SUMMARY

Introduction: CT enterography - or abdominal scan with a special protocol to assess the small bowel – has become a valuable tool for patients with suspected bowel disorders. It is based on the use of a combination of intravenous contrast medium and large volumes of a neutral oral contrast administered by mouth in order to distend the intestinal lumen and allow imaging of the small bowel lumen, wall thickness, and enhancement patterns. Materials and methods: Ninety cases of patients who came to a university clinic were collected retrospectively between May 2007 and February 2009. Preparation included a residue-free liquid diet and total fasting 24 and 4 hours before the study, respectively. In total, 2,000 cm³ of water were administered, supplemented afterwards with 100 cm³ of the intravenous contrast medium at a rate of 4 cm³/sec. An early arterial phase was performed at 20 seconds and a portal phase at 60 seconds after initiating the administration of the intravenous contrast. Results: The most frequent findings were diverticular disease, cystic lesions, neoplasms, Crohn’s disease, ileitis, mechanical obstruction, hiatal hernia, cholelithiasis, hepatic hemangiomas, internal hernia, duodenal diverticulum, polyposis, intestinal malrotation, and active bleeding. Conclusions: CT enterography is a useful non-invasive study for the diagnosis of small bowel diseases. It provides a satisfactory small bowel distension in most cases without the need of enteral tube advancement.

KEY WORDS (MESH)
Tomography, X-ray computed
Small intestine
Crohn’s disease
Inflammatory bowel diseases

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Colitis, ulcerative

Introduction

CT enterography - or abdominal scan with a special protocol to assess the small bowel – has become a valuable tool for patients with suspected bowel disorders. Proper evaluation of the small bowel is achieved with a combination of intravenous contrast medium and a large volume of neutral contrast administered orally to stretch the intestinal lumen and produce images for the assessment of the lumen, thickness, and pattern of enhancement of the small intestinal walls. Like a conventional CT scan, this technique allows for the assessment of the entire abdomen and pelvis. The purpose of this article is to review the characteristics of CT enterography and to describe the methods used in 90 patients from our institution, as well as the imaging findings.

Technical aspects

CT enterography is based on the combined use of oral and intravenous contrast to visualize the small intestine by means of fine sections and multiplanar reconstructions (1-4) using multidetector computed tomography (MDCT). (1) With multiplanar views, tracking and imaging of the small bowel is easy due to the possibility to localize and examine the extent of a disease following a similar orientation as that provided by conventional barium studies on a coronal plane. (5)

Contrast media

Accurate imaging requires the oral administration of neutral contrast medium with attenuation values ranging between 10 and 30 HU, similar to those obtained with water. (1,6) Neutral agents allow for complete imaging of the normal gut wall because of the ability to analyze grade and enhancement pattern. (7,8) Multiple neutral agents have been used, including water or water with other agents (such as methylcellulose, mannitol, polyethylene glycol or milk) and low-density barium solutions (volume [Low-Hounsfield-value barium sulphate], E-Z-EM). (2,5,7,9-13)

These substances reduce water resorption in the lumen and improve gut distension. However, none of them have been tested sufficiently for generalized use. (14) Finally, proper imaging requires adding intravenous contrast (2,3,6) in order to determine the enhancement pattern of the intestinal wall. (1)

Degree of distension

The degree of distension accomplished is proportional to the quantity of contrast material consumed, the consumption rate, and the time elapsed before the study. (1) An appropriate analysis requires a separation of the intestinal loop walls in order to reduce potential false positive results. (1) Once appropriate stretching is achieved, the thickness of the small bowel walls is seen to vary from almost imperceptible to up to 2 mm. (15) In a well-distended
bowel, any wall thickness greater than 3 mm is considered abnormal.(4) Mural thickening, in turn, may be classified under three categories: mild (3-4 mm), moderate (5-9 mm), and marked (more than 10 mm).(1)

**CT enterography vs. enteroclysis**

Oral agents eliminate the need to use an enteral tube for a CT with enteroclysis.(10,11,14) Enteroclysis entails additional radiation from fluoroscopy (14), which is undesirable in some cases; moreover, patients do not usually tolerate the procedure, making it a more time-consuming for the radiologist attempting to pass the tube.(10) However, CT with enteroclysis continues to be the best test for detecting partial obstructions and intraluminal masses.(16)

**Patient preparation**

For the correct visualization of the intestinal wall, patient preparation requires diet restriction(6) in order to reduce false positive results in the interpretation of focal lesions such as polyps or tumors.(1) Patients are brought in two hours before the test in order to ensure rest and adequate oral preparation.(1,8)

**Advantages of CT enterography**

Advantages of CT enterography include ease of performance; simple scanner parameters (managed by the team of technologists); less radiation compared with enteroclysis studies(3); and images that surgeons and gastroenterologists are familiar with. Finally, the time of use of the CT room is less than 10 minutes, and the time from the moment the oral contrast is administered until the test is performed is less than two hours.

**Limitations of CT enterography**

The main limitation of CT enterography is secondary to the use of water as the single neutral contrast because it is absorbed by the gut mucosa and creates suboptimal stretching, especially of the terminal ileum in some cases(16), particularly when preparation is inadequate.(1,3,10,11,14)

**Indications for CT enterography**

Because it is non-invasive and fast, CT enterography has become the first-line test for patients with suspected small bowel disorders.(7,8,17). The main indications for performing this test include inflammatory bowel disease (2,6); obscure GI bleeding; and suspected neoplasms.(1) Additionally, it is useful for detecting other abdominal and pelvic diseases (18) or incidental findings in patients with abdominal pain.(1)

**Inflammatory bowel disease**

In the majority of cases, inflammatory bowel disease may be classified as either ulcerative colitis or Crohn’s disease.(2,6) Diagnosis is challenging, mainly in cases with mild inflammation confined to the small bowel.(2) Aside
from the clinical findings, imaging has become the method of choice for assessing the intestinal wall and extra-intestinal lesions.(2) Thickening of the intestinal wall is the most important imaging criterion used as an indicator of Crohn's disease or ulcerative colitis.(6)

Wall enhancement may be transmural or affect some of the layers, giving rise to a stratified appearance. This finding, determined by increased mucosal enhancement, low attenuation of the submucosa and increased muscularis enhancement, creates the “bull’s eye sign” or mural stratification sign.(6) (Fig. 1.) Increased wall enhancement after the administration of intravenous contrast is considered indicative of active disease (8,19,20), and it may even correlate with the degree of disease activity.(17)

**Crohn’s disease**

Crohn’s disease is an idiopathic transmural inflammatory process that may affect any portion of the small bowel.(18) Reported incidence has been increasing, raging from 3.1 to 14.6 for every 100,000 people in the United States, and from 0.7 to 9.8 for every 100,000 people in Europe.(21) It varies according to the different regions between 1.5 and 24.5 for every 100,000 people/year.(22) The small bowel is affected in 30 to 40 per cent of patients, and the most frequently affected portion is the ileum, with terminal damage in 90 per cent of cases. In 40 to 50 per cent of cases, both the ileum and the colon are affected, whereas only the colon is affected in 25 per cent of cases. (6)

The high spatial resolution of CT enterography enables visualization of active Crohn’s disease.(23) The most common findings include thickening of the wall greater than 3 mm in a distended small bowel loop (24); increased mucosal enhancement, and mural stratification (Fig 2); altered mesenteric fat; the “comb sign”; leaks; abscesses; adhesions; and adenopathies. (4,6,8,18,25,26)

The “comb sign” refers to the ingurgitation of the vasa recta, penetrating the intestinal wall perpendicular to the lumen and creating a comb-like appearance.(Fig. 3) Although this sign is not always found in Crohn’s disease, it correlates with higher C reactive protein values, apparently because of perienteric inflammation.(16) When present, this sign is indicative of greater activity, histological inflammation and endoscopic severity. (16,27,28) Because of its performance, CT enterography is the first-line modality for the diagnosis and staging of Crohn’s disease.(4,29)

*Fig. 1. Patient diagnosed with Crohn’s disease, showing increased wall enhancement and thickening (more than 3 mm). Together, increased mucosal enhancement, submucosal edema, and increased muscularis enhancement, form the “bull’s eye” mural stratification sign (arrows).*

*Fig 2. Coronal view in a 56 year-old female diagnosed with Crohn’s disease, showing evidence of mural stratification.*
Fig 3. Forty-eight year-old female diagnosed with Crohn’s disease. Coronal section showing the ingurgitation of the vasa recta, or “comb sign” (arrows).

**Ulcerative colitis**
Ulcerative colitis affects between 250,000 and 500,000 individuals in the United States, with an incidence of 2-7 per 100,000 people/year. It affects only the large intestine, with a continuous distal-to-proximal distribution, most frequently in the rectum. Findings range from superficial erosions to large ulcerations, although penetration into the muscularis occurs only in severe cases; the mucosa appears thickened because of infiltration into the lamina propria, whereas in chronic cases, a marked hypertrophy of the muscularis typically produces contraction and stenosis of the affected segment. CT enterography in this group of patients is mainly used to rule out findings suggesting Crohn’s disease.

**Disadvantages of CT enterography when assessing patients with inflammatory bowel disease**

Despite being highly effective, CT enterography has its limitations in the assessment of inflammatory bowel disease, particularly in patients requiring follow-up scans because of radiation exposure. In those cases, magnetic nuclear resonance may be considered as an option for follow-up.

**Obscure gastrointestinal bleeding**
Obscure gastrointestinal bleeding accounts for approximately 20-30 per cent of the 30,000 hospital admissions due to GI bleeding in the United States every year. In more than half of these cases there is rebleeding, usually requiring additional studies. Angiodysplasia is the pathology most commonly found in obscure gastrointestinal bleeding followed by neoplasms that account for 5-10 per cent of all cases of obscure GI bleeding of the small bowel.

Other less common causes include ulcers (because of Crohn’s disease or secondary to the use of non-steroidal anti-inflammatory agents) (Fig. 4), Meckel’s diverticulum, vasculitis, small bowel diverticula, and aortoenteric fistulae. The usefulness of CT enterography for the detection of gastrointestinal bleeding originating in the small bowel has not been studied extensively and is under research.

**Bowel obstruction**
In patients with recurrent small bowel obstructions and a history of abdominal and pelvic surgery, adhesions are the most common cause of this problem. CT enterography is useful in determining its presence, localization, cause and associated complications, in particular ischemia; however, as was mentioned previously, the study of choice in suspected partial bowel obstruction is CT with enteroclysis.
Celiac disease (sprue)

Celiac disease is an autoimmune disorder produced by gluten exposure, resulting in damage to the small bowel. Characteristically, it affects by layers, leading to jejunal atrophy, ileal hypertrophy, inverted folding patterns, and intussusceptions (35), as well as dilatation and layer separations of the small bowel.(36) These patients have a higher risk of developing lymphoma and small bowel carcinoma (35).

Small bowel tumors

The most common small bowel tumors include adenocarcinoma, carcinoid, lymphoma (Fig. 5), and gastrointestinal stromal tumors (GIST). Non-malignant tumors include hamartomatous polyps, Peutz-Jeghers syndrome, and hyperplastic polyps (8).

Incidental findings

Incidental findings have been described in up to 3.5 per cent of patients undergoing CT enterography (Fig. 6). These include pancreatic and liver masses, endometrial cancer, pseudoaneurysms of the splenic artery, and primary sclerosing cholangitis as an extraenteric complication of inflammatory bowel disease.(8)

Materials and methods

Inclusion criteria

A retrospective review is undertaken of clinical records of patients assessed at the Gastroenterology and General Surgery Clinics of our university and taken to CT enterography between May 2007 and February 2009. Overall, 90 cases were identified, including non-hospitalized and hospitalized patients. Patient characteristics and indications for the study are summarized in Table 1.

Table 1. Population characteristics and indications for CT enterography

<table>
<thead>
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<td>54.74</td>
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<td>49(64.4%)</td>
<td>76</td>
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<td>14</td>
<td>21</td>
<td>27.6</td>
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<tr>
<td>Bowel obstruction</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>10.5</td>
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<tr>
<td>Neoplasms</td>
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<td>Lymphoma</td>
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<td>1</td>
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<td>Carcinomatosis</td>
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<td>2</td>
<td>2.63</td>
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<tr>
<td>Lymphoid</td>
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<td>1</td>
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### Table
<table>
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<th>Condition</th>
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<th>Odds Ratio</th>
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<td>Cancer of intestinal origin</td>
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<td>0.01</td>
<td>1.31</td>
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<tr>
<td>Connective tissue disease</td>
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<td>0.00</td>
<td>1.31</td>
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<tr>
<td>Gastrointestinal bleeding</td>
<td>4</td>
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<td>18.40</td>
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<td>Inflammatory bowel disease</td>
<td>1</td>
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<td>5.26</td>
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<tr>
<td>Short bowel syndrome</td>
<td>1</td>
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<td>1.31</td>
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<tr>
<td>Abdominal pain</td>
<td>4</td>
<td>0.05</td>
<td>22.36</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>27</td>
<td>(35.5%)</td>
<td>100.00</td>
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</table>

**Fig. 4.** Maximum intensity projection (MIP) on the coronal plane in a patient with anemic syndrome under study, showing intraluminal leak of the contrast medium (arrows) corresponding to the non-neoplastic focus of bleeding in a jejunal loop.

**Fig. 5.** Axial view in a patient diagnosed with lymphoma showing “aneurysmal” dilatation of a proximal ileal segment and concentric mural thickening.

**Fig. 6.** Axial view in a 76 year-old male diagnosed with a solid exophytic mass in the greater curvature of the stomach consistent with gastric cancer.

### Preparation and technique
All patients were prepared with a 24-hour residue-free liquid diet and complete fasting 4 hours before the study. Each patient received a total of 2,000 cm³ of water (divided into 500 cm³, 75, 65, 25 and 15 minutes before the study). Additionally, they received 100 cm³ of intravenous isosmolar water-soluble contrast medium (Optyray™), 320 mg, at a rate of 4 cm³/second. An early arterial phase was done at 20 seconds and a portal phase at 60 seconds after initiating the administration of the intravenous contrast. The scans were performed in a 16 channel multidetector General Electric scanner with 3.0 mm slices, 3.0 mm collimation, multiplanar reconstruction and maximum intensity projection (MIP).

### Image evaluation
The studies were interpreted separately by four individual radiologists (JEFZ, FMHS, GGR and DUJ) from the Body Imaging area (CT and MRI). More than 90 per cent of the studies were reviewed separately by a subspecialist in abdominal imaging (DUJ).

### Findings
During the review of the clinical records of the patients included in the study it was not possible to determine the indication for CT enterography in 14 of them because of insufficient clinical data or absence of final diagnostic confirmation. Consequently the analysis included only the data of 76 patients for whom relevant and complete information for inclusion in the study was available; however, the technical aspects of CT enterography were applied to all 90 patients.

The mean age of the study population was 54, with a distribution of males and females of 35.5% and 64.4%, respectively. Irritable bowel syndrome, the main indication for CT enterography (27.6%), was found more frequently in women with a history of recurrent abdominal pain and alteration of the intestinal habitus as a result of diarrhea or constipation, and other symptoms like fecal urgency, bloating, sensation of incomplete evacuation, and flatulence. The purpose of CT enterography was to rule out structural abnormalities, which is a prerequisite for confirming the diagnosis. The indications for performing CT enterography are summarized in Table 1.

CT enterography was required in 18.4% of cases as part of the work-up for gastrointestinal bleeding. These patients had multiple comorbidities, and the exact source of bleeding was identified in one case (1.31%) where the interventional radiology group was able to confirm and control the bleeding site.

Seventeen studies were performed in cases where the predominant clinical finding was non-specific abdominal pain (22.3%). This condition, again, was highest among women. Results were positive in two cases of obstructed small bowel loops, and in one case they were consistent with Crohn’s disease.

Four patients were studied for suspected inflammatory bowel disease or follow-up thereof (5.26%). Findings were positive in one confirmed case of Crohn’s disease, non-digestive disease was found in another one, and the two remaining studies were interpreted as normal. There were five cases of neoplasic disease (6.57%), one of them with a history of primary small bowel carcinoma. The most frequent indication was suspected carcinomatosis (40%).

Other disorders such as post-resection short bowel syndrome (1.31%) and connective tissue disease with suspected bowel involvement (1.31%) were the minority of cases. Findings included the expected post-surgical changes in the first case and a normal outcome in the second case.

Nine scans (11.84%) were found to show evidence of small bowel changes. In this group there were findings consistent with inflammatory bowel disease in four patients (5.26%). Other less frequent disorders included small bowel loop obstructions in three cases (3.94%) and neoplasic involvement of the ileum in two cases (2.63%), one of which was related to familial polyposis (Fig. 7). In 38 scans (50%), lesions of other abdominal and pelvic organs were found, the most common findings being diverticular disease in 11 cases (14.47%), and hiatal hernia in four (5.26%). There was evidence of cystic lesions in the liver, kidneys, adrenal glands or pancreas in eight scans
(10.5%), liver and kidneys being the most frequently affected organs.

The presence of hiatal hernia was demonstrated in two scans (2.63%) as an isolated finding in cases with no prior history of abdominal surgery (Fig. 8). Five scans (6.57%) revealed post-surgical changes with not additional GI tract involvement. Other lesions such as cholelithiasis, diffuse alteration of the abdominal fat with no other finding, dolicosigmoid, hepatic hemangioma, portal vein thrombosis, gastric polyps, and biliary dilatation were the single finding in seven scans, each representing 1.31% of the total results. Finally, of all the CT enterographies, 25 (32.89%) were found to be normal. Findings are summarized in Tables 2 and 3.

Table 2. Summary of findings and percentage of cases found on CT enterography

<table>
<thead>
<tr>
<th>Reading</th>
<th>Cases</th>
<th>%</th>
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<tbody>
<tr>
<td>Inflammatory bowel disease</td>
<td>4</td>
<td>5.26</td>
</tr>
<tr>
<td>Small bowel loop obstructions</td>
<td>3</td>
<td>3.94</td>
</tr>
<tr>
<td>Obstruction of other segments</td>
<td>2</td>
<td>2.63</td>
</tr>
<tr>
<td>Neoplastic disease</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Small bowel loops</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>• Polypoid disease</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>• Peritoneal seeding</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Diverticular disease</td>
<td>11</td>
<td>14.47</td>
</tr>
<tr>
<td>• Sigmoid colon</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>• Ascending colon</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Cystic lesions</td>
<td>8</td>
<td>10.52</td>
</tr>
<tr>
<td>• Liver</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>• Kidney</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>• Adrenals</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>• Pancreas</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Lower GI tract bleeding</td>
<td>1</td>
<td>1.31</td>
</tr>
<tr>
<td>Post-surgical changes</td>
<td>5</td>
<td>6.57</td>
</tr>
<tr>
<td>Internal hernia</td>
<td>2</td>
<td>2.63</td>
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<tr>
<td>Other findings*</td>
<td>11</td>
<td>14.47</td>
</tr>
<tr>
<td>Normal</td>
<td>25</td>
<td>32.89</td>
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*Hiatal hernia, cholelithiasis, diffuse abnormality of the abdominal fat with no other finding, dolicosigmoid, hepatic hemangioma, portal vein thrombosis, gastric polyps, biliary dilatation.

Table 3. Summary of findings not associated to small bowel loop
**disease on CT enterography**

<table>
<thead>
<tr>
<th>Reading</th>
<th>Cases</th>
<th>%</th>
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<tbody>
<tr>
<td>Hiatal hernia</td>
<td>2</td>
<td>18.18</td>
</tr>
<tr>
<td>Cholelithiasis</td>
<td>1</td>
<td>9.09</td>
</tr>
<tr>
<td>Diffuse alteration of abdominal fat with no other finding</td>
<td>1</td>
<td>9.09</td>
</tr>
<tr>
<td>Dolicosigmoid</td>
<td>1</td>
<td>9.09</td>
</tr>
<tr>
<td>Hepatic hemangioma</td>
<td>1</td>
<td>9.09</td>
</tr>
<tr>
<td>Portal vein thrombosis</td>
<td>1</td>
<td>9.09</td>
</tr>
<tr>
<td>Gastric polyps</td>
<td>1</td>
<td>9.09</td>
</tr>
<tr>
<td>Biliary dilatation</td>
<td>1</td>
<td>9.09</td>
</tr>
<tr>
<td>Internal hernia</td>
<td>2</td>
<td>18.18</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>11</strong></td>
<td><strong>100.00</strong></td>
</tr>
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</table>

Bearing in mind the data shown in Table 1, three main indications were defined for performing CT enterography: irritable bowel syndrome, abdominal pain and GI bleeding. Of this group, representing more than 50% of the sample, results were normal in nine patients where the indication was abdominal pain, although no diagnosis or additional clinical findings were confirmed; likewise, among the patients with suspected GI bleeding, the source of bleeding was confirmed only in one case.

In patients with suspected Crohn’s disease, findings were consistent in only one case; however another three positive cases that had been referred with a different indication or clinical suspicion were also identified. These findings are not only of imaging interest, but, more importantly, they must be analyzed as part of the multi-disciplinary management of patients with suspected small bowel disorders in order to determine clear indications for CT enterography.

From the technical point of view, it was determined that the use of water as the sole oral medium created suboptimal stretching of the small bowel loops in 20% of patients, in particular jejunal loops. For this reason, after the study was completed, the protocol was modified and, at present, oral preparation at the service is done with 2,000 cm3 of water with 2.5% mannitol. This has led to improved bowel loop distension, at least until now.

On the other hand, image evaluation found that the arterial phase of the scan does not provide additional diagnostic findings, and it is believed that it is possible to perform only the portal phase without affecting the quality or the interpretation of the scans, thus reducing the radiation dose by 50%.

**Discussion**

CT enterography has began to replace older studies such as intestinal transit, mainly due to the large amount of information it provides, given that multi-detector scanning offers high spatial resolution not only of the bowel loops but also of the abdominal and pelvic structures that may be associated
with the clinical picture of these patients.

Fig. 7. Axial view in a patient with familial polyposis. There is a focal intraluminal mass that enhances homogenously with contrast (arrow).

Fig. 8. Coronal view showing jejunal loop displacement towards the right hemiabdomen, lateral to the ascending colon, a finding consistent with internal hernia.

Studies using the endoscopic videocapsule that allow detailed visualization of the intestinal mucosa pose the risk of bowel obstruction, in particular in patients with post-surgical adhesions, pathological processes, or physiological stenoses. Our findings show a lower incidence of Crohn’s disease than that reported by other authors in similar studies.(8) This fact is attributed to the incidence of inflammatory bowel disease in our population. Incidental findings also constitute a majority of the results obtained by other examiners (6) and reflect, in part, the use of this diagnostic tool in conditions other than the indications mentioned above.

Conclusions

CT enterography is an excellent diagnostic tool for the study of small bowel disorders, including, in particular, Crohn’s disease, mechanical bowel obstruction, and small bowel neoplasms. CT enterography offers the additional benefit of assessing abdominal and pelvic structures other than the small intestine, allowing for alternative diagnoses to guide medical and surgical management. The arterial phase of the scan did not offer relevant information in any of the patients and it was removed from the protocol for CT enterography at our institution.

Finally, the high dose of radiation to which patients are exposed, in particular those requiring follow-up, has led to the alternative use of enteral magnetic resonance. At present we already have a significant number of cases that may be the subject of analysis in a future study.

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