

# Water enema multidetector CT technique and imaging of diverticulitis and chronic inflammatory bowel diseases

Alba H. Norsa · Massimo Tonolini · Sonia Ippolito · Roberto Bianco

Received: 12 November 2012 / Revised: 8 January 2013 / Accepted: 19 February 2013 / Published online: 19 March 2013  
© The Author(s) 2013. This article is published with open access at Springerlink.com

## Abstract

**Background** Water enema multidetector computed tomography (WE-MDCT) is currently considered the most accurate imaging modality to provide high-resolution multiplanar visualisation of the colonic wall and surrounding structures.

**Methods** This pictorial review presents our experience with WE-MDCT applications outside colorectal tumour staging, particularly for investigating diverticular disease and chronic inflammatory bowel diseases. A detailed explanation of the technique is provided, including patient preparation, the acquisition protocol, and study interpretation.

**Results** WE-MDCT allows accurate preoperative visualisation of diverticular disease, acute and complicated diverticulitis. Ulcerative, indeterminate, or Crohn's colitis can be assessed including longitudinal distribution, mural thickening and enhancement patterns, pseudopolyps, associated perivisceral changes, adjacent organ involvement, and features suggesting carcinoma. Elective WE-MDCT represents a useful complementary technique in patients with impossible, incomplete, or inconclusive endoscopy, can allow study of a stricture's features and the upstream bowel, and helps planning medical, endoscopic, or surgical treatments.

**Conclusion** Urgent WE-MDCT with limited or no bowel preparation may prove useful in acutely symptomatic patients, as it may obviate a risky or contraindicated endoscopy, can

determine disease severity, and allows making correct therapeutic choices.

## Teaching Points

- *Water enema multidetector CT provides high-resolution multiplanar visualisation of the colonic wall.*
- *WE-MDCT allows accurate visualisation of diverticular disease, acute and complicated diverticulitis.*
- *In chronic inflammatory bowel diseases WE-MDCT depicts the distribution, mural and perivisceral changes.*
- *Elective WE-MDCT usefully complements incomplete endoscopy to assess strictures and upstream colon.*
- *Urgent WE-MDCT with limited or no bowel preparation in acute diseases may obviate endoscopy.*

**Keywords** Contrast enema · Computed tomography (CT) · Colonoscopy · Diverticular disease · Acute diverticulitis · Chronic inflammatory bowel diseases · Ulcerative colitis · Crohn's disease · Indeterminate colitis

## Introduction

### Background

Traditionally, diagnostic imaging of the large bowel relied on double-contrast barium enema. Although optical colonoscopy (OC) remains the gold standard to investigate colorectal disorders, since the introduction of multidetector scanners, CT colonography (CTC) using air or carbon dioxide (CO<sub>2</sub>) for colonic distension has recently become an established alternative technique, with high sensitivity for detection of benign and malignant tumours [1, 2]. The key advantages of CTC include good patient acceptance and tolerability compared to OC, feasibility in patients with impossible or incomplete endoscopy, and a limited radiation dose with acquisition

A. H. Norsa · M. Tonolini (✉) · S. Ippolito · R. Bianco  
Department of Radiology, "Luigi Sacco" University Hospital,  
Via G.B. Grassi 74,  
20157 Milan, Italy  
e-mail: mtonolini@sirm.org

A. H. Norsa  
e-mail: alba.norsa@gmail.com

A. H. Norsa  
Radiology, Sant'Ambrogio Clinical Institute, Via Faravelli,  
Milan, Italy

protocols used for screening purposes. However, CTC has some intrinsic drawbacks, including the need for specific equipment for CO<sub>2</sub> insufflation, a double acquisition in supine and prone positions, and time-consuming image analysis and interpretation by experienced radiologists. Furthermore, contrast-enhanced CTC with a full radiation dose is indicated in patients with known or suspected colorectal carcinoma (CRC) and provides improved assessment of perivisceral and extraintestinal abnormalities [1–3].

Water enema multidetector CT (WE-MDCT) includes retrograde colonic distension using water coupled with mural enhancement by intravenous contrast medium and provides excellent visualisation of the enhanced colonic wall and good contrast between the wall itself, the hypodense lumen, and the pericolonic fat. Advantages of WE-MDCT over air CTC include a simpler acquisition in the supine position only and a short learning curve without the need for complex post-processing. WE-MDCT provides a panoramic multiplanar visualisation of intestinal abnormalities, associated extramural findings or complications, with sub-millimetre spatial resolution reproducing the classical orientation of double-contrast barium enema that is familiar to most surgeons. Currently, WE-MDCT is increasingly proposed as the most accurate imaging technique in patients with suspected or proven colorectal neoplasms [4–7] and to diagnose bowel endometriosis [8, 9].

## Aim

Previous experiences using CTC to assess inflammatory bowel diseases (IBD) yielded conflicting results, with unsatisfactory visualisation of mucosal abnormalities, assessment of mural thickening hampered by wall compression from luminal air overdistension, and a potential increased risk of perforation because of the fragile, inflamed colonic walls [10–12].

Optimally tolerated, WE-MDCT provides very accurate evaluation of wall thickness and enhancement in normal and pathologic conditions, and detailed visualisation of associated perivisceral and extraintestinal abnormalities. Therefore, WE-MDCT represents an appealing modality to investigate also acute and chronic inflammatory disorders of the large bowel, particularly when endoscopy is incomplete and/or with possible complications involving the perivisceral planes or adjacent organs [12–14].

In this pictorial essay we review the WE-MDCT technique and acquisition protocol, including patient preparation, and present our experience with WE-MDCT in the assessment of diverticular disease, acute diverticulitis (AD), and chronic IBD such as ulcerative colitis (UC), Crohn's disease (CD), and indeterminate colitis.

## Water enema multidetector CT technique and interpretation

### Bowel preparation

During the early years of our experience, we recommended that preliminary bowel cleansing should be obtained unless contraindicated by emergency conditions or poor performance status. At our department, prior to elective WE-MDCT patients receive a standard oral bowel preparation consisting in 4–6 doses of a laxative isoosmolar non-absorbable solution such as polyethylene glycol powder (Isocolan, Bracco, or SELG-ESSE 1000, Promefarm, Milan, Italy) dissolved in 500 ml water per dose the day before the examination, in association with a low-residue diet for 3 days. Patients then fast for 12 h after a liquid dinner the evening before the scheduled exam [8, 9].

Recently, other centres have suggested that cathartic bowel cleansing may be unnecessary, since WE-MDCT yields satisfactory results even if the colon is not clean, as tumours can be easily distinguished from faecal residues [7]. On the basis of these experiences, we started performing WE-MDCT with no or limited bowel preparation, such as with laxative (sennosides) capsules plus magnesium citrate solution, in patients with acute intestinal symptoms.

### Contraindications

We do not perform or recommend WE-MDCT without bowel preparation when toxic megacolon, free perforation, and acute peritonitis are clinically suspected and/or radiographically detected. In patients with clinical and/or radiographic diagnosis of large bowel obstruction, which is caused by CRC in almost 60 % of cases, retrograde colonic distension is unnecessary because standard enhanced MDCT reliably evaluates the site and underlying cause of obstruction thanks to the intrinsic contrast provided by the upstream dilatation with endoluminal fluid [15].

### Patient preparation

In the CT suite, patient preparation is performed by experienced radiology nurses, with gentle insertion of a lubricated enema tube into the rectum with the patient lying on the CT scanner table in the left lateral decubitus position. The tube is then connected to a bag that contains 2 l of warm tap water, and retrograde colonic distension is obtained through gravity during 3–5 min. Afterwards, the patient is instructed to turn on his right side to improve water distribution and is then positioned supine for CT acquisition. Alternatively, incontinent patients may have an enema performed using an inflatable balloon tip.

Unless contraindicated, we routinely administer pharmacological hypotonisation with 20 mg hyoscine butylbromide (Buscopan, Boehringer Ingelheim, Florence, Italy) intravenously injected prior to scan planning. Hypotonisation improves patient comfort, facilitates colonic wall distension, and reduces peristalsis, motion artefacts, mural spasms and contraction, allowing better assessment of the mural thickness and identification of true luminal stenosis.

#### MDCT acquisition protocol

Then volumetric CT acquisition of the abdomen and pelvis during a single breath-hold is performed during intravenous injection of 110–130 ml of non-ionic iodinated contrast medium (such as 350 mgI/ml iomeprol or 370 mgI/ml iopromide) using an automated power injection at a 2.5 ml/s flow rate, with a 75-s scan delay. Acquisition parameters on a 64-slice CT scanner include 120 KV, 300 mAs, 0.891 pitch, 0.75 s rotation time, and 64 × 0.625 mm collimation. The estimated radiation exposure during WE-MDCT acquisition using this protocol is usually in the range of 12–14 mGy.

#### Exam safety

Then, the water enema is drained before the patient leaves the CT suite. The total examination time is about 10 min. In agreement with other authors, in our experience preliminary preparation and examination are well tolerated by the majority of patients, and we did not observe any adverse effects or complications [7].

#### Exam interpretation and pitfalls

WE-MDCT is a reproducible technique that does not need complex post processing or 3D interpretation; therefore, a very short learning curve is to be expected for radiologists who are familiar with abdominal studies [7]. Images are routinely reconstructed along axial, coronal, and sagittal planes; however, the attending radiologist usually reviews the study on a dedicated workstation with the possibility to save arbitrary reconstruction images focussed on the key findings, including oblique or curved-planar reformations. In WE-MDCT, optimal contrast is observed between the well-distended lumen with water density, the enhanced colonic wall, and the normal fat-density pericolonic planes (Fig. 1). Mural thickness should be measured in a non-dependent, well-distended portion. In a well-distended bowel, the normal mural thickness should not exceed 2–3 mm. During exam interpretation, radiologists should carefully search for non-distensible segments along the large bowel with or without prestenotic dilatations (diameter over 5 cm),

signs of mural thickening, hyperenhancement, and/or stratification, endoluminal projections, and diverticular outpouchings. Perivisceral fat changes such as increased density, hypervascularisation, adipose proliferation, or adenopathies should be sought. Furthermore, WE-MDCT allows comprehensive imaging of associated or incidental abnormalities involving the abdominal organs, lymph nodes, peritoneum, mesentery, retroperitoneum, lumbar and pelvic skeleton [14].

Potential pitfalls of the technique are mostly represented by non-distended bowel segments and by the presence of faecal residues, which is the rule when bowel preparation is limited or avoided. Other authors have reported a 95 % sensitivity and specificity for the detection of CRC in unclean bowel. In our experience, endoluminal stools usually do not hamper a correct assessment of the colonic wall thickness and enhancement pattern. Conversely, sub-centimetre polyps and fine mural details such as those characteristic of UC may be obscured [4, 7].

## Diverticular disease

### Epidemiology and role of imaging

Colonic diverticular disease is extremely common in the developed world, as it affects over half of the population over 65 years and most usually or predominantly involves the sigmoid tract. Symptomatic AD or complications occur in up to 25–30 % of individuals with diverticulosis [16, 17].

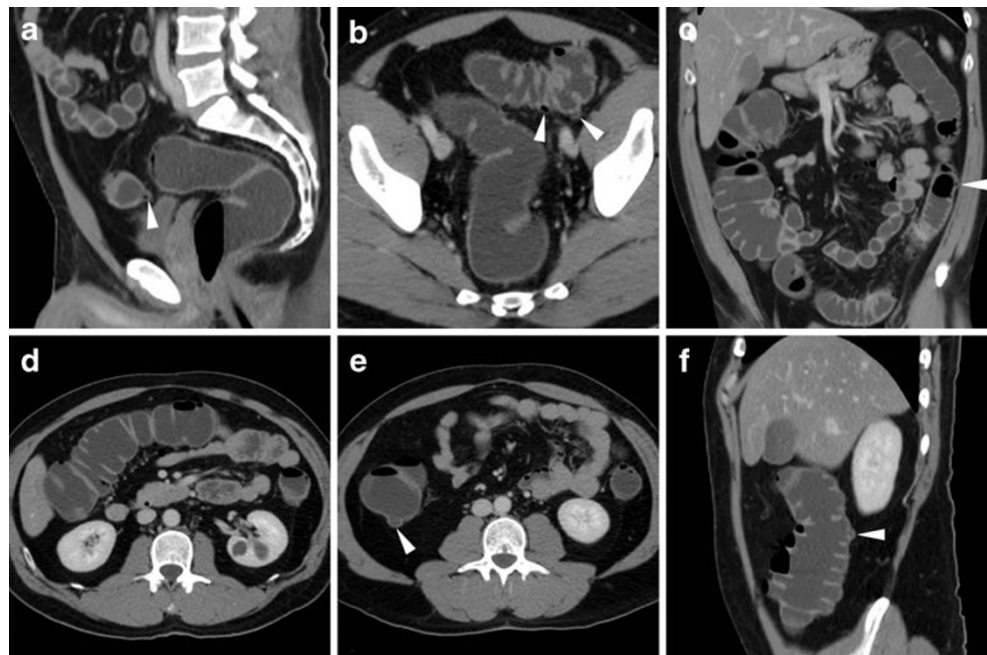
Currently, cross-sectional imaging with MDCT has largely replaced contrast enema in the urgent assessment of patients with AD, since it allows the identification of both colonic abnormalities (particularly mural thickening and diverticula) and inflammatory changes in the pericolonic fat planes [18, 19].

At our department, we are increasingly performing WE-MDCT to investigate colon diverticular disease, in both elective and urgent settings. To our best knowledge, these applications have never been previously reported in the literature.

### Diverticulosis: WE-MDCT findings

Acquired with preliminary bowel cleansing, elective WE-MDCT may be a helpful investigation in selected patients with impossible or incomplete endoscopy to visualise pre-operatively the distribution of diverticular changes and to explore the upstream colon. The hallmark imaging appearance of uncomplicated diverticulosis is confidently detected, including fluid- and/or air-filled diverticular outpouchings of the colonic wall, usually associated with mural thickening due to muscular hypertrophy and/or spasm (Figs. 1, 2 and 3) [20]. Although diverticula are a common finding, at air CTC

**Fig. 1** Water-enema multidetector CT (WE-MDCT) technique and interpretation in a 40-year-old male with clinical suspicion of acute diverticulitis. Multiplanar contrast-enhanced images show good distension of the rectosigmoid colon (**a, b**), hypersegmented proximal sigmoid, and distal descending colon with mild diffuse mural thickening and small diverticular outpouchings (*arrowheads in a, b, c*). Good distension of the upstream transverse and right colon (**d–f**) with at least one diverticulum in the ascending tract. Perivisceral inflammatory changes and abscess collections are confidently excluded



equivocal appearances such as thrombus-filled, faecalith, or inverted diverticula may cause significant diagnostic uncertainty, particularly with primary 3D interpretation [21]. WE-MDCT provides optimal presurgical assessment of the severity and extent of colon wall thickening and confident exclusion or identification of perivisceral inflammatory changes (Figs. 1, 2 and 3).

#### Acute diverticulitis: WE-MDCT findings

Diverticulitis results from diverticulum occlusion by stool, inflammation, or food particles, causing a microperforation and surrounding pericolic inflammation. Conventional contrast-enhanced MDCT is extensively used and highly reliable in detecting AD, grading its severity, excluding an underlying carcinoma, and identifying its most usual complications such as abscesses and contained perforations with 96–98 % accuracy. The usual MDCT features include

segmental wall thickening with spasm, submucosal oedema, diverticula, vascular engorgement, and inflammatory changes in the pericolic fat, plus fascial, mesenteric, and/or peritoneal fluid (Fig. 3a–c) [16, 18].

Although a precise comparison with conventional enhanced MDCT in terms of accuracy is not available, in our experience WE-MDCT with limited or no bowel preparation has proved useful in subacute AD conditions following conservative treatment (Fig. 3d–f). The detailed visualisation with better distension and the accurate extent measurement of the involved tract provided by WE-MDCT is regarded by our surgeons as useful for planning resection.

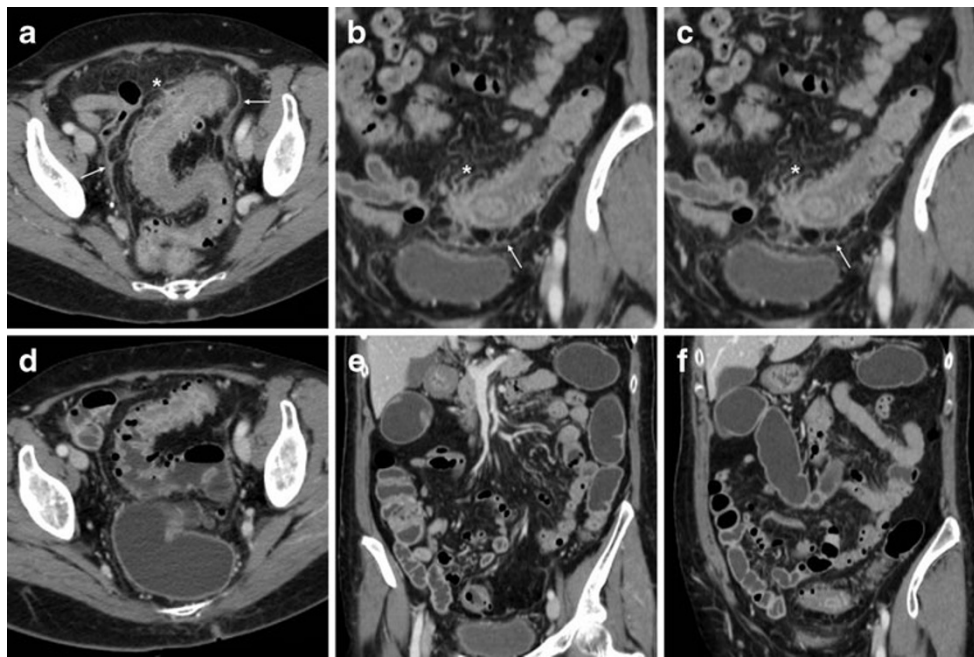
Furthermore, WE-MDCT can be safely performed in acute, symptomatic cases when endoscopy is risky (Figs. 4 and 5), provided that the above-mentioned contraindications have been excluded. In our experience, retrograde water distension of the sigmoid and descending colon is generally well tolerated and not over-invasive compared to standard MDCT.



**Fig. 2** A 45-year-old woman with known, symptomatic colon diverticular disease, investigated with WE-MDCT because of poor patient tolerance to colonoscopy, to exclude signs of acute diverticulitis. The elongated sigmoid colon shows mild, diffuse mural thickening with

homogeneous attenuation (**a**) and some sub-centimetre diverticula (*detail in b*), without perivisceral fat stranding, signs of perforation, or abscess collections. Good distension of the upstream colon is seen in (**c**), without further abnormalities





**Fig. 3** A 75-year-old woman initially investigated with conventional contrast-enhanced MDCT during a bout of acute diverticulitis (**a–c**). Severe stratified mural thickening is observed throughout the entire sigmoid colon, with oedematous submucosa, diverticula, perivisceral fat inflammatory changes (\*), and fascial fluid (*thin arrows*). Three weeks later, after conservative treatment, WE-MDCT with limited

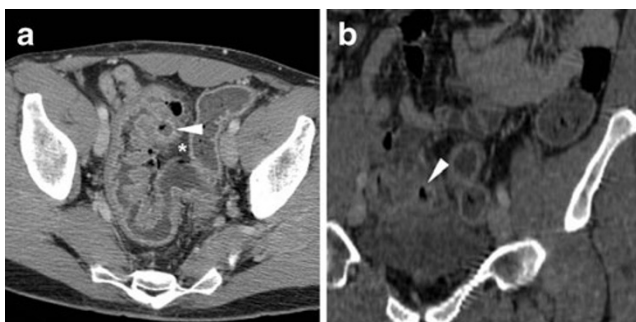
bowel preparation was performed to plan surgery, when endoscopy was still considered contraindicated. A significant decrease of sigmoid mural thickening and resolution of perivisceral acute inflammatory changes are observed (**d–e**), allowing limited laparoscopic sigmoid colon resection to be performed. Good distension of the upstream large bowel is achieved, without further abnormalities

During AD bouts, WE-MDCT effectively shows the extent and severity of mural thickening of the descending and sigmoid colon, a prominent mucosal enhancement of inflamed mucosa and diverticula, and associated pericolic fat inflammation (Fig. 4). Further complications such as abscess formation or adjacent organ fistulisation are reliably detected by both standard MDCT and WE-MDCT, but not by endoscopy or contrast enema. As according to previous extensive experience with standard MDCT in AD, abscesses

are detected in up to 30 % of patients and appear as abnormal pericolic collections with air, fluid, or debris content, enhancing walls, and surrounding inflammatory changes (Fig. 5) [16, 18, 20, 22].

Furthermore, the improved assessment of mural thickening features, perivisceral changes, and lymphadenopathies with WE-MDCT may prove helpful to distinguish AD from other inflammatory, ischaemic, or neoplastic conditions that may affect the colon [20, 22, 23].

In conclusion, the rationale for performing WE-MDCT in diverticular disease couples an accurate presurgical visualisation with the possibility to obviate OC or complement a limited endoscopic exploration. Considering the controversial recommendation of performing OC after a CT diagnosis of diverticulitis to exclude the coexisting presence of CRC, which is reported in approximately 2 % of cases, WE-MDCT may allow improved selection of patients to receive endoscopy [24, 25].

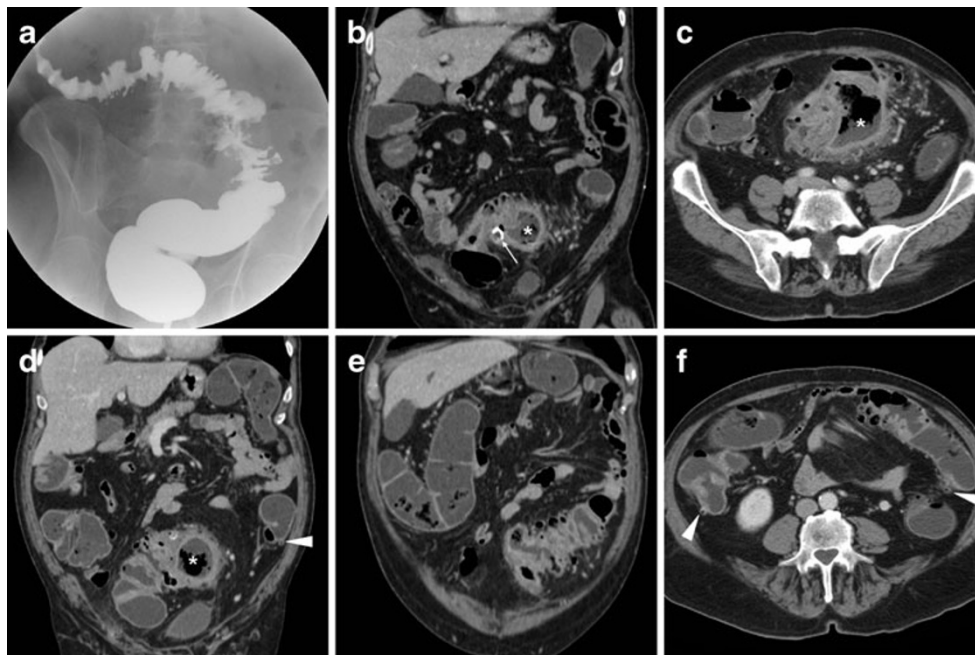


**Fig. 4** A 45-year-old male with clinical and laboratory findings indicative of acute diverticulitis. WE-MDCT without bowel preparation shows severe mural thickening of the sigmoid colon (**a**) with mildly increased density of the perivisceral fat (\*) and multiple diverticula, at least one of which shows an enhancing wall consistent with acute inflammation (*arrowheads*). Perforation and extraintestinal abscesses are excluded, allowing conservative treatment

## Chronic inflammatory bowel diseases

### Epidemiology and role of imaging

Predominantly observed in developed countries, IBD includes a group of life-long disorders with a relapsing and remitting course, whose precise aetiology is unknown,



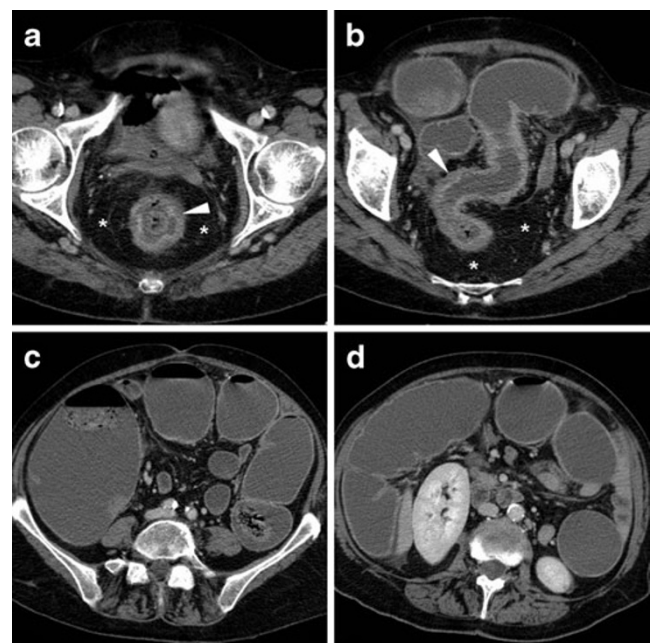
**Fig. 5** A 77-year-old male with known colon diverticular disease. Water-soluble contrast enema (**a**) initially performed during an acute bout of diverticulitis shows a severe “saw-tooth” hypersegmentation appearance and distal narrowing of the sigmoid colon consistent with the clinical diagnosis, but without information concerning the pericolonic structures. WE-MDCT depicts mural thickening of the sigmoid and distal

descending colon (**b–e**) with a large abscess (\*) with mixed faecal and gas content. Some non-complicated diverticula are seen in the upstream large bowel (*arrowheads* in **d, f**). Note the surgical clip from previous resection of a polyp (*thin arrow*) and endoluminal faecal residues from incomplete bowel preparation. Surgical resection of the involved colon and abscess debridement were performed

including chronic bowel inflammation along with extraintestinal manifestations, and can be categorised as ulcerative colitis (UC) and Crohn’s disease (CD) in the vast majority of patients.

Traditionally, radiologic investigation of colonic IBD to complement endoscopy relied on double-contrast barium enema, an exam that in experienced hands could depict the abnormal mucosal patterns and measure the longitudinal disease extent, but without providing information concerning mural thickening and pericolonic changes [26]. Previous experiences with peroral MDCT enterography of both the small and large bowel reported that the sensitivity for the detection of colorectal IBD was strictly related to the degree of luminal distension and concluded that improved distension methods were necessary to optimise cross-sectional imaging of UC and colonic CD [27].

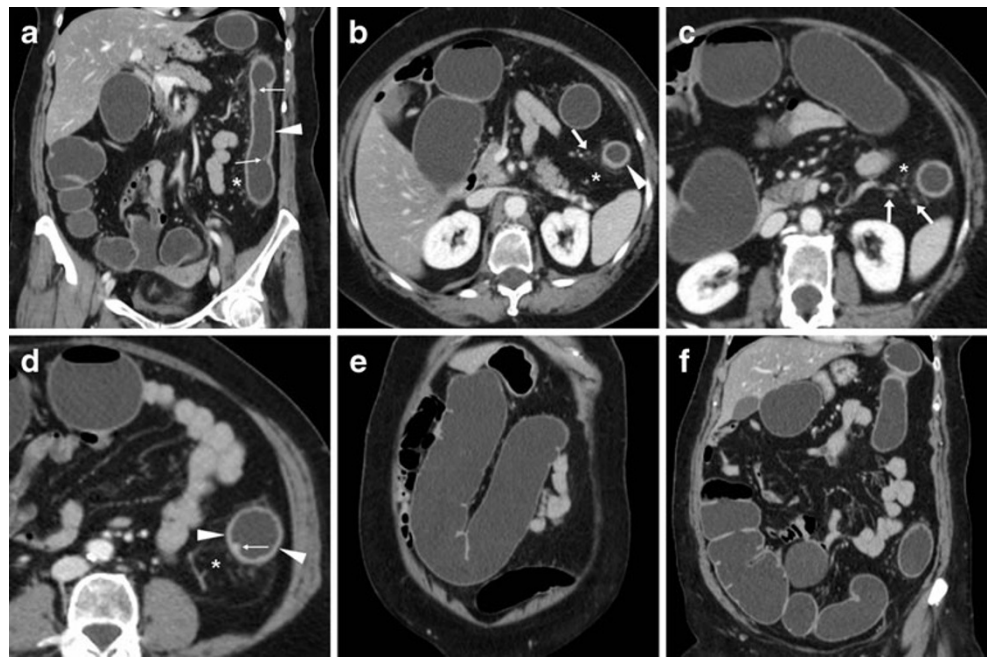
Recently, some authors investigated CTC in the assessment of large bowel abnormalities in IBD patients, such as mural thickening, lumen narrowing, loss of haustration, and pseudopolyps. However, in this population air insufflation should be performed carefully because the inflamed, more fragile intestinal wall poses a greater risk of colonic perforation [10–12]. Furthermore, conflicting CTC results with unsatisfactory visualisation of subtle mucosal changes and limited assessment of mural thickening led the European Crohn’s and Colitis Organisation (ECCO) to state in their guidelines that “the limited available data do not



**Fig. 6** A 69-year-old female with known ulcerative colitis investigated with WE-MDCT using limited bowel preparation during an acute disease exacerbation. The rectum and sigmoid colon show circumferential mural thickening (*arrowheads*) with a “water halo sign” appearance (**a**) and associated perirectal fat proliferation (\*). The upstream colon appears well-distended with normal mural thickness and some endoluminal faecal residues (**c, d**). Findings are consistent with left-sided acute, severe colitis and allow obviating the need for endoscopy



**Fig. 7** A 63-year-old female with ulcerative colitis. Elective WE-MDCT shows moderate, uniform mural thickening throughout the descending colon (*arrowheads*) with tiny endoluminal projections corresponding to endoscopic finding of pseudopolyps (*thin arrows*). The proliferating pericolonic fat shows increased density and vascularity (\*) with some tiny lymph nodes (*arrows*). The upstream transverse and right colon is well distended with preserved haustra

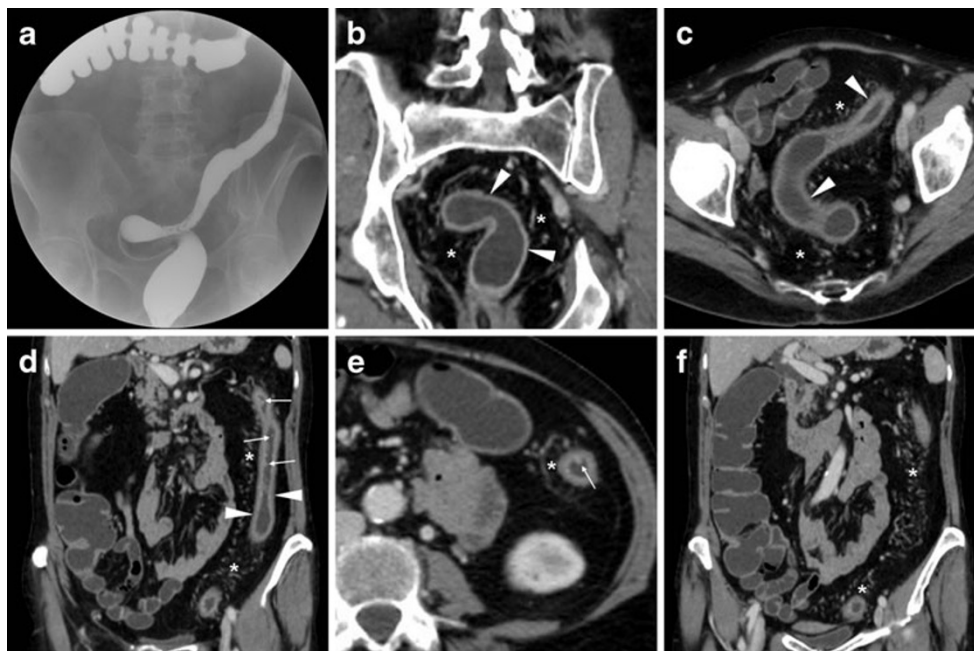


demonstrate a diagnostic value for assessing the disease extent in patients with suspected or proven UC” [28].

*Ulcerative colitis*

*Disease features* Pathologically, UC is characterised by extensive mucosal ulceration and diffuse non-granulomatous

inflammation, which usually commences in the rectum and extends proximally in a continuous, confluent, and concentric manner to affect a variable entity of the large bowel. The diagnosis is established by a combination of medical history, clinical evaluation, and consistent endoscopic and histological findings. OC represents the reference standard for UC disease assessment, since it allows direct visualisation and



**Fig. 8** A 65-year-old female with ulcerative colitis, initially investigated with water-soluble contrast enema, shows a “water-pipe” appearance of shortened, narrow left colon with advanced haustral loss (a). After medical treatment, elective WE-MDCT was performed because of incomplete colonoscopy. Discrete, circumferential mural thickening is observed from the rectum to the splenic flexure (*arrowheads*),

corresponding to endoscopic severe disease, with confirmation of several millimetric pseudopolyps (*thin arrows*) throughout the descending tract. Markedly increased vascularity is seen in the proliferating perirectal and pericolonic fat planes (\*). Most of the transverse and right colon appear to be spared

biopsy of mucosal changes and is necessary for assessing disease extent, severity, activity, and post-treatment modifications [26, 28].

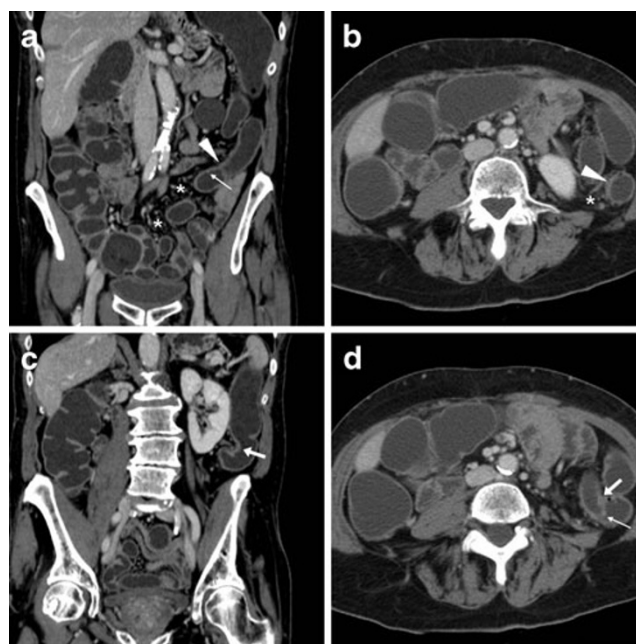
Classified according to the Montreal criteria as proctitis, left-sided (distal to the splenic flexure), or extensive colitis (including pancolitis), the distribution of UC influences patient management and prognosis, and dictates the drug delivery system regarding the choice of oral and/or topical therapy. Furthermore, UC is associated with a markedly increased risk of developing CRC compared to the general population, which depends on both the duration and extent of disease, and may reach 7.6 % of patients with extensive longstanding UC. Therefore, the longitudinal distribution determines the start and frequency of periodic CRC surveillance [28–30].

**Role of imaging** Historically, CT has had a limited role in imaging patients with UC because of its low sensitivity for early disease stages. Conversely, in our experience selected patients with UC may benefit from WE-MDCT, for example to determine disease severity in acute conditions when endoscopy is contraindicated because of the increased risk of perforation or exacerbation (Fig. 6), when a discrepancy exists between clinical and endoscopic findings (Fig. 7), or in elective cases with incomplete endoscopic exploration (Figs. 7, 8 and 9) [14].

**Mural WE-MDCT findings** Despite being primarily a mucosal disease, UC is commonly characterised by mural colon thickening, so that WE-MDCT may be a useful complement OC to assess the bowel wall in its full-thickness, as well as mesenteric and extraintestinal changes. As with double-contrast enema, in UC WE-MDCT allows an easy identification of the transition between the involved large bowel, which is not completely distended despite pharmacological hypotonisation, and the upstream healthy segments that usually appear well distended with preserved haustral folds. Usually, UC changes show a continuous distribution from the rectum (which is spared in 4 % of cases only) to the left-sided or entire colon (Figs. 6, 7, 8 and 9) [14].

In UC, colon wall thickening is of moderate size (6–9 mm), circumferential, and symmetric in the majority of cases. In the only series that investigated the role of MDCT in UC, wall thickening was positively associated with endoscopic, clinical, and histopathological severity [14].

Mural stratification is seen in up to 70 % of cases. During acute phases of UC, the stratified appearance is due to mucosal hyperenhancement (corresponding to endoscopic erosion and ulceration changes) coupled with a thickened oedematous submucosa. The resulting “target” or “water halo” sign seen in transverse planes, characterised by a low-attenuation intermediate ring, represents acute IBD



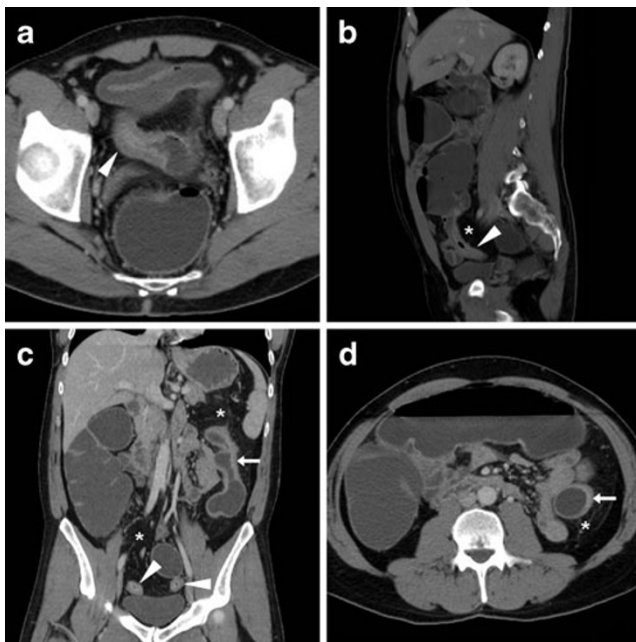
**Fig. 9** A 63-year-old male with ulcerative colitis and endoscopy limited to 45 cm from the anal verge because of non-distensible colon with diffuse mucosal changes and pseudopolyps. Elective WE-MDCT shows moderate mural thickening throughout the rectosigmoid and descending tract consistent with left-sided colitis (arrowheads) and associated pericolonic fat changes (\*). In the proximal descending colon, a focal substenosis with asymmetric mural thickening (arrows) and pseudopolyps (thin arrow) is detected, prompting endoscopic and biptic re-evaluation, which allowed excluding carcinoma and dysplasia. Fair distension of the transverse and right colon with preserved mural thickness and haustra

(Fig. 6) [14, 20, 22, 26]. Due to the high correlation of mural stratification and mucosal hyperenhancement with clinical and endoscopic severity, WE-MDCT may be helpful in acute UC as an alternative to OC to confirm disease severity (Fig. 6) [14].

With disease progression, mucosal ulceration and denudation lead to the formation of inflammatory pseudopolyps, which can be visualised at WE-MDCT as tiny, solid, endoluminal projections (Figs. 7, 8, and 9). The associated marked hypertrophy of the muscularis mucosa and transmural fibrosis characteristic of UC sub-acute phases produce diffuse, uniform mural thickening, reduced distension and shortening of the involved colon, and segmental or diffuse luminal narrowing (Figs. 7, 8 and 9) [12, 14, 26].

**Perivisceral WE-MDCT findings** Additional extraintestinal changes observed in UC include proliferation of pericolonic fat with hyperaemia and vascular engorgement, and a slightly increased attenuation (10–20 HU) compared to normal abdominal fat due to oedema and inflammation, often containing nodular densities corresponding to enlarged lymph nodes (Figs. 6, 7, 8 and 9). These changes are more





**Fig. 10** A 47-year-old male with known ileocolic and perianal Crohn's disease. WE-MDCT performed because of incomplete colonoscopy shows pronounced, stratified mural thickening of the distal ileum (*arrowheads*) consistent with active disease. A long non-distensible segment of the descending tract shows eccentric, asymmetric, and homogeneous mural thickening consistent with chronic fibro-stenosing disease (*arrows*)

consistently identifiable and highly suggestive of UC in the perirectal area, resulting in presacral space widening and sometimes rectal narrowing [12, 14].

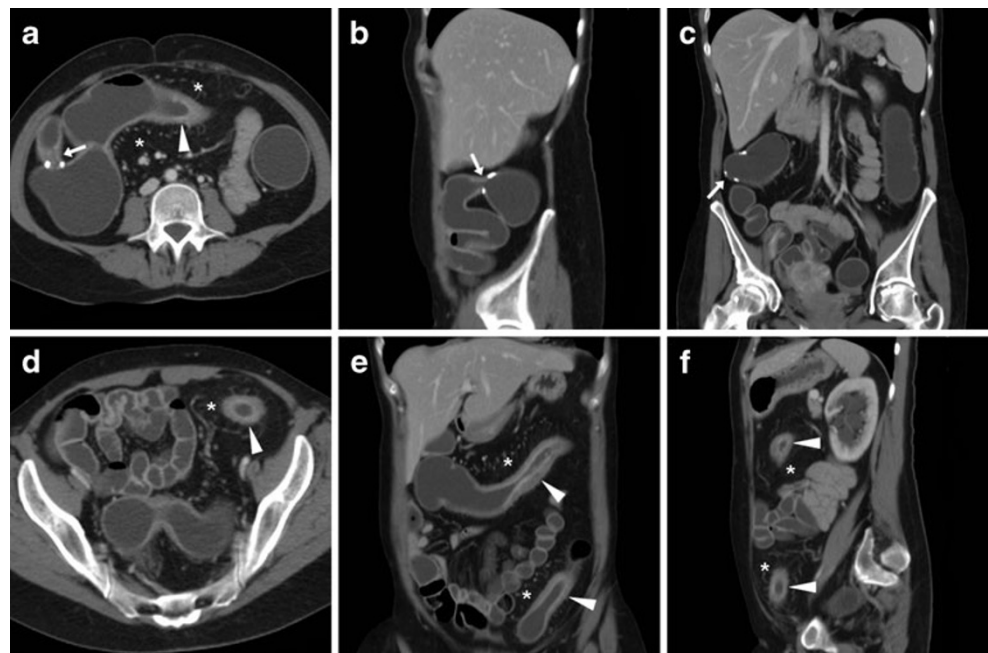
In chronic stages of UC, the colon submucosa undergoes widening and adipose infiltration, resulting in “fat halo

sign” mural stratification with a fat-density intermediate ring separating the bowel mucosa from the outer soft-tissue muscularis propria and serosa, a finding that is seen far more commonly in UC (61 %) than in CD (8 % of cases) [20, 22, 31].

Notably, early superficial and flat mucosal changes observed at OC, such as granulation due to oedema, hyperaemia, and increased mucin secretion, remain below the high-resolution power of MDCT [12, 14].

**Colorectal cancer in ulcerative colitis** Although patients with UC usually undergo periodic OC, because of the substantial risk of CRC, WE-MDCT studies in UC patients should be carefully scrutinised to identify features that suggest an underlying malignancy, particularly in patients with failed endoscopic surveillance or incomplete endoscopy. In the largest cohort including 17 patients with IBD-related CRC, at MDCT neoplasms were often indiscernible from the underlying inflammatory colon disease, yielding a 47 % overall sensitivity. Although the same study did not compare studies obtained with water, positive, or no intraluminal contrast, optimal colonic distension by WE-MDCT should probably improve the limited accuracy reported for detection of CRC in the setting of IBD [32]. A soft-tissue mass or a mural thickening greater than 1.5 cm that is asymmetric and/or with homogeneous solid attenuation and focal loss of mural stratification should be promptly reported as suspicious and needing biopsy. Furthermore, OC detection of a colonic stricture in UC represents an indication for further imaging investigation with WE-MDCT to assess both its features and the proximal colon (Fig. 9) [12, 28, 29, 32].

**Fig. 11** A 52-year-old female with previous ileocecal resection for Crohn's disease. Multiplanar images from WE-MDCT show patent enterocolic anastomosis (*arrows*) without signs of disease recurrence. The intermediate-distal transverse colon and the sigmoid show two extensive tracts with stratified mural thickening (*arrowheads*) consistent with active “skip” colonic Crohn's disease, associated with a characteristic “comb sign” appearance of the pericolonic fat and vasa recta (\*)





**Fig. 12** A 34-year-old male with Crohn's disease. Combined WE-MDCT and peroral enterography shows active disease in the terminal ileum (*arrowheads*) with marked, stratified mural thickening, causing entero-colonic fistulisation, plus fistulisation to the retracted, tethered upper right bladder dome (*thin arrows*)

### Crohn's disease

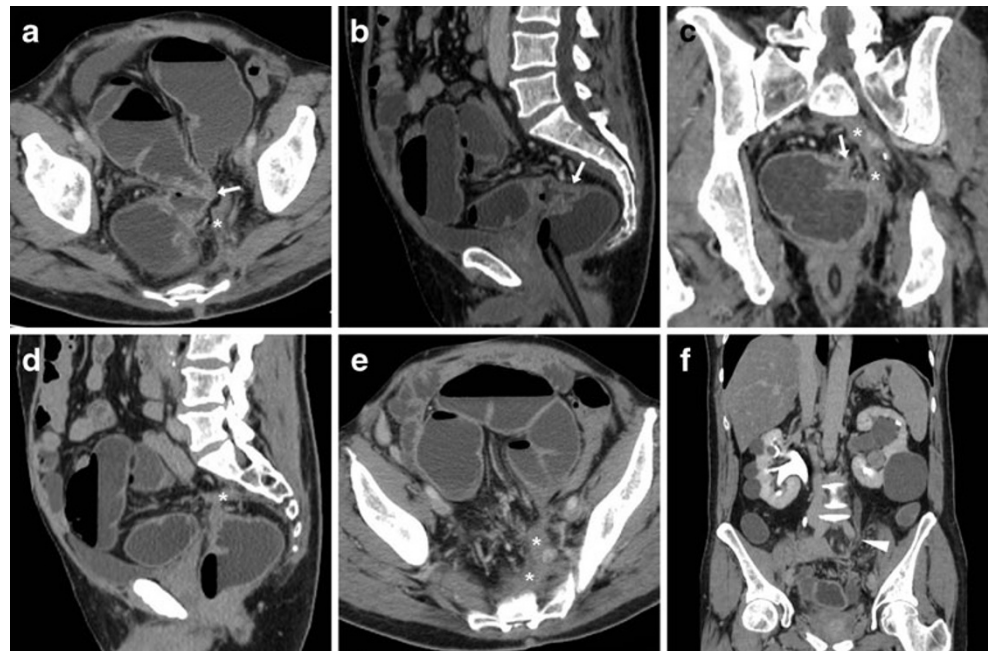
**Disease features and role of imaging** Pathologically characterised by chronic transmural granulomatous inflammation with ulcers, CD may affect any portion of the gastrointestinal tract, most commonly the terminal ileum and right colon, and can be classified as having a stricturing,

penetrating, or inflammatory behaviour. The large bowel is involved in up to 40–50 % of patients, either with or without ileal disease, and very rarely at the rectum. Since patient management and planning of medical and surgical treatment relies on information concerning disease extent, features, and activity, according to our experience selected patients with colonic CD may benefit from WE-MDCT. In nearly half of cases, retrograde distension of the ileum is observed because of an incompetent ileocecal valve. Alternatively, WE-MDCT can be coupled with peroral hypodense enteric distension to obtain an optimised, comprehensive assessment of small and large bowel CD and of associated extraintestinal manifestations [12, 13].

**Mural WE-MDCT findings** Compared to UC, colonic CD mural thickening is usually segmental and discontinuous, with affected regions alternating with spared “skip” tracts, and of a greater entity (11–13 mm versus 7–8 mm in UC) (Figs. 10, 11, and 12). Intense contrast enhancement of the inflamed mucosa and a “target” appearance are seen during active phases (Figs. 10, 11, and 12), whereas long-standing CD develops transmural fibrosis resulting in the loss of mural stratification and lesser, homogeneous mural enhancement (Fig. 10) [20, 22, 26]. Conversely, early changes such as enlarged lymphoid follicles and aphthoid ulcers limited to the mucosa cannot be resolved by MDCT [13].

**Postoperative and perivisceral WE-MDCT findings** In patients with previous intestinal resection, WE-MDCT allows easy identification of the surgical anastomosis (Fig. 11) and of possible local recurrence [13]. The characteristic extraluminal manifestations of CD are readily identified,

**Fig. 13** A 55-year-old male with longstanding Crohn's disease preoperatively investigated with WE-MDCT because of an impassable stricture at the rectosigmoid junction (*arrows*) due to extensive fibrotic adhesive bands (\*) tethered to the sacrum, causing tapering of the left ureter at the pelvic brim (*arrowhead in f*) and upstream hydronephrosis



including mesenterial fibro-fatty proliferation and enlarged lymph nodes, pericolic stranding, and the “comb sign” representing vascular dilatation, tortuosity, and wide spacing of the vasa recta in the afferent mesentery (Figs. 10 and 11) [12, 26, 33].

*Imaging of complications* Furthermore, WE-MDCT allows detection of the hallmark complications of penetrating CD, including perianal inflammation, perivisceral abscess collections, hydronephrosis, internal fistulisation (to the abdominal wall, other bowel segments, urinary bladder, or iliopsoas muscles) (Figs. 12 and 13) thereby allowing correct surgical planning [13, 26, 34]. Finally, although with a limited incidence compared to UC, neoplastic degeneration may occur in longstanding CD, so that cross-sectional imaging studies should be scrutinised for features suggesting the possibility of an underlying CRC [13, 32].

*Indeterminate colitis*

Currently, the term indeterminate colitis is adopted by pathologists when a histologic specimen shows overlapping features between CD and UC. Clinically, “colitis yet to be classified” should be adopted for the minority (up to 6 %) of patients where a definitive distinction between UC and CD

cannot be made on the basis of history, endoscopy, histopathology, and appropriate radiologic studies [28].

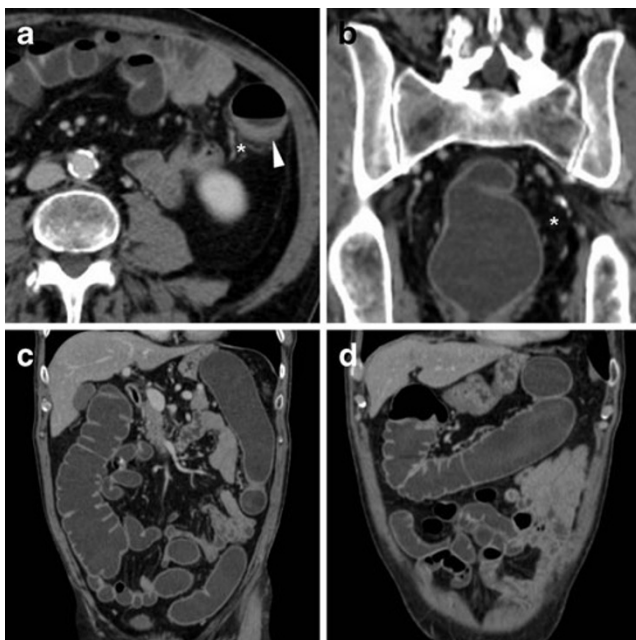
In these patients, WE-MDCT can be performed as a complement to OC to investigate disease distribution and features of mural and extraintestinal changes, and may, to some degree, contribute to the differential diagnosis between CD and UC (Fig. 14) [12].

**Conclusion**

In our experience, WE-MDCT is a rapid, easy-to-perform, safe, and well-tolerated technique that combines preliminary bowel cleansing, distension by hypodense intraluminal

**Table 1** Proposed indications and scope for performing water enema multidetector CT (WE-MDCT)

Indication	Scope
Suspected or known colorectal carcinoma	Local staging
	Upstream bowel exploration if endoscopy is incomplete
	Planning surgery
	Distant staging
Colonic stricture of unclear nature	Assess stricture features
	Planning endoscopic biopsy or surgery
	Upstream bowel exploration if endoscopy is incomplete
Colonic diverticulosis	Disease distribution
	Exclusion of complications
	Planning surgery
Acute/subacute diverticulitis <sup>a</sup>	Obviate endoscopy
	Detection or exclusion of complications
	Planning surgery
Inflammatory bowel diseases (ulcerative, Crohn’s, or indeterminate colitis)	Disease severity
	Disease distribution
	Differential diagnosis between UC and CD
	Colorectal cancer screening
	Assess stricture features
	Upstream bowel exploration if endoscopy is incomplete
Acute exacerbations of inflammatory bowel diseases <sup>a</sup>	Planning surgery or endoscopic dilatation
	Post-surgical anatomy
	Disease severity
	Disease distribution
Bowel endometriosis (2)	Obviate endoscopy
	Detection or exclusion of complications
	Disease detection and staging



**Fig. 14** A 69-year-old male with clinical, endoscopic, and biptic diagnosis of indeterminate colitis. WE-MDCT requested to further characterise the disease yielded good distension of the large bowel, with perirectal and pericolonic fat changes (\*) and moderate asymmetric mural thickening of the descending colon (arrowhead), findings closely resembling those of a left-sided ulcerative colitis

<sup>a</sup>Urgent WE-MDCT with limited or no bowel preparation. (1) See Refs. 4 to 7. (2) See Ref. 8



contrast, and pharmacological hypotonisation with contrast-enhanced MDCT acquisition of the abdomen and pelvis, and it provides excellent multiplanar high-resolution visualisation of acute and chronic disorders involving the large bowel including diverticulosis, AD, UC, and CD colitis [4–7, 12]. Although with the drawback of the radiation dose, in our opinion, WE-MDCT represents a relatively new approach to imaging the large bowel that may prove particularly useful as a complementary technique in patients with incomplete OC when endoscopic dilatation procedures or surgical interventions are being planned and to comprehensively assess disease activity, and associated perivisceral and extraintestinal manifestations. Proposed indications for performing elective and urgent WE-MDCT are summarised in Table 1 [12, 14].

**Acknowledgment** We would like to acknowledge the professional nurses Nerea Bevilacqua, Claudio Bonomi, Eugenia Ferron, and Giacomo Nocera for their valuable help in developing and performing the WE-MDCT technique as well as for their daily care of patients in the radiology department.

**Open Access** This article is distributed under the terms of the Creative Commons Attribution License which permits any use, distribution, and reproduction in any medium, provided the original author(s) and the source are credited.

## References

- Pickhardt PJ, Wise SM, Kim DH (2010) Positive predictive value for polyps detected at screening CT colonography. *Eur Radiol* 20:1651–1656
- Pickhardt PJ, Hassan C, Halligan S et al (2011) Colorectal cancer: CT colonography and colonoscopy for detection—systematic review and meta-analysis. *Radiology* 259:393–405
- Neri E, Halligan S, Hellstrom M, et al. (2012) The second ESGAR consensus statement on CT colonography. *Eur Radiol* Sep 15 [Epub ahead of print]
- Soyer P, Sirol M, Dray X et al (2012) Detection of colorectal tumors with water enema-multidetector row computed tomography. *Abdom Imaging* 37:1092–1100
- Soyer P, Hamzi L, Sirol M et al (2012) Colon cancer: comprehensive evaluation with 64-section CT colonography using water enema as intraluminal contrast agent—a pictorial review. *Clin Imaging* 36:113–125
- Ridereau-Zins C, Sibileau E, Pavageau AH, et al. (2011) Accuracy of water enema-MDCT in colon cancer staging: a prospective study. *Cancer Imaging* 11 Spec No A:S115
- Ridereau-Zins C, Aube C, Luet D et al (2010) Assessment of water enema computed tomography: an effective imaging technique for the diagnosis of colon cancer: Colon cancer: computed tomography using a water enema. *Abdom Imaging* 35:407–413
- Biscaldi E, Ferrero S, Remorgida V et al (2007) Bowel endometriosis: CT-enteroclysis. *Abdom Imaging* 32:441–450
- Biscaldi E, Ferrero S, Fulcheri E et al (2007) Multislice CT enteroclysis in the diagnosis of bowel endometriosis. *Eur Radiol* 17:211–219
- Tarjan Z, Zagoni T, Gyorke T et al (2000) Spiral CT colonography in inflammatory bowel disease. *Eur J Radiol* 35:193–198
- Carrascosa P, Castiglioni R, Capunay C et al (2007) CT colonoscopy in inflammatory bowel disease. *Abdom Imaging* 32:596–601
- Regge D, Neri E, Turini F et al (2009) Role of CT colonography in inflammatory bowel disease. *Eur J Radiol* 69:404–408
- Paparo F, Bacigalupo L, Garelo I et al (2012) Crohn's disease: prevalence of intestinal and extraintestinal manifestations detected by computed tomography enterography with water enema. *Abdom Imaging* 37:326–337
- Patel B, Mottola J, Sahni VA et al (2012) MDCT assessment of ulcerative colitis: radiologic analysis with clinical, endoscopic, and pathologic correlation. *Abdom Imaging* 37:61–69
- Taourel P, Kessler N, Lesnik A et al (2002) Non-traumatic abdominal emergencies: imaging of acute intestinal obstruction. *Eur Radiol* 12:2151–2160
- Ambrosetti P, Becker C, Terrier F (2002) Colonic diverticulitis: impact of imaging on surgical management—a prospective study of 542 patients. *Eur Radiol* 12:1145–1149
- Carvajal Balaguera J, Camunas Segovia J, Pena Gamarra L et al (2006) Colovesical fistula complicating diverticular disease: one-stage resection. *Int Surg* 91:17–23
- Werner A, Diehl SJ, Farag-Soliman M et al (2003) Multi-slice spiral CT in routine diagnosis of suspected acute left-sided colonic diverticulitis: a prospective study of 120 patients. *Eur Radiol* 13:2596–2603
- Tack D, Bohy P, Perlot I et al (2005) Suspected acute colon diverticulitis: imaging with low-dose unenhanced multi-detector row CT. *Radiology* 237:189–196
- Horton KM, Corl FM, Fishman EK (2000) CT evaluation of the colon: inflammatory disease. *Radiographics* 20:399–418
- Lefere P, Gryspeerdt S, Baekelandt M et al (2003) Diverticular disease in CT colonography. *Eur Radiol* 13(Suppl 4):L62–L74
- Thoeni RF, Cello JP (2006) CT imaging of colitis. *Radiology* 240:623–638
- Yeung KW, Kuo YT, Huang CL et al (1998) Inflammatory/infectious diseases and neoplasms of colon. Evaluation with CT. *Clin Imaging* 22:246–251
- Sai VF, Velayos F, Neuhaus J et al (2012) Colonoscopy after CT diagnosis of diverticulitis to exclude colon cancer: a systematic literature review. *Radiology* 263:383–390
- Lau KC, Spilsbury K, Farooque Y et al (2011) Is colonoscopy still mandatory after a CT diagnosis of left-sided diverticulitis: can colorectal cancer be confidently excluded? *Dis Colon Rectum* 54:1265–1270
- Gore RM, Balthazar EJ, Ghahremani GG et al (1996) CT features of ulcerative colitis and Crohn's disease. *AJR Am J Roentgenol* 167:3–15
- Johnson KT, Hara AK, Johnson CD (2009) Evaluation of colitis: usefulness of CT enterography technique. *Emerg Radiol* 16:277–282
- Stange EF, Travis SP, Vermeire S et al (2008) European evidence-based consensus on the diagnosis and management of ulcerative colitis: Definitions and diagnosis. *J Crohns Colitis* 2:1–23
- Biancone L, Michetti P, Travis S et al (2008) European evidence-based consensus on the management of ulcerative colitis: Special situations. *J Crohns Colitis* 2:63–92
- Zisman TL, Rubin DT (2008) Colorectal cancer and dysplasia in inflammatory bowel disease. *World J Gastroenterol* 14:2662–2669
- Ahualli J (2007) The fat halo sign. *Radiology* 242:945–946
- Hristova L, Soyer P, Hoeffel C et al (2012) Colorectal cancer in inflammatory bowel diseases: CT features with pathological correlation. *Abdom Imaging*
- Madureira AJ (2004) The comb sign. *Radiology* 230:783–784
- Tonolini M, Campari A, Bianco R (2012) Common and unusual diseases involving the iliopsoas muscle compartment: spectrum of cross-sectional imaging findings. *Abdom Imaging* 37:118–139