinal ischemia, may simultaneously show different enhancement patterns in contiguous segments of bowel and in different stages of disease.

Images for this section:

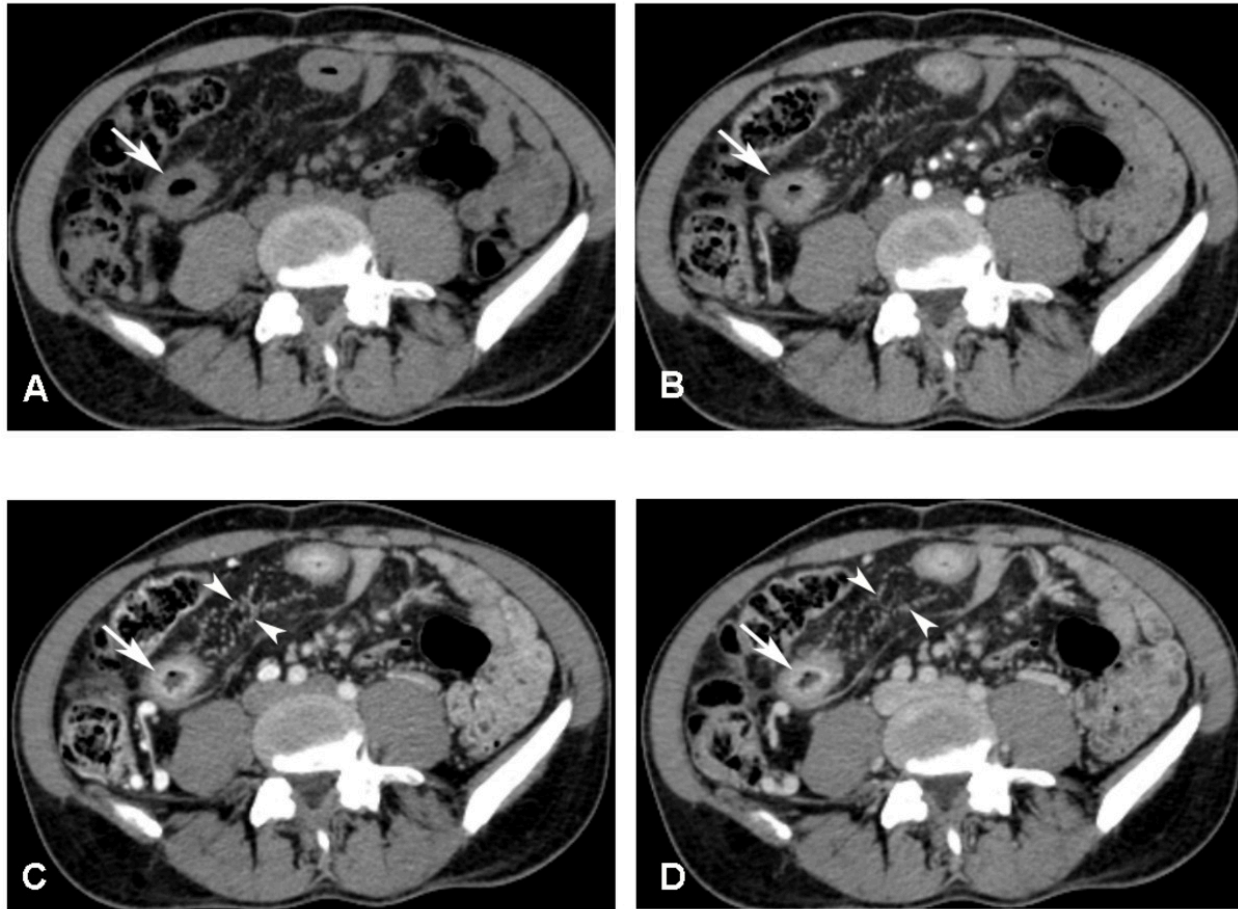


Fig. 1: MDCT scans of a 30 year-old male with Chron disease. Both unenhanced (figure 1A) and enhanced images (figures 1B-D) show bowel wall thickening (arrows); the target sign (figures 1B-D) and the comb sign (arrowheads in figure 1C-D)are well depicted after contrast administration.

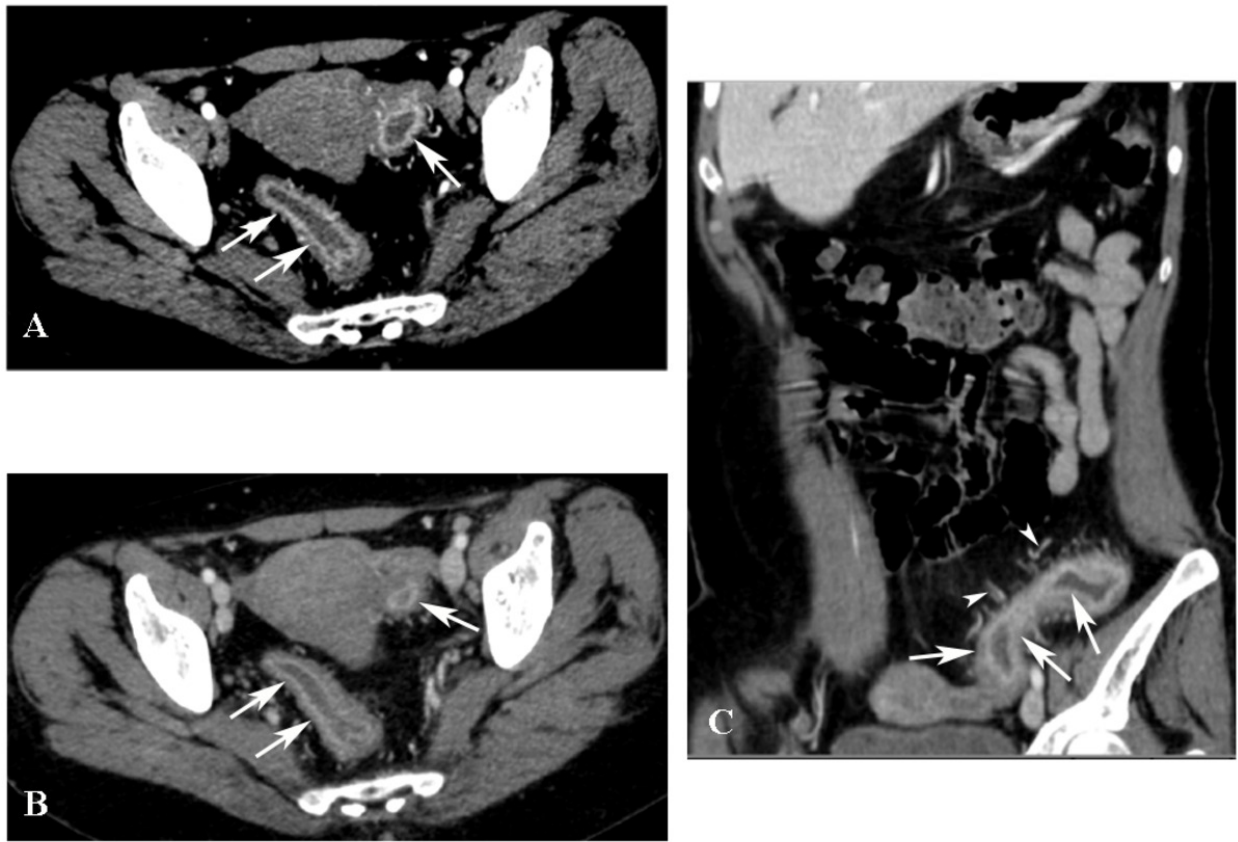


Fig. 3: Ulcerative colitis in 44 year-old female. Contrast enhanced axial MDCT images in arterial (figure 3A) and venous (figure 3B) phases show restosigmoid mild wall thickening with "target sign" (arrows). A coronal reconstruction also demonstrates pericolic vasa recta dilatation (arrowheads).

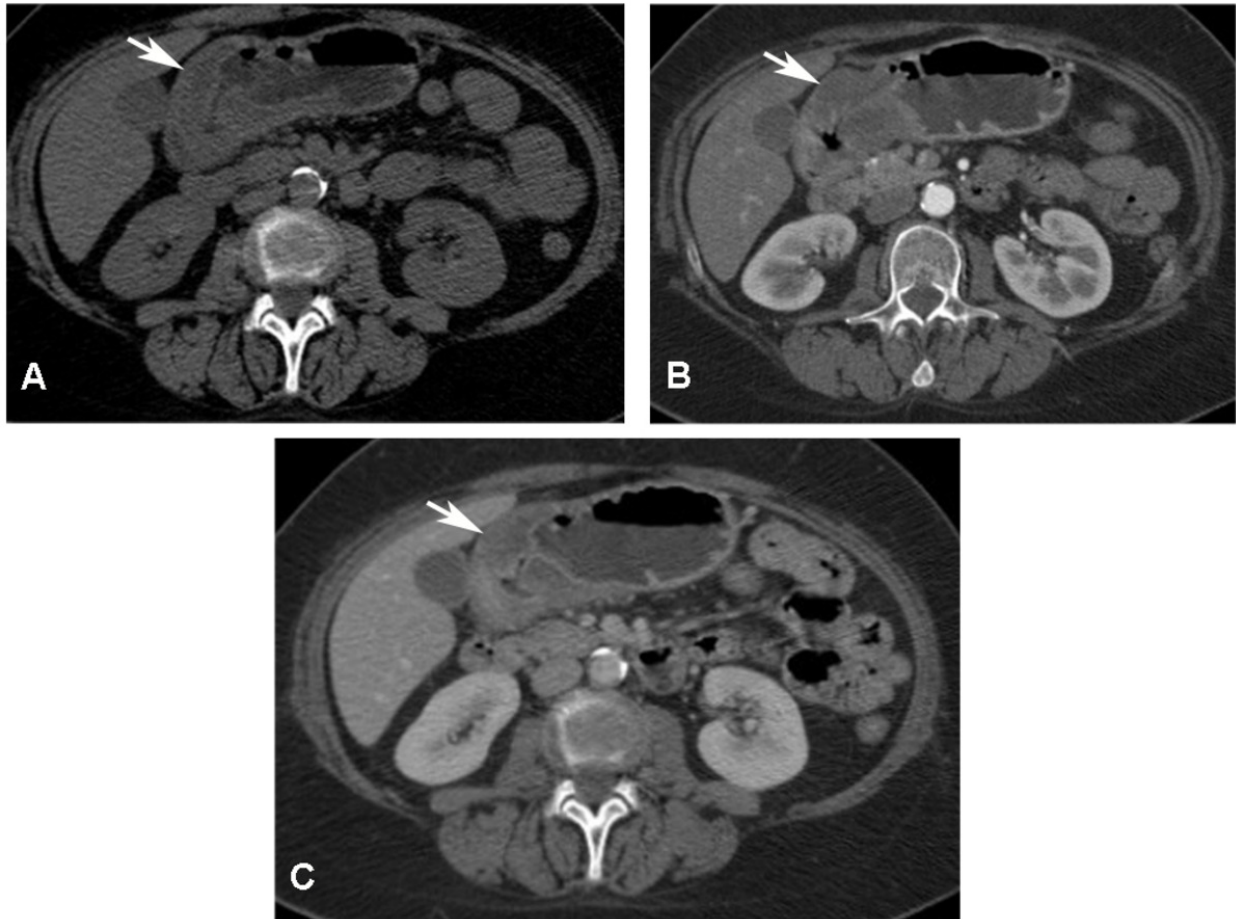


Fig. 4: A 60 year-old female with gastric lymphoma. Axial unenhanced MDCT image (figure 4A) shows a diffuse homogenous thickening of the antral wall (arrows); after contrast administration an homogenous pattern of enhancement is observed both in arterial (figure 4B) and venous (figure 4C) phases (arrows).

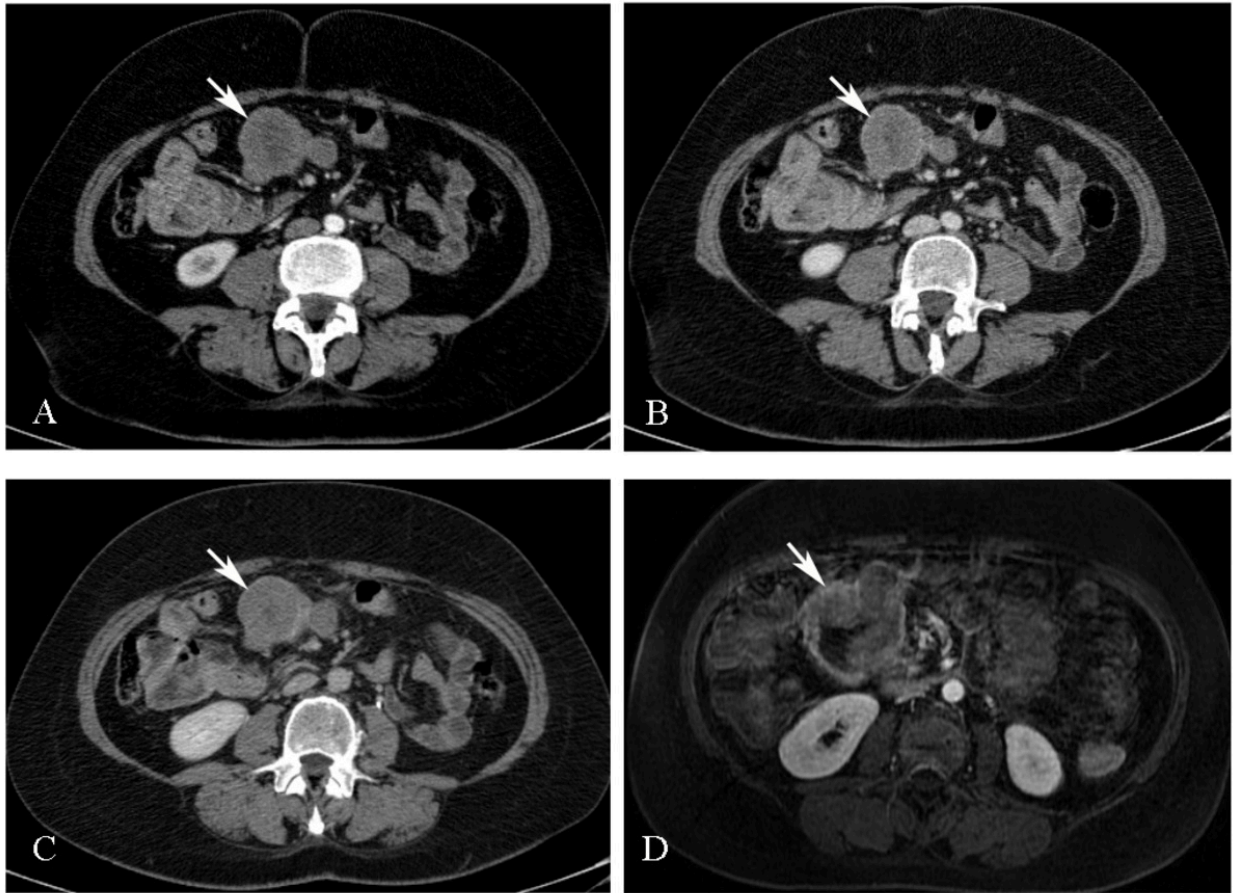


Fig. 5: A 53 year-old female with jejunal lymphoma. Axial contrast enhanced MDCT scans in arterial (figure 5A), venous (figure 5B) and delayed (figure 5C) phases depict a wall thickening with homogenous and concentric enhancement of a proximal jejunal loop (arrows). In figure 5D a T1-weighted enhanced MRI image also shows the proximal jejunal loop thickening with homogenous enhancement (arrow).

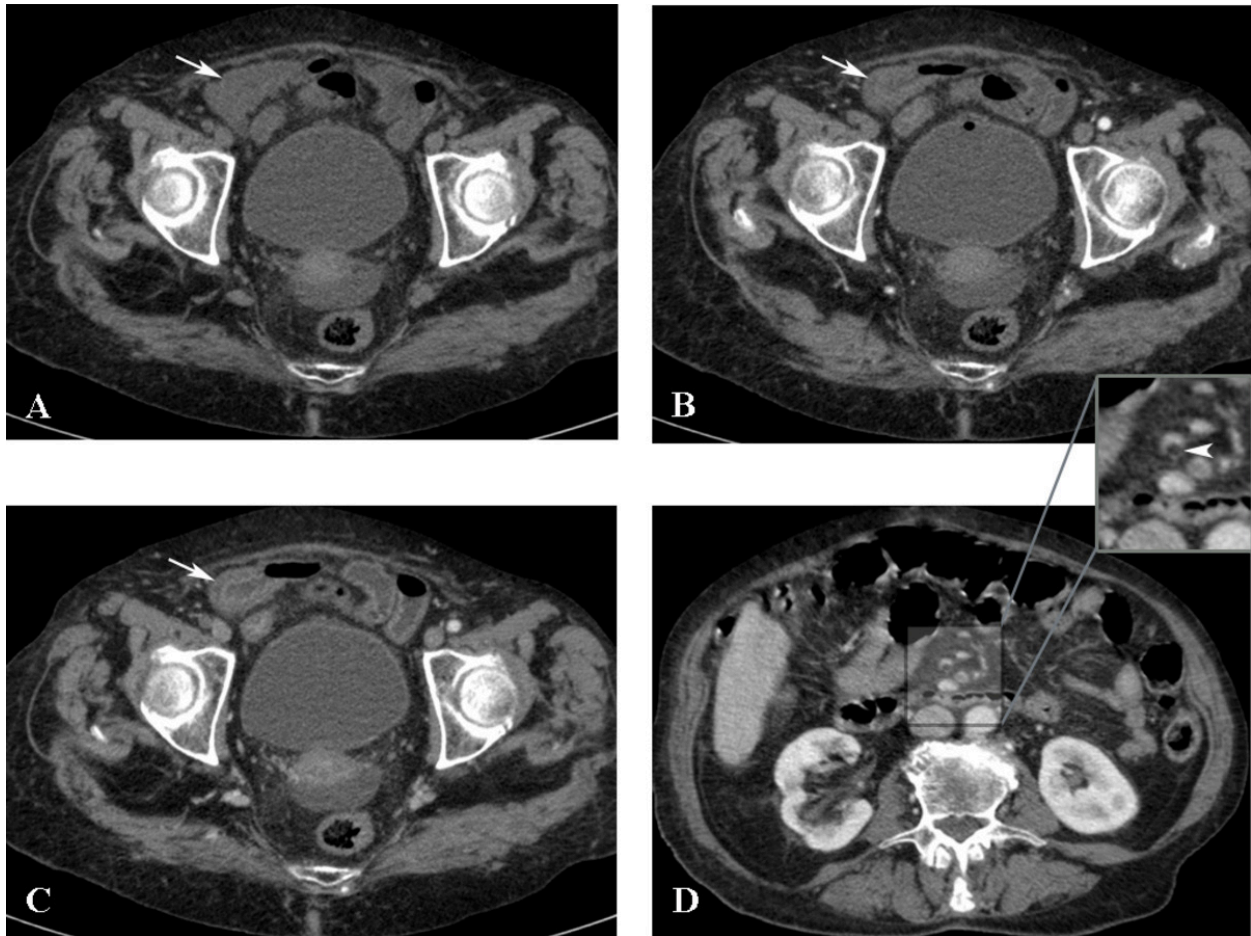


Fig. 6: A 87 year-old female with bowel arterial ischemia. Axial unenhanced MDCT image (figure 6A) shows a mild bowel wall thickening (arrow); after contrast administration in arterial (figure 6B) and venous phase (figure 6C) wall thickening with the target sign is better appreciable (arrows). Figure 6D demonstrates a partial filling defect in a superior mesenteric artery branch (arrowhead in magnification).

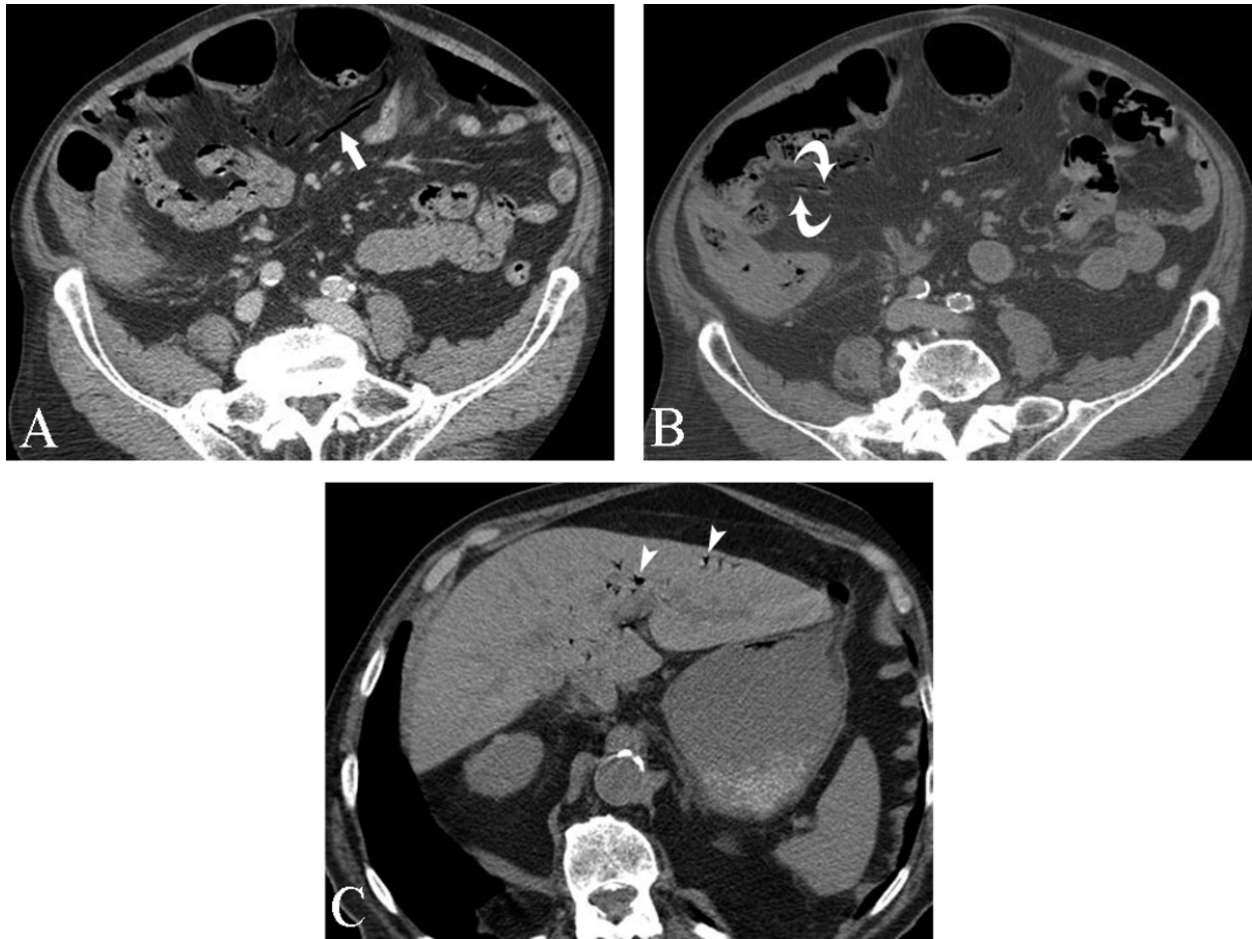


Fig. 7: A 87 year-old male with bowel venous ischemia. Figure 7A and 7B (respectively arterial and venous phase) show pneumatosis of regional mesenteric venous branches (arrows) with air-contrast level (curved arrows). In figure 7C pneumatosis is also visible in intra-hepatic portal branches (arrowheads).

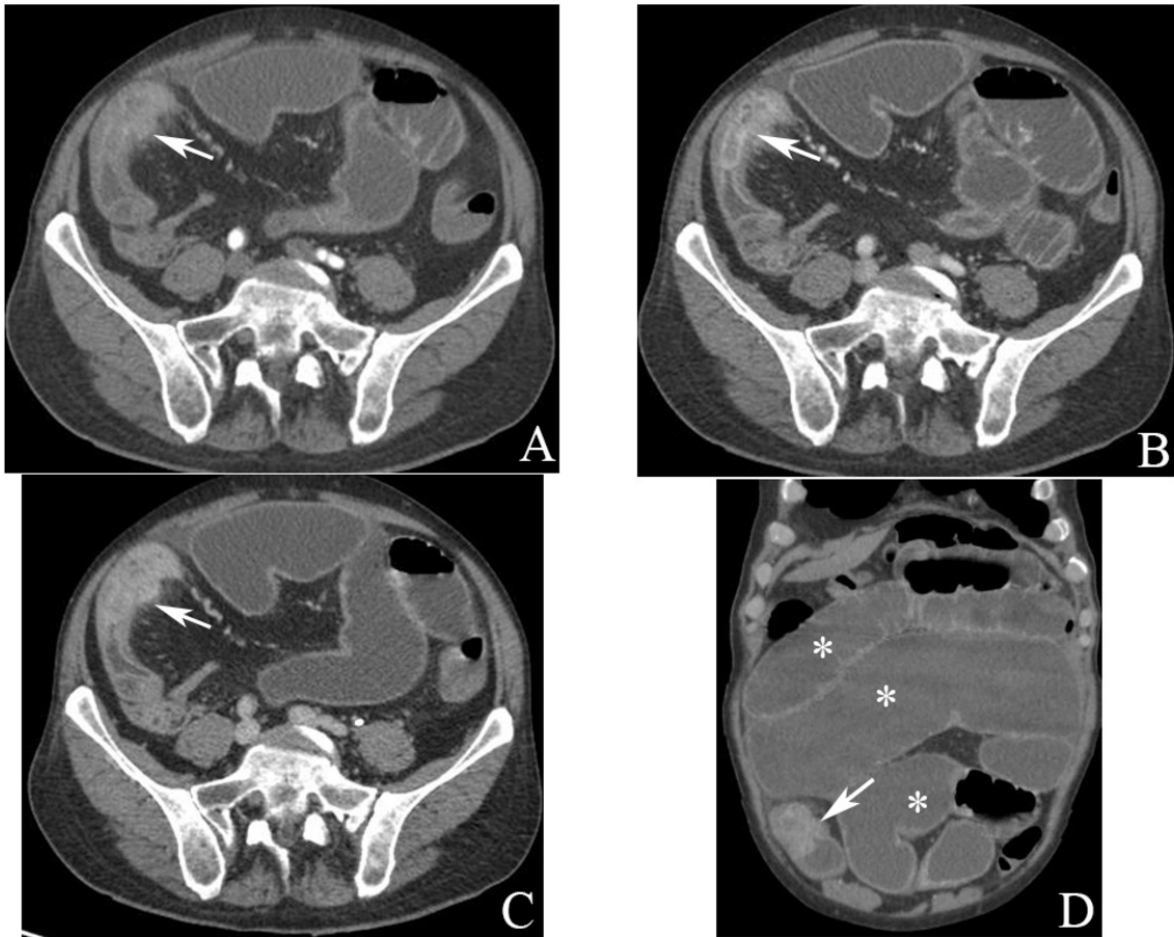


Fig. 2: Chron's disease in a 73 year-old male. Axial MDCT enhanced images (figure 2A-C) show wall thickening (arrows) with heterogeneous stratified enhancement ("target sign"). In figure 2D a coronal MDCT reconstruction shows lumen stenosis with above small bowel enlargement (asterisks).

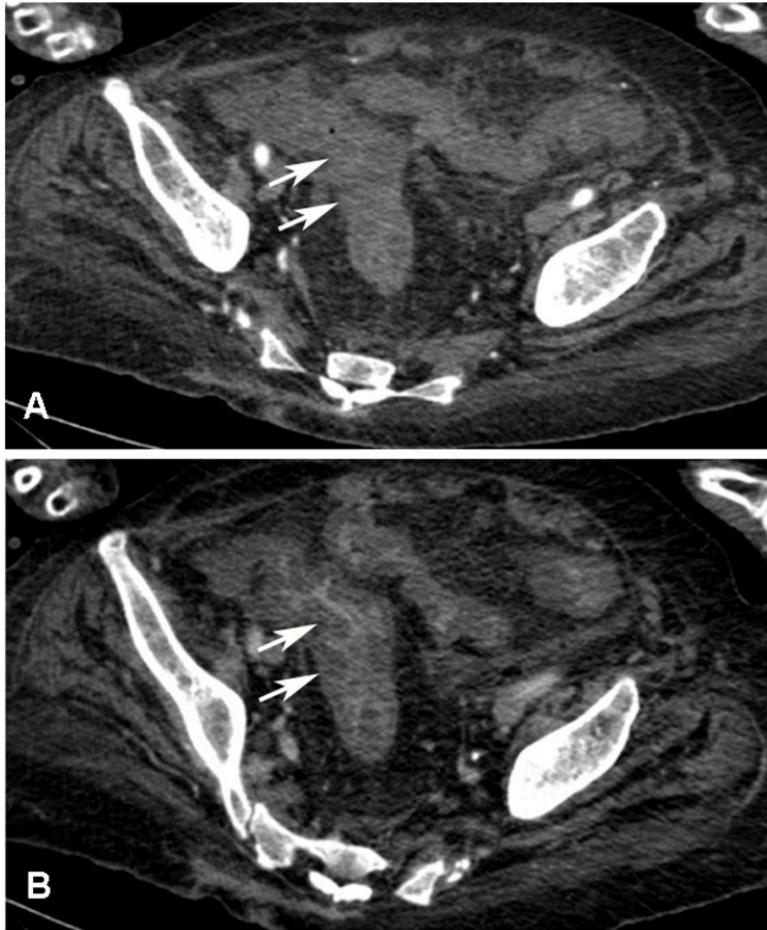


Fig. 10: A 92 year-old male with pseudomembranous colitis. Large bowel wall thickening (arrows) is shown in figure 10A (MDCT enhanced arterial phase image). Venous phase MDCT image (figure 10B) demonstrates the "accordion sign".

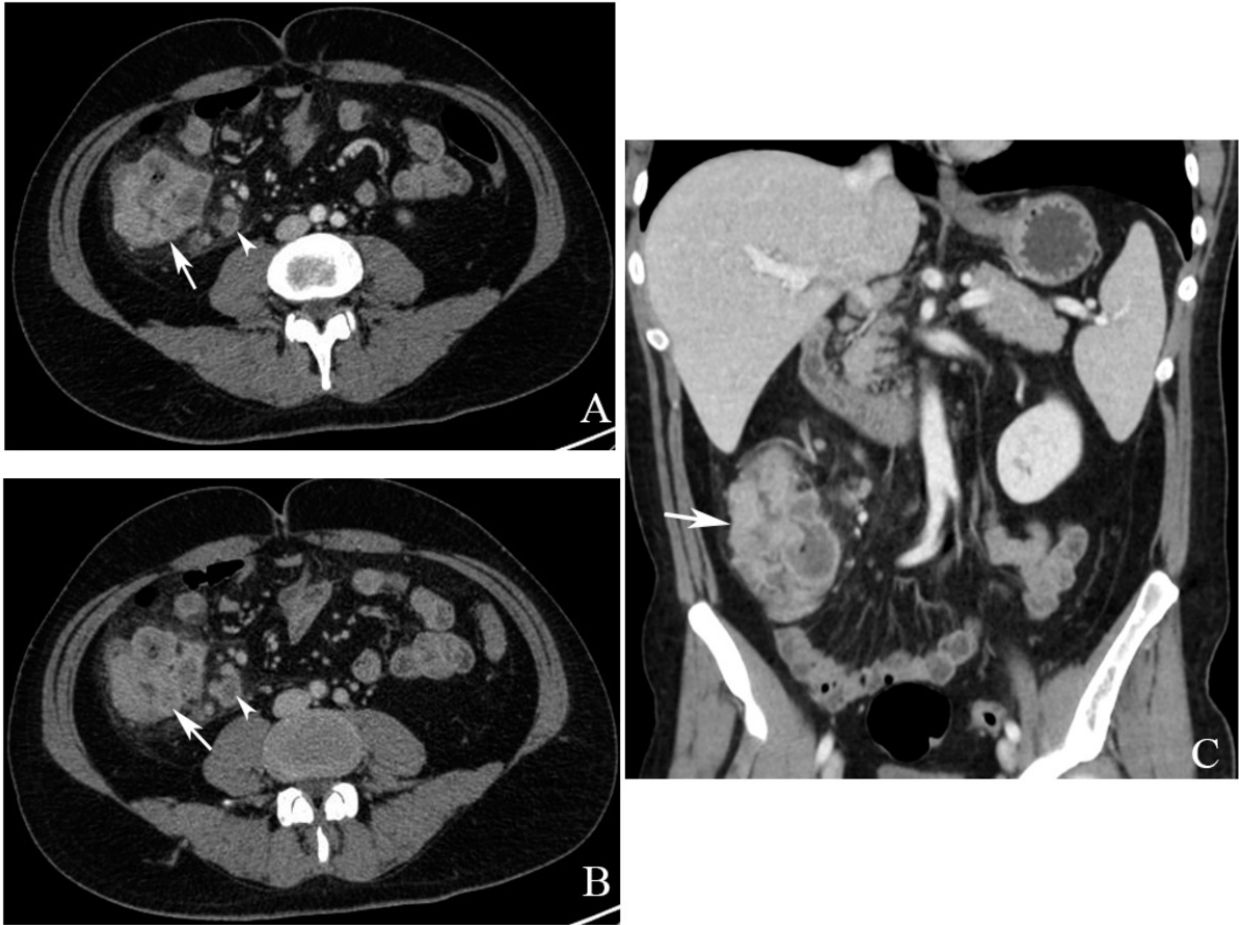


Fig. 11: A 40 year-old male with adenocarcinoma. Arterial (figure 11A) and venous phase (figure 11B) axial MDCT scans and coronal reconstruction (figure 11C) demonstrate irregular wall thickening, with heterogeneous mixed enhancement pattern (arrows) and narrowing of the lumen; a necrotic lymph node (arrowheads) next to the lesion is also observed.

Conclusion

Evaluation of contrast enhancement pattern, combined with other radiological and clinical features, is a useful tool in order to reach a correct diagnosis.

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Personal Information

Federica Roccasalva, MD

f.roccasalva@gmail.com

Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico- Vittorio Emanuele"
Via Santa Sofia 78 - 95123, Catania - Italy

Marina Piccoli, MD
p.mari4@hotmail.it

Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico- Vittorio Emanuele"
Via Santa Sofia 78 - 95123, Catania - Italy

Stefano Palmucci, MD
spalmucci@sirm.org

Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico- Vittorio Emanuele"
Via Santa Sofia 78 - 95123, Catania - Italy

Letizia Antonella Mauro, MD
mauroletizia@tiscali.it

Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico- Vittorio Emanuele"
Via Santa Sofia 78 - 95123, Catania - Italy

Giuseppina Cappello, MD
giuseppina.cappello@gmail.com

Radiodiagnostic and Oncological Radiotherapy Unit
University Hospital "Policlinico- Vittorio Emanuele"
Via Santa Sofia 78 - 95123, Catania - Italy

Giovanni Carlo Ettore, Professor

g.ettore@unict.it

Radiodiagnostic and Oncological Radiotherapy Unit

University Hospital "Policlinico- Vittorio Emanuele"

Via Santa Sofia 78 - 95123, Catania - Italy