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# The added value of MDCT enterography using oral lactulose solution in detection, characterization, and guiding management of small bowel disorders

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## Abstract

**Background:** Small bowel variable symptoms present a diagnostic challenge for both gastroenterologists and radiologists due to SI length, overlapping serpentine course and continuous motility. CT enterography was introduced in the last two decades as the cornerstone imaging modality in diagnosing small bowel disorders using a mixture of an oral solution containing water and a gastrointestinal diluting agent. This study aims to demonstrate the added value of MDCTE in evaluating and guiding the management of small bowel disorders in order to reduce SI-related morbidity and mortality.

**Results:** Data analysis of 80 patient records involved in this study demonstrated the high accuracy of MDCTE in detecting different small bowel disorders and their related pathologies, confirmed by laboratory and histopathological analyses.

**Conclusions:** MDCT enterography with oral lactulose solution is now the mainstay of imaging in the detection, characterization, and guiding management of small bowel disorders with great value of low-dose techniques in CD patient's follow-up in order to reduce ionizing radiation exposure.

**Keywords:** Small intestine (SI), CT enterography (CTE), Crohn's disease (CD), Lemmel syndrome, Superior mesenteric artery syndrome (SMA), Median arcuate ligament syndrome (MALS), Gastrointestinal stromal cell tumor (GIST)

## Background

Despite advances in modern endoscopy, which allows for excellent luminal evaluation without assessment of extraluminal abnormalities, the complex nature of the small bowel poses a diagnostic challenge for radiologists and gastroenterologists [1].

Early changes in small bowel disorders are usually subtle, with an extreme diversion in the presenting

symptoms due to wide variation in small intestinal pathology. These symptoms may include pain, anorexia, recurrent vomiting, weight loss, obstruction, bleeding, perforation, or jaundice. These unspecific symptoms and unreliable clinical findings may result in a significant delay in diagnosis [2].

Computed tomography enterography (CTE) was described for the first time 25 years ago and significantly increased the prediction of small bowel disorders compared to routine pelviabdominal owing to oral administration of a large volume of neutral enteric contrast material with CT attenuation similar to water, scanning during the phase of maximal small bowel

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enhancement with the use of thin sections, multiplanar reformatting (MPR), and maximum intensity projection (MIP) technologies [3].

In addition to being cheap, quick, and available, MDCTE is a unique noninvasive method with superb spatial and temporal resolution as it displays not only the entire bowel wall thickness but also permits evaluation of the surrounding mesentery and peri-enteric fat as well as deep ileal loops in the pelvis without superimposition and provides a global overview of the abdomen, while exposure to ionizing radiation is the main limitation of CTE [4, 5].

MDCT enterography is now most commonly used for detecting local signs of inflammation such as hyperenhancement, mural thickening, stratification, abscesses, and fistulas, as well as extra-enteric manifestations of IBD, obstruction, localizing sites of GI tract bleeding, and detecting small bowel neoplasms as well as its pivotal role in guiding therapeutic management [6, 7].

Although small bowel tumors are uncommon, they are frequently included in the differential diagnosis of small bowel disease because of their nonspecific presenting symptoms, with adenocarcinoma being the most common primary small bowel malignancy, followed by carcinoids, lymphoma, and GIST, respectively, with leiomyomas accounting for the majority of benign tumors [8].

Water, whole milk, polyethylene glycol, and water with methyl cellulose, lactulose, and barium solution with sorbitol are among the many neutral and positive oral contrast agents used. Positive contrast agents may obscure fine details of mucosal enhancement and are usually limited to postoperative cases, suspected polyps, or webs [9].

We discuss the use of CTE in current clinical practice and its benefits and limitations with various pathologies encountered.

## Methods

Between October 2019 and October 2021, 80 patients with suspected small intestinal pathology were evaluated retrospectively for symptoms and clinical suspicion using MDCT enterography using oral lactulose solution.

## Inclusion criteria

All adult patients with suspected small intestinal symptoms ranging from abdominal pain, chronic diarrhea, bleeding, obstruction, recurrent vomiting, or jaundice.

## Exclusion criteria

- Patients with high serum creatinine, pregnancy, and allergy to contrast media.
- Patients diagnosed with an extra-enteric origin.
- Patients with high-grade obstruction who cannot tolerate neutral contrast mixture.

## MDCT protocol

Following 6-h fasting, all patients were subjected to multidetector computed tomography enterography (MDCTE) using a multidetector-row helical CT scanner (Toshiba Aquilion Prime 160 CT).

In the radiology unit, detailed patient history and clinical data such as prior operations or endoscopy, symptoms, and previous radiological studies were obtained.

Unless contraindicated, patients were instructed to drink a large volume of neutral oral contrast medium solution, a mixture of 1250 cc of water and 250 cc of lactulose (67%) over a one-hour period in a continuous manner after IV spasmolytic (Buscopan).

Afterward, 1.5 ml/kg of nonionic contrast was administered intravenously at a rate of 4 ml/s through the antecubital vein.

For perfect timing imaging of the arterial and enteric phases, a technologist used bolus tracking to create a region of interest within the lumen of the upper abdominal aorta with the ROI trigger threshold being set at 150 HU with scanning initiated 6 s after the threshold CT number is achieved.

Seventy-four patients were subjected to combined CT angiography and CT enterography images during the arterial phase, which started 20–30 s after CM administration, and the enteric venous phase began at 60–70 s after CM administration, while in the remaining six patients with known CD, we did only post-contrast enteric phase using low-dose techniques as to reduce radiation exposure in repeated follow-up.

Non-contrast images were obtained in all patients to rule out intramural hemorrhage. Also, it is used for enhancement comparison.

In axial images, abdominopelvic CT images were captured in the supine position utilizing a 160-detector-row MDCT scanner (Toshiba Aquilion Prime 160 CT) with a 5 mm slice thickness in axial images extending from the lower chest to the symphysis pubis. Following the CT scan, 2 mm thinner slices were reconstructed for all patients to produce sagittal and coronal reformatted images.

**Image analysis**

Filtered reconstruction algorithms were used to reconstruct all MDCT images. After reconstructing the raw data with medium soft tissue reconstruction algorithms, the thin slices were sent to the workstation (Vitrea workstation).

The interpretation was made using multi-planner reconstruction (axial, sagittal, and coronal) views, MIP (maximum intensity projection), and curved MPR (multi-planner reformatted images).

Multiple criteria were used to classify small bowel lesions, including nature, location within the small bowel, number, length, and thickness of affected segments, pattern of enhancement as well as presence of extra-enteric abnormalities.

**Data verification**

The detailed surgical operation, entero/endo or colonoscopy, and histopathological records were reviewed in all patients.

**Statistical analysis and data interpretation**

Data were analyzed using IBM SPSS Corp., released in 2013. IBM SPSS Statistics for Windows, version 22.0. Armonk, NY: IBM Corp. Qualitative data were expressed using numbers and percent, whereas quantitative data were described using median (minimum and maximum) and interquartile range for nonparametric data and mean and standard deviation for parametric data after testing normality using the Kolmogorov–Smirnov test. The significance of the obtained results was determined at a p value of (0.05).

**Results**

The study included 80 patients, 46 males and 34 females, with ages ranging from 16 to 79 years (mean age  $\pm$  SD = 45.28  $\pm$  10.25) (Table 1). They were selected from inpatients and outpatients of the Gastroenterology Surgical Center at Mansoura University from October 2019 to October 2021.

**Table 1** Socio-demographic characteristics of the studied group

Age	Male		Female	
	N = 46	%	N = 34	%
16–19	2	4.3	2	5.9
20–29	7	15.2	4	11.8
30–39	12	26.1	7	20.6
40–49	8	17.4	4	11.8
50–59	10	21.7	6	17.6
60–69	3	6.5	6	17.6
70–79	4	8.7	5	14.7

Data regarding the patients’ laboratory and other interventional procedures were obtained from their medical records. Table 2 shows the MDCTE diagnosis in the study population. There were 24 SI inflammatory and infectious disorders (Figs. 1, 2 and 3), 12 SI vasculature disorders (Figs. 4 and 5), 27 intestinal neoplasms (Figs. 6 and 7), 13 developmental anomalies (Figs. 8 and 9), and 4 mechanical small bowel obstruction (Fig. 10).

**Inflammatory and infectious disorders**

**Crohn’s disease (CD)**

Enteric involvement is often transmural and segmental with characteristic skip lesions. It may be of inflammatory, stricturing, or penetrating nature.

CT features include asymmetric wall thickening of more than 3 mm with stratified mural hyperenhancement, either intramural edema in active Crohn’s or submucosal fat deposition in chronic CD (Fig. 1A).

More than 50% luminal reduction is considered luminal narrowing, while luminal narrowing with proximal intestinal dilatation of more than 3 cm is considered stricture. Stricture may be due to an active inflammatory process or chronic fibrosis necessitating surgical resection and anastomosis (Fig. 1B).

An ulcer is defined as any mucosal surface breakthrough with intraluminal contents extending into the

**Table 2** Final diagnosis of the studied cases

Final diagnosis	Total no.	%
<i>Inflammatory and Infectious disorders</i>	n = 24	30.0
IBD	17	70.9
Non-IBD (FMF and duodenitis)	3	12.5
Specific infection (TB)	2	8.3
Nonspecific imaging findings	2	8.3
<i>Vascular disorders</i>	n = 12	15.0
Occlusive with mesenteric ischemia	2	16.7
Compressive syndromes	7	58.3
Duodenal varices (venous collaterals)	1	8.3
Shock bowel syndrome (hypoperfusion complex)	2	16.7
<i>Neoplastic lesions</i>	n = 27	33.8
Benign	9	33.3
Malignant	18	66.7
<i>Developmental anomalies</i>	n = 13	16.3
Lemmel syndrome	3	23.1
Malrotation anomalies	10	76.9
<i>Small bowel obstruction</i>	n = 14	17.5
External hernia	2	14.3
Intussusception	1	7.1
Adhesions	1	7.1
Other causes (previously categorized)	10	71.4

Note: inconclusive numbers



**Fig. 1** Crohn's disease. CTE images in three different patients. **A** Axial images showed multiple segments of mild ileal wall thickening, engorged vasa recta (comb sign) representing active inflammatory CD. **B** Coronal reformatted images in another patient showed an ileal segment of moderate wall thickening and luminal narrowing with proximal upstream dilatation representing active CD with inflammatory stricture formation. **C** Axial images of another patient showed moderate wall thickening with submucosal fat deposition, hyper-enhancing mucosa and multiple rose thorn ulcers with entero-entero-myo-cutaneous fistula formation representing chronic penetrating CD with signs of active inflammation. **D** Sagittal reformatted low-dose CTE images of the same patient after one year of biological therapy showed stationary course of the disease. Ectopic pelvic left kidney in both (A) and (B)

bowel wall. The main feature of penetrating Crohn's disease is an extra-enteric extension beyond the serosa, which may be blind-ended as in the sinus tract or connected with an adjacent organ or skin, forming a fistulous tract that may be simple or complex with multiple branching tracts and abscess formation (Fig. 1C, D).

**Familial Mediterranean fever (FMF)**

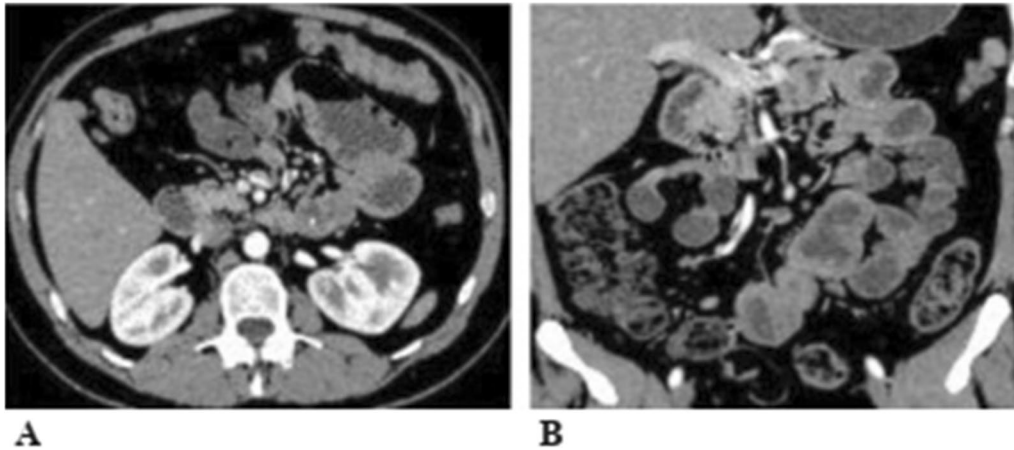
Imaging findings are nonspecific and include segmental bowel wall thickening, alternating luminal dilation, narrowing, and lymphadenopathy. Angiographic findings include the presence of luminal irregularities and abrupt caliber changes in the vasculature (Fig. 2).

**Intestinal tuberculosis (TB)**

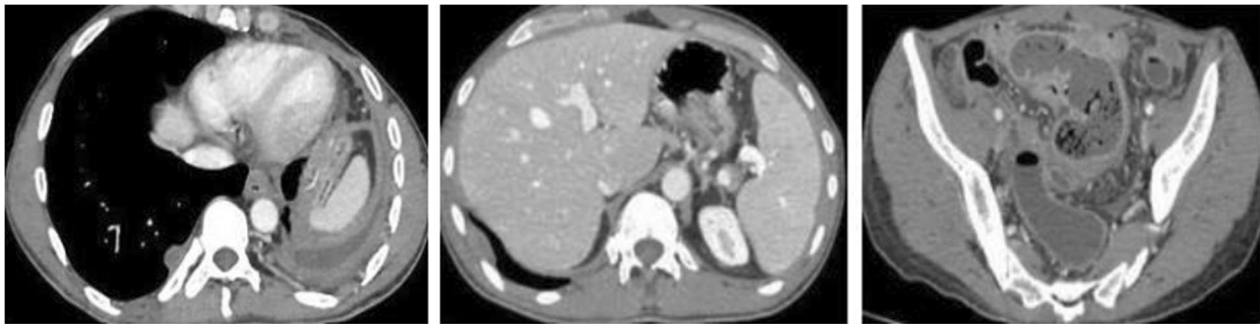
Mural thickening, stricture formation with subsequent obstruction, and caseating mesenteric lymphadenopathy are the most common findings in intestinal TB. Other extraintestinal findings include peritoneal thickening, cystic nodules, and high-density ascites (Fig. 3).

**Upper abdomen vascular compressive syndromes Superior mesenteric artery syndrome (SMA)**

In SMA syndrome, the third duodenal part is seen compressed between the abdominal aorta and SMA with an aortomesenteric angle of less than 22 degree and a distance between 2 and 8 mm, resulting in



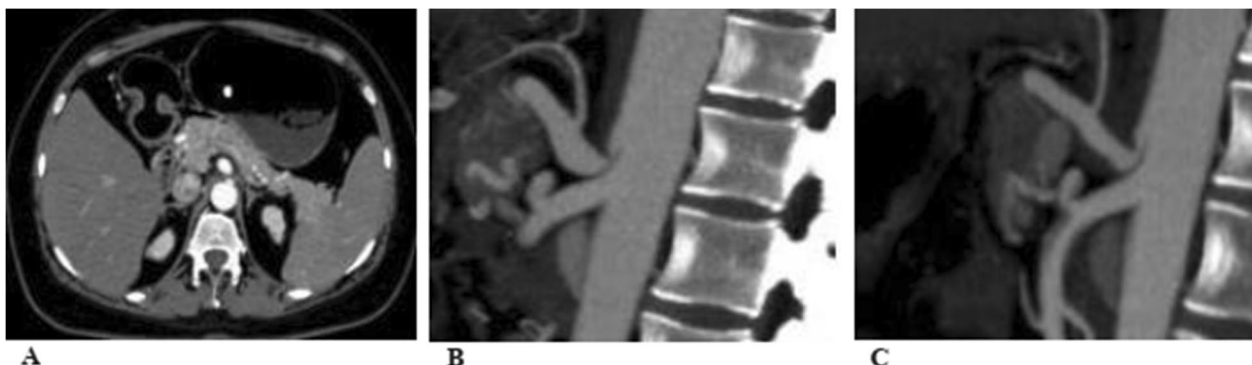
**Fig. 2** Familial Mediterranean fever (FMF). **A** and **B** Axial and coronal reformatted CTE images in a 34-year-old male patient who presented with recurrent vomiting and abdominal pain revealed multiple segments of jejunal and ileal wall thickening with mural calcific foci, prominent mesenteric vasculature. Pathologically proved FMF complicated by amyloidosis



**Fig. 3** Abdominal tuberculosis (TB). Axial CTE images of a 44-year-old prisoner complaining of severe abdominal pain and fever. **A** showed left-sided pleural empyema and right cystic pleural nodule. **B** showed another right cystic pleural nodule and omental cystic nodule. **C** showed marked ileal wall thickening and dilatation with small bowel faces sign. The patient showed +ve QuantiFERON-TB Gold (QFT)



**Fig. 4** Superior mesenteric artery syndrome (SMA) in a 19-year-old female patient complaining of weight loss and repeated vomiting. **A** Upper GI series showed dilatation of the second duodenal part with narrowing of the third part. **B** Axial CTE images showed narrow distance between the aorta and SMA. **C** Sagittal reformatted MIP angiographic images showed aortomesenteric angle measures about 18 degree



**Fig. 5** Median arcuate ligament artery syndrome (MALS) or Dunbar syndrome. A 37-year-old female patient complaining of chronic anemia, recurrent vomiting, and weight loss. **A** Axial angiographic images showed thickened MAL with multiple submucosal duodenal collaterals. **B** Sagittal reformatted MIP angiographic images showed hooked appearance of celiac trunk with focal stenosis and post-stenotic dilatation as well as multiple duodenal collaterals. **C** Post-transection of MAL sagittal reformatted MIP angiographic images showed mild relief of focal compression and post-stenotic dilatation



**Fig. 6** Benign, malignant GIST, and leiomyoma. CTE images in three different patients. **A** Axial images in the arterial phase showed intraluminal hyper-enhancing soft tissue mass with prominent feeders. Pathologically proven benign GIST. **B** Axial arterial images in another patient showed hyper-enhancing heterogenous ileal mass with hypertrophied feeders. Pathologically proven malignant GIST with +ve DOG1 and CD117. **C** Coronal reformatted images in another patient with positive rectal contrast showed a well-defined iso-enhancing jejunal lesion causing intestinal obstruction. Pathologically proven leiomyoma. Positive for  $\alpha$ -SMA but negative for DOG1, CD117

second duodenal part dilatation. It may be congenital or acquired due to loss of abdominal fat and rapid weight loss (Fig. 4).

**Median arcuate ligament syndrome (MALS) (Dunbar syndrome)**

CTA features of median arcuate ligament syndrome include proximal narrowing of the celiac trunk with or without post-stenotic dilatation and a classic hooked appearance on sagittal reformatted images. In severe cases, collaterals through the pancreatic and duodenal arteries are developed, which prevent intestinal hypoperfusion (Fig. 5).

**Neoplastic lesions**

**Benign gastrointestinal stromal tumor (GIST)**

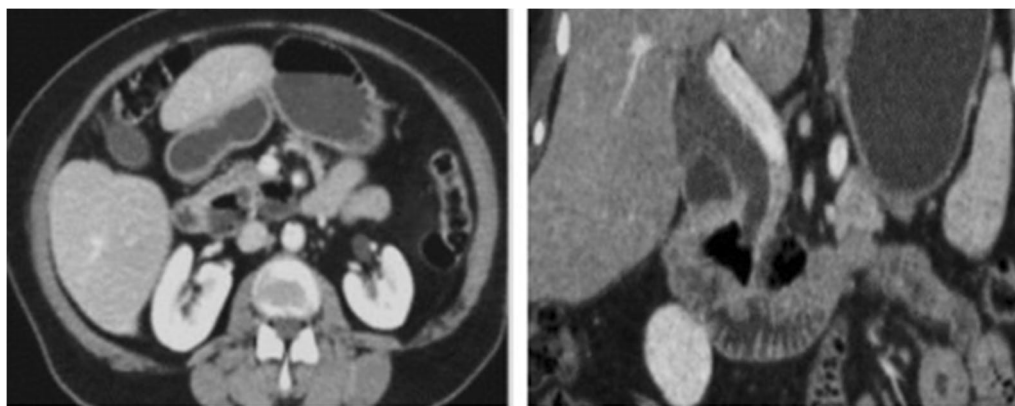
GISTs are distinct benign or malignant mesenchymal tumors that arise from Cajal’s interstitial cells with unique immunoreactivity for KIT (CD 117). Benign GIST is far more frequent than malignant and manifests as a homogeneously enhancing soft tissue mass usually smaller than 5 cm and may contain calcifications (Fig. 6A).

**Malignant gastrointestinal stromal tumor (GIST)**

Malignant GIST is typically larger than 5 cm with an exophytic pattern of growth, areas of necrosis, and rarely calcifications. Malignant GIST frequently invades adjacent structures and metastasizes (Fig. 6B).



**Fig. 7** Small bowel malignant masses. CTE images in three different patients. **A** Axial images showed avidly enhancing mesenteric soft tissue mass with surrounding desmoplastic reaction and subacute intestinal obstruction representing carcinoid tumor. **B** Axial images in another patient showed long segments of jejunal and descending colon hyper-enhancing eccentric wall thickening with entero-colic fistula formation representing jejunal adenocarcinoma. **C** Axial images in another patient showed marked circumferential wall thickening of both small and large bowel loops with a gray pattern of enhancement and generalized abdominopelvic lymphadenopathy. Biopsy proven NHL, B cell type



**Fig. 8** Lemmel syndrome. **A** and **B** Axial and coronal reformatted CTE images in a 55-year-old female presented with jaundice showed two large PADS with air and fluid densities inside, one of them is seen compressing the lower CBD resulting in upstream dilatation and subsequent biliary obstruction in the absence of stones or masses

**Leiomyoma**

It appears as poorly enhancing mass with calcification and ulceration in large masses. Larger tumors with surrounding lymphadenopathy have a higher malignant potential and are usually treated surgically (Fig. 6C).

**Carcinoid**

It appears as an avidly enhancing submucosal or mesenteric soft tissue mass with calcification, surrounding desmoplastic reaction leading to SBO and vascular encasement with subsequent ischemia. Liver metastasis is common (Fig. 7A).

**Adenocarcinoma**

It manifests as circumferential or eccentric mural thickening with enhancing mass and subsequent irregular luminal narrowing. Advanced stages of the disease showed peri-enteric fat infiltration, lymphadenopathy, and distant and peritoneal metastasis (Fig. 7B).

**Lymphoma**

Lymphoma appears either mass-like thickening without obstruction or wall thickening greater than 2 cm with gray enhancement pattern. It could be a primary or apart of systemic disease. The terminal ileum is the



**Fig. 9** Patterns of malrotation. CTE images in three different patients. **A** and **B** Axial and coronal reformatted images in patient with non-rotation of the intestine showed right-sided SI and left-sided colon with appendix arising from the midline caecum, circumaortic left renal vein and abnormal direction of the pancreatic body and tail (heterotaxy). It also showed multiple splenules (not shown in images) (polysplenia syndrome). **C** Axial images in another patient with reversed rotation of the intestine showed also right-sided SI, left-sided colon, retro-mesenteric colon and midgut volvulus. **D** Axial images in another patient with malrotation showed right-sided jejunum with normal position of the colon and abnormal vertical relationship between mesenteric vessels. Also, there is moderate left-side ileal wall thickening with submucosal edema pattern, suggesting malrotation with left paraduodenal hernia

most commonly affected site and typically affects elderly patients (Fig. 7C).

**Developmental anomalies**

The most common small bowel developmental anomalies are malrotation and duodenal diverticula which maybe symptomatic or asymptomatic.

**Lemmel syndrome**

The presence of a periampullary diverticulum (PAD) compressing the distal CBD with subsequent extrahepatic biliary obstruction and jaundice in the absence of

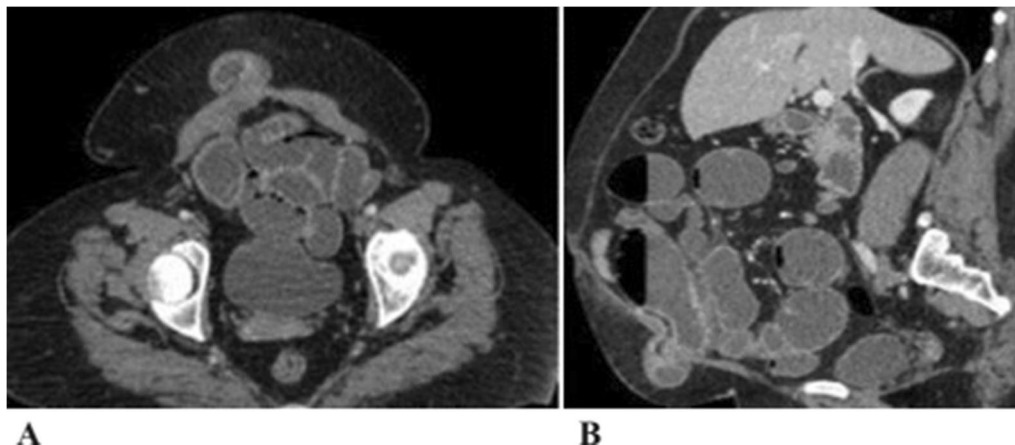
masses or stones is the main diagnostic finding in Lemmel syndrome (Fig. 8).

**Malrotation anomalies**

Malrotation anomalies may occur as a single finding or part of syndromes (Fig. 9). It was classified into non-rotation, malrotation, or reversed rotation. The most critical CT features include the abnormal position of the duodenojejunal junction, jejunum, caecum, and/or abnormal relationship of mesenteric vessels.

Non-rotation is characterized by a right-sided SI and left-sided colon, as well as the failure of the duodenum to





**Fig. 10** Mechanical small bowel obstruction. **A** and **B** Axial and sagittal reformat CTE images in a 53-year-old female complaining of vomiting 2 days post-laparoscopic cholecystectomy showed markedly dilated long ileal segment up to external incarcerated hernia through cesarean section scar. Surgically proved case

cross the midline (Fig. 9A, B), while in reversed rotation (Fig. 9C), a retro-mesenteric colon is the most common feature.

In malrotation (Fig. 9D), there is an abnormal duodenal jejunal junction position and right hemiabdomen jejunal loops, while the colon has a normal peripheral position. Furthermore, the relationships between the mesenteric artery and vein vary greatly. It can be normal, vertical, or reversed, and it can be complicated by midgut volvulus (Fig. 9C) or internal hernia (Fig. 9D).

#### Small bowel obstruction (SBO)

Intestinal adhesions followed by hernias and cancer are the most frequent etiologies of small bowel obstruction. Other causes include Crohn's disease, blunt/iatrogenic trauma, foreign bodies/bezoars, volvulus, and gall stone ileus (Fig. 10).

#### Discussion

Currently, CTE is performed for most indications including patients with occult gastrointestinal bleeding and suspected pancreatic or neuroendocrine tumors. By extension, CT angiography provides a time-efficient method for patients with acute GI bleeding, allowing for faster selective catheterization and embolization of bleeding vessels with increased sensitivity due to the negative oral contrast use [10].

Leduc et al. illustrated that lactulose is the best agent used in CTE, producing better small bowel distension than Metamucil, PEG, and water alone after testing four different oral neutral contrast agents with a large sample size. Additionally, it is inexpensive, well-tolerated, and rapidly consumed with fewer reported side effects, which

is consistent with our findings, as lactulose provides adequate luminal distention while having fewer reported side effects [11].

In the current study, we did not use any positive oral contrast materials as they obscure early mucosal changes, which is consistent with a study done by Ali et al. [12], who also stated that positive oral contrast agents (containing iodine) are not routinely used for CTE and limited only to postoperative cases.

In this study, a retrospective data analysis was done for 80 patients complaining of SI disorders for whom MDCT enterography was done in an attempt to reach the etiological diagnosis. The MDCTE diagnosis was correlated with the laboratory and histopathological findings in all cases.

#### Inflammation

In this study, small bowel neoplasm and inflammation were the most common SI pathology, which aligns with Paulsen et al. and Shokralla et al., who demonstrated that SI inflammatory disorders are the most prevalent cause of bowel-related symptoms in adults, followed by neoplastic lesions in the elderly (4,6). Twenty-four patients (30%) were diagnosed with small bowel inflammatory disorders, 17 (70.9%) of which were proven laboratory and histopathologically to be due to IBD, and 7 cases (29.1%) were due to non-IBD causes including FME, duodenitis, and nonspecific findings. Shokralla et al. and Tochetto et al. demonstrated that estimated CTE sensitivity to detect small bowel inflammation was approximately 90% using biopsy as the reference standard and increased if associated with clinical, laboratory data, and follow-up [4, 13].

According to Roda et al. [14], Crohn's disease most commonly manifests in patients younger than 30 years old, with a second peak between 60 and 79 years old, which aligns with the findings of this study, which found that 13 patients were under 30 years old and four patients were over 60 years old. In order to reduce exposure to radiation in follow-up patients, low-dose techniques are used, including reducing milliamperage, kilovolt, and iterative reconstructions [15].

In our study, terminal ileum was affected in all patients with characteristic skip lesions, which is consistent with Elsayes et al. [3], who mentioned that CD could affect any part of the gastrointestinal tract, with a particular affinity for the terminal ileum.

According to Guglielmo et al. [16], asymmetrical mural thickening is specific to Crohn's disease, whereas symmetrical was associated with other conditions such as ischemia or infection. This finding is compatible with our findings, which showed asymmetrical wall thickening in all Crohn's patients.

Mural stratification is not unique to Crohn's disease, according to Afifi et al. [17]. It has been observed in other small bowel diseases such as ischemia, ulcerative colitis, and radiation enteritis, aligning with our study in which two patients with nonspecific infection and one with ischemia presented with mural stratifications [15].

According to Ali et al. and Guglielmo et al., patients with active CD had an engorged vasa recta, peri-enteric edema, reactive regional LNS, and a submucosal edema pattern of mural enhancement. In contrast, there is a mesenteric fibrofatty proliferation and submucosal fat deposition in chronic patients. This finding is compatible with our findings, in which 13 people had active and 4 had chronic disease with submucosal fat deposition [12, 16].

According to Guglielmo et al., stricture caused by acute disease is manifested by bowel wall hyperenhancement and mural stratification. It is usually treated medically, whereas lack of enhancement and loss of stratification indicate transmural fibrosis and may necessitate surgical intervention. Four of the strictures in this study were active and were treated medically, while the other two were chronic and required resection and anastomosis [16].

In this study, we discovered nine patients with renal anomalies, six of whom were ectopic and three had horseshoe kidneys, which had never been reported in the literature.

#### **FMF**

According to Matsumoto et al., FMF commonly affects young patients and is characterized by splenomegaly,

asymmetric wall thickening, abrupt changes in the caliber of the mesenteric vasculature, and luminal dilatation. This finding is consistent with our findings, in which one patient had SI wall thickening alternating with areas of bowel dilatation and minimal ascites. Furthermore, there is a link between FMF and amyloidosis. This finding is consistent with our findings, in which one patient had FMF and amyloidosis, resulting in SI dysmotility and calcifications [18].

#### **TB**

Intestinal TB is common in developing countries, low socioeconomic communities, and among prisoners, according to Ladumor et al., aligning with our findings, which revealed that one prisoner and one poor female farmer had both been diagnosed with intestinal TB. It commonly affects the terminal ileum and caecum due to abundant lymphatic tissue and relative stasis of gut contents and is characterized by mural thickening, caseating LNs, peritoneal thickening, cystic nodules, and high-density ascites, matching our findings in two patients with cachexia, night fever, and sweating. CTE has also shown mural thickening, stricture formation, obstruction with small bowel faces, and cystic peritoneal nodules. A positive QuantiFERON-TB Gold test was performed on these patients [19].

#### **SMA**

The main diagnostic criteria of SMA syndrome are an aortomesenteric angle of less than 22° and a distance of less than 10 mm at the level of the third part of the duodenum, as well as proximal bowel dilatation. This finding agrees with the current study, in which SMA was present in five patients with an aortic–mesenteric angle less than 22 degree, and a distance between 5 and 10 mm in three patients and less than 5 mm in two patients [20].

According to Sahni et al., rapid weight loss increases the risk of SMA syndrome, consistent with our study, in which two patients experienced rapid weight loss, followed by SMA manifestation. Medical and nutritional therapy relieves these patients' symptoms without surgery [20]. Laparoscopic duodenojejunostomy (DJ) is the gold standard of management in SMA patients, with good mid- and long-term results and few complications, and is only reserved for patients who have failed medical and nutritional therapy. Only one patient had a duodenojejunostomy in this study [20].

#### **MALS**

MALS is commonly detected in young patients with a slight female predilection as an anatomic variant or as part of compression syndrome with postprandial pain

being the most common complaint, aligning with our findings in which three patients were diagnosed with MALS, two of whom were female, all was in the second and third decades [21, 22].

Transection of MAL is the most appropriate surgical intervention in patients with hemodynamic changes and collateral development, according to Gozzo et al. and Nasr et al. In our study, one patient with high-grade stenosis and collaterals underwent MAL transection, which resulted in improved symptoms [21, 22].

### **Neoplastic**

According to Williams EA et al., primary SI tumors affects the elderly. This finding aligns with the current study findings, in which all patients are over 50 years old [23].

Primary malignant tumors of the small bowel are less common than benign tumors, according to Jasti et al. and Sokhandon et al. This finding contradicts the findings of this study, which found malignant SI tumors in 18 patients but benign ones in only nine patients [2, 8].

In contrast to carcinoid, which commonly affects the distal ileum, it is found that duodenal adenomatous tumors are more common than ileal and jejunal, compatible with this study, in which one patient's ileum was affected by a carcinoid tumor. One patient had a duodenal adenoma, two had adenocarcinoma of the duodenum, and one had adenocarcinoma of the ileum [2, 8].

Adenoma and gastrointestinal stromal tumors (GIST) are the most common benign small bowel tumors with a malignant predisposition, consistent with the findings of this study, which found that GIST was the most common SI neoplasm in ten patients. According to Williams et al. [23], approximately 40% of GISTs develop in the small bowel, most commonly in the duodenum or jejunum, which is supported by the findings of this study, which revealed that GIST affected the duodenum in four patients, the jejunum in four, and the ileum in two patients.

Adenocarcinoma manifests as circumferential or eccentric mural thickening with enhancing mass and subsequent irregular luminal narrowing, according to Yang et al. Peri-enteric fat infiltration, lymphadenopathy, and distant and peritoneal metastasis were all observed in the advanced stages of the disease. This finding corresponded to our study, in which three patients met the criteria mentioned earlier [24].

According to McLaughlin et al., benign GISTs are far more common than malignant GISTs, and they usually extend exophytically from the bowel lumen. This finding is consistent with the findings of this study, which discovered GIST in three patients with benign criteria and seven with malignant criteria. Benign lesions are smaller than 5 cm in size and have poor enhancement, whereas malignant lesions are larger in size and have

heterogeneous enhancement as well as areas of necrosis. A tumor diameter of more than 10 cm is a strong predictor of cancer, which aligns with the findings of this study, which discovered GIST in three patients with benign criteria and seven with malignant criteria [25].

According to Ramai et al., leiomyoma is a rare mesenchymal tumor that frequently affects the jejunum when it occurs in the small bowel. It may appear as homogeneously enhanced mass with calcification and ulceration. Larger tumors with surrounding lymphadenopathy have a higher malignant potential and are typically treated surgically. This finding corresponds with this study, in which one patient had jejunal leiomyoma with subsequent SBO and was pathologically proven to be DOG1 negative [26].

According to Jasti et al. [8], the ileum is the most common site of small bowel involvement with lymphoma due to the presence of abundant lymphoid tissue, corresponding to our findings, in which three of five lymphoma patients had ileal involvement. Lymphoma is more common in men and has a higher peak prevalence in their seventh decade of life. In our study, only two patients were over the age of 70, and three were in their fifth decade. However, it is common because it affects three male patients [8].

Lymphoma can be identified by significant wall thickening (>2 cm), eccentric stenosis, and coexisting lymphadenopathy. This finding was consistent with this study, in which all lymphoma patients had wall thickening greater than 2 cm [8].

According to Jasti et al. adenocarcinoma, it is more common in the proximal small bowel than lymphoma, which is more common distally. The presence of multiple foci also favors lymphoma over primary adenocarcinoma. This finding is consistent with this study, which found adenocarcinoma in the duodenum and jejunum in three patients and lymphoma in the ileum in three patients [8].

### **Developmental anomalies**

#### **Lemmel**

Lemmel syndrome was first identified in 1934 by Lemmel and is a rare form of obstructive jaundice. PAD is a common incidental finding in 1–27% of patients, according to Bernshteyn et al., and is complicated by jaundice in less than 5% of them, with intraluminal types being more common than extraluminal types. This finding is consistent with our findings, in which duodenal diverticula were described as an accidental finding in eight patients (6.4%) and as a cause of biliary obstruction in three subjects (2.4%) [27]. Management options ranged from conservative in asymptomatic patients to surgery in biliary obstruction patients, aligning with our study in which all patients underwent surgery to relieve the biliary obstruction.

### Malrotation

Perez et al. stated that malrotation anomalies are typically undiagnosed until adulthood, which corresponded to our findings in which all patients were diagnosed in adulthood but differed from Neville et al., who stated that 90% of patients are diagnosed in their first years of life [28, 29].

According to Neville et al., normal DJJ adheres to the left lumbar vertebral pedicle, and any deviation from this location is considered a malrotation anomaly. This finding corresponds to this study's findings as all patients with malrotation had the DJJ not located to the left of the spine, either partially crossing (in 5 patients) or not crossing the spine at all (5 patients) [29].

Non-rotation is distinguished by right-sided SI and left-sided colon, failure of the duodenum to cross the midline, left hemiabdomen caecum, and the absence of pancreatic uncinata process, according to Deniffel et al. This finding corresponds to this study that included four patients with non-rotation presented by DJJ not crossing the spine, right-sided small bowel loops, and left-sided colon [30].

According to Perez et al. and Deniffel et al., reversed rotation is manifested by a retro-mesenteric colon and an absence of pancreatic uncinata process, which corresponds to our study, which has one case of reversed rotation with a retro-mesenteric colon and a corkscrew relationship between mesenteric vessels [28, 30].

The main features of malrotation, according to Perez et al. and Deniffel et al., are abnormal duodenojejunal junction position and right hemiabdomen jejunal loops with a normal peripheral position of the colon, with a wide variety in the relationships between mesenteric vessels, which matches this study in which two patients with malrotation were presented with right-sided jejunal loops [28, 30]. Due to chronic congestion, it may be complicated by midgut volvulus and mesenteric cyst formation. Furthermore, internal hernias are frequently associated with malrotation anomalies caused by abnormal parietal bands.

### Limitations

- Exposure to radiation.
- Emergency services for acute patients are not available in our center.
- This retrospective study excluded all patients who did not adhere to our oral regimen or vomited.

### Conclusions

Nowadays, MDCT enterography using oral lactulose solution presents the mainstay of imaging in detection, characterization, and guiding management of small bowel disorders with great value of low-dose techniques in CD patient's follow-up as to reduce ionizing

radiation exposure. Surgical, histopathological, and laboratory findings are critical confirmatory methods in order to increase the validity and reproductivity of MDCTE.

### Abbreviations

SI: Small intestine; CT: Computed tomography; MDCT: Multidetector computed tomography; CTE: Computed tomography enterography; CM: Contrast media; PAD: Periampullary diverticula; SMA: Superior mesenteric artery; MALS: Median arcuate ligament syndrome; IBD: Inflammatory bowel disease; CD: Crohn's disease; FMF: Familial Mediterranean fever; GIST: Gastrointestinal stromal cell tumor; SBO: Small bowel obstruction;  $\alpha$ -SMA: Alpha-smooth muscle actin; DOG1: Discovered on GIST-1; CD117: Cluster of differentiation.

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### Author contributions

MS and EF contributed to the study's conception and design; acquired, analyzed, and interpreted the data; processed CT findings at the CT workstation; revised the clinical data; and contributed to the drafting of the manuscript. EM, MM, and AG contributed to the study's conception and design, collected patients' data, processed CT findings at the CT workstation, and contributed to writing and revising the manuscript. All authors mentioned read and approved the final manuscript.

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### Availability of data and materials

The sets of data used and/or analyzed during the study are available upon sensible request.

### Declarations

#### Ethics approval and consent to participate

No individual data were included in the study. This study was approved by the Research Ethics Committee of the Faculty of Medicine at Mansoura University in April 2019. Reference number of approvals: MD.19.04.168. All patients participating in this study were informed of what it entails and gave verbal informed consent to take part in this research. If the patient was unconscious at the time of the study, written informed consent for their participation was provided by their legal guardian.

#### Consent for publication

Revision of the patients' records included in this study revealed that all patients gave written informed consent to use and publish the data obtained within this study. If the patient was unconscious when consent for publication was requested, written informed consent for the publication was provided by their legal guardian.

#### Competing interests

The authors of this study declare that they have no competing interests.

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