Intrapatient comparison between CT-colonography and CT with water enema for the assessment of colonic distension

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Aims and objectives

The achievement of an adequate colonic distension is a critical requisite for the CT study of the large bowel, because the incomplete distension of the intestinal walls may simulate several pathologic conditions (i.e. inflammatory bowel diseases) or hide the presence of tumors or polypoid lesions. CT colonography (CTC) has been widely developed and implemented in the latest years and has many different indications for the assessment of the colon, such as in case of incomplete optical colonoscopy, in frail and elderly patients and when endoscopy is contraindicated or not possible [1]. It consists in distension of the large bowel with air or carbon dioxide and it allows an excellent evaluation of colonic abnormalities [2]. On the other hand, CT with water enema (CTWE), although used at many institutions, did not receive extensive attention in the medical literature. This technique is based on colonic distension with water (administered through a rectal enema tube) followed by intravenous administration of iodinated contrast media, allowing a more accurate visualization of the intestinal wall [3]. In recent years, a few studies aimed to compare the degree of small and large bowel distension obtained with different CT protocols [4], but they did not consider patients undergoing CTC in their analysis. Our purpose was to compare the grade of distension of the different large bowel segments obtained using CTC and CTWE in the same cohort of patients, providing data concerning different pathological findings detected with these two techniques.
Methods and materials

Inclusion of patients

This was a retrospective, single-center, institutional review board approved study. Patients were included by performing a search in our single-institution radiology database looking for patients who underwent both CTC and CTWE, searching in a 8-years range. Specific indications were recorded. We enrolled 27 patients who underwent both CTC and CTWE within a mean interval of 32.9 months (SD 27 months) between the two examinations. Demographic distribution was as follows: 9 male (mean age at first examination 72.8 years, SD 5.9 years), 18 female (mean age at first examination 60 years, SD 29.7 years). 17 out of 27 patients underwent CTC as first examination, while 10 out of 27 patients underwent first CTWE.

CTWE and CTC techniques

Bowel cleansing consisted in a low-residue diet during the 3 days before both CTWE or CTC examination. The day before the examination each patient was instructed to drink continuously four doses of a granular powder (Isocolan; Bracco, Milan, Italy), containing polyethylene glycol, anhydrous sodium sulfate, sodium bicarbonate, and potassium chloride, dissolved in 2 L of water.

CTWE technique was performed as previously described by Paparo et al. [4]. All examinations were performed with a 64-slice multi-detector CT scanner (Light Speed VCT, GE Medical Systems, Milwaukee, WI) with the patient in supine position and inspiratory apnea. Contrast-enhanced CT was performed using the following scanning parameters: 120 kV, 300-400 mAs (with automatic mA modulation in the z axis), 0.6 s rotation time, detector collimation 40 mm, section thickness 5 mm, and table speed 35 mm per rotation. Bowel hypotonia was obtained by iv injection of 2 mL hyoscine-N-butylbromide 20 mg/mL (Buscopan, Boehringer Ingelheim), in order to reduce abdominal discomfort of patients and to avoid motion artifacts during the acquisition. A lubricated enema tube was inserted into the rectum and connected to a bag containing 2,000 mL of lukewarm tap water, which was gently infused through gravity in 3-4 min, with the patient placed supine on the CT table. Bowel wall enhancement was produced by intravenous administration of iodinated contrast medium with an iodine concentration of 350 mg/mL (Iobitridol, Xenetix, Guerbet). The flow rate was set at 3.2-3 mL/s with an automatic injector and acquisition was started in the portal phase, 45 s after the arterial peak in the upper abdominal aorta using a bolus-tracking software. The estimated mean effective dose for CTWE protocol was 11 mSv.

CTC technique was performed as described in previous works [5]. The pre-imaging protocol for CTC included bowel preparation (as described for CTWE) and, 3 hours before examination, fecal tagging with 100 mL of oral iodinated contrast media. Gas
distension of the colon was obtained with room air gently pumped using a hand-held squeeze bulb in the rectum through a short cannula. Supine and prone acquisitions in inspiratory apnea were obtained with the same 64-slice multi-detector CT scanner using the following protocol: 120 kV, 80 mA, 0.6 s rotation time, detector collimation 40 mm, section thickness 5 mm, and table speed 35 mm per rotation. No intravenous iodinated contrast medium was administered. The CTC protocol had an average effective dose of 6 mSv.

Image analysis

All CT examinations were reviewed on a dedicated workstation (ADW4.5, General Electric Medical Systems), using the 1.25mm thickness reconstructed images to obtain multi planar reconstructions (MPR). Both quantitative and qualitative analyses were performed in consensus by two radiologists (LC, MR) with 5-years and 8-years of experience in abdominal imaging respectively. CTC and CTWE examinations were reviewed in a random order, performing an independent evaluation for supine (CTC-S) and prone (CTC-P) acquisition of CTC. For purposes of analysis, the large bowel was divided into six segments: rectum, sigmoid colon, descending colon, transverse colon, ascending colon, and coecum, as proposed by Ajaj et al. [6]. The quantitative analysis of intestinal distension was performed measuring (in millimeters) the largest cross-sectional diameter (from outer wall to outer wall) of each bowel segment, considering either the axial or the coronal plane reconstructed images, both on CTC and CTWE examinations (Fig. 1). Distension measurements were taken in correspondence to healthy, unaffected bowel segments. The qualitative analysis was also performed on a per-segment basis using a continuous 3-point scale (0, poor; 1, good; 2, optimal), as described by Megibow et al. [7]. Score 2 (optimal) was assigned when the segment was distended, the wall was uniformly visualized, and a fold pattern could be recognized. A poor score (0) meant that the segment was collapsed without any luminal separation, the walls could not be seen, and a fold pattern could not be recognized. The last two degrees of distension (i.e. good and optimal) were considered as a satisfactory result. The percentage of bowel segments with an adequate distension for diagnostic purposes was obtained summing the relative percentages of segments that received both good and optimal scores, as described by Paparo et al. [4].

Statistical analysis

Statistical analysis was performed to assess the presence of a significant difference between the grade of bowel distension obtained with CTC-S, CTC-P and CTWE protocols on a per-segment basis. The normality of data derived from quantitative per-segment analysis was assessed. Since measurements of the largest cross-sectional diameter of some bowel segments did not follow the normal distribution, all these quantitative data were considered as non-parametric and expressed as medians and range (minimum to maximum). The Kruskal-Wallis test for non parametric data was used to assess the
presence of a significant difference among the medians of measurements obtained from the four groups. After obtaining a significant Kruskal-Wallis test, the Mann-Whitney U-test was applied for pairwise comparisons. Frequencies obtained from qualitative per segment analysis were compared using the Chi-square test, while pairwise comparisons were conducted by means of the Fisher's exact test.
Fig. 1: Axial (A, B) and coronal (C, D) reformatted images of CTC (A, C) and CTWE (B, D) examinations of the same patient: the largest cross-sectional diameters were measured in millimeters on a per segment basis.

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Results

There was no statistical difference concerning BMI and comorbidities in our population at the time of the first investigation compared to that of the second one. The mean interval time was of 32.9 months (SD 27 months). Moreover, no statistical difference was found in terms of imaging quality between first and latest examinations.

Qualitative analysis

Qualitative analysis regarding bowel distension per segment and radiological protocol is reported in details in Table 1.

Rectum

Adequate distension was successfully achieved with all three protocols with no statistical difference. Indeed, lumen distension was judged poor only in one case of CTC-S, and in no case with CTC-P and CTWE. However, optimal distension was significantly more frequently achieved by means of CTC-P and CTWE (61.5% and 66.6%) than CTC-S (22.2%) (p<0.05 and p<0.01, respectively).

Sigmoid colon

Adequate distension was more frequently achieved by means of CTC-P and WE compared to CTC-S (p<0.05). CTC-S provided adequate visualization of the lumen in 62.9% of cases, while it was adequate in all patients during CTC-P and CTWE (p<0.01). These latters provided similar incidence of optimal, good and poor luminal distension, both slightly higher compared to the imagines captured during CTC acquisition in supine position (p=n.s.) (Fig. 2).

Descending colon

Similar to the sigmoid segment, intestinal distension was judged adequate in all CTC-P and CTWE examinations against 85.2% of the images obtained during CTC-S. However, this discrepancy failed to reach statistical significance. Moreover, intestinal distension was judged optimal only in 18.5%, 34.6% and 25.9% of examinations conducted with CTC-S, CTC-P and CTWE, respectively. However, good distension was obtained in the majority of cases (66.6%, 65.4% and 74.1%, respectively).

Transverse colon
Adequate distension was achieved in similar proportion in all three protocols. Although not statistically significant, differently from the abovementioned colonic segments, the efficiency of CTC-P tended to be inferior to CTC-S, which was equal to CTWE: 88.5% vs 100% vs 100%. Similarly, optimal distension was achieved in 70% of CTC-S and CTWE examinations, while 38.5% during CTC-P (p=n.s.).

**Ascending colon**

Adequate distension was successfully achieved with all three protocols with no statistical difference (CTC-P 95.8%, CTC-S and CTWE 100%). Optimal distension was more frequently achieved with CTWE (88%) compared to CTC-S (48%; p<0.01) and CTC-P (70.8%; p=n.s.).

**Coecum**

Adequate distension was successfully achieved with all three protocols with no statistical difference (CTC-P, CTC-S and CTWE 100%). Optimal distension was more frequently achieved with CTWE (76%) compared to CTC-S (70.8%) and CTC-P (60%). However, this tendency failed to reach statistically significant difference.

**Quantitative analysis**

Data retrieved from per segment quantitative analysis are shown in Table 2.

**Rectum**

Distension of the rectum was significantly higher during CTC-P (47 mm) and CTWE (45 mm) compared to CTC-S (38 mm) (p<0.01). No statistical difference was found between CTC-P and CTWE.

**Sigmoid and descending colon**

Distension of the "left" colon was better achieved by means of CTC-P and CTWE compared to CTC-S: 26 and 27 mm vs 19 mm in the sigmoid colon (p<0.01 and P=0.03, respectively); 38.5 and 36 mm vs 32 mm in the descending colon (p=0.01 and p=0.03, respectively).

**Transverse colon**

As already above mention in the qualitative analysis, a better distension of the transverse colon was achieved by means of CTC-S (52 mm) and CTWE (54 mm) compared to the
CTC-P protocol (47 mm). However, none of the three protocol resulted superior to the others from a statistical point of view.

**Ascending colon**

Distension of ascending colon was slightly superior in CTC-P (59 mm) and CTWE (57 mm) than in CTC-S (54 mm) protocol. However, this discrepancy failed to reach a statistical significant difference.

**Coecum**

Similarly to the transverse colon segment, CTC-P (56.5 mm) provided a slightly inferior distension of the coecal lumen compared to CTC-S (60 mm) and CTWE (62 mm). However, none of the three protocol resulted superior to the others from a statistical point of view.

Overall, CTC-P provided a better lumen distension and visualization of the left colon compared to the imaging acquisition in the supine position (p<0.01). Although no statistically significant, this discrepancy is not observed in the transverse and ascending segment, where an apparent benefit was achieved with the supine over the prone position. CTWE provided adequate lumen distension in all the colonic segments and was superior to CTC-S protocol for the visualization of sigmoid and descending lumen (p<0.05).

**Pathological findings**

In this small series of patients, a number of pathological findings regarding the large bowel was reported, including 8 cases of diverticulosis (Fig. 2), one patient with rectal and descending polyps (Fig. 3), one patient with a concentric thickening of the transverse colon walls (Fig. 4) and one patient with a tumor of the splenic flexure (Fig. 5). In addition, there was one case in which the evaluation of the ileocecal valve at CTC was suspect for inflammatory thickening (Fig. 6A), while CTWE showed a normal terminal ileum with regular wall enhancement (Fig. 6B).
Table 1: Results of qualitative per segment analysis. Number (and percentage) of patients with an optimal, good, poor and adequate distension of different large bowel segments for each CT group (supine acquisition of CTC, prone acquisition of CTC, CT-WE). The number of examinations with adequate bowel distension was calculated summing those with an optimal and those with a good distension. *1/27 patient underwent only supine CTC acquisition due to technical issues. **2/27 patients underwent right emicolectomy.

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![Images of CTC and CTWE axial images](https://example.com/)

**Fig. 2:** CTC in supine (A) and prone (B) position and CTWE (C) axial images of the same patients. The sigmoid colon showed a better overall distension in CTC-P and CTWE compared to CTC-S acquisition; mural enhancement provided by CTWE allows an accurate evaluation of the intestinal walls, while delineation of diverticular outpouchings is equally confident with CTC-P images.
**Table 2:** Results of per segment quantitative analysis. Median values (CI95%) of distension of each large bowel segment are expressed in mm.

<table>
<thead>
<tr>
<th>Colonic segment</th>
<th>Median lumen distension (mm; CI95%)</th>
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<tbody>
<tr>
<td></td>
<td>CTC-S</td>
</tr>
<tr>
<td>Rectum</td>
<td>38 (28.4 – 42.8)</td>
</tr>
<tr>
<td>Sigmoid colon</td>
<td>27 (0.8 – 29.9)</td>
</tr>
<tr>
<td>Descending colon</td>
<td>32 (25.5 – 37.0)</td>
</tr>
<tr>
<td>Transverse colon</td>
<td>52 (48.0 – 55.0)</td>
</tr>
<tr>
<td>Ascending colon</td>
<td>54 (48.8 – 57.6)</td>
</tr>
<tr>
<td>Coecum</td>
<td>60 (51.5 – 65.4)</td>
</tr>
</tbody>
</table>

**Fig. 3:** CTWE (A) and CTC (B) axial images of the same patient, demonstrating a pedunculated polyp arising from the anterior wall of the rectum (arrow): note that the identification of the polyp is easier and more reliable on CTC image, due to the sharper contrast of air compared to water. Endoscopic three-dimensional reconstruction (C) confirms the presence and the size of the polyp.
Fig. 4: Axial (A) and sagittal (B) reformatted images of CTC showing a concentric thickening of the transverse colon walls (arrows), confirmed by axial (C) and sagittal (D) CTWE reformatted images. In this patient the findings were well appreciable both on CTC and CTWE examinations.

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Fig. 5: CTC (A, B) of a patient with a tumor of left colon: the tumor can't be confidently recognized nor on axial (A) and coronal (B) reformatted images, appearing as an ill-defined mass (* on A) apparently occupying the highest segment of descending colon (arrow in B). CTWE (C, D) better delineates tumor's shape and borders (* on C and arrow on D), providing more accurate information about its vascularization, size and location.

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Fig. 6: False positive of CTC, showing a doubtful thickening of the walls of the terminal ileum (arrow) with associated enlarged ileocecral lymphnodes (A); at CTWE, no significant abnormality was observed in the ileocecral valve region (B).

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Luminal distension is a fundamental requirement for CT imaging of the bowel, because collapsed segments may hide the presence of tumors or polypoid lesions and mimic wall thickening simulating pathologic conditions such as Crohn's disease [8]. A recent paper already focused on the comparison between CTC and CTWE, specifically concerning the incidence of hiatal hernia as an incidental and physiological consequence of the colonic distension [5]; however, to our knowledge, a detailed comparison between these two techniques regarding the degree of large bowel distension has not been reported in literature so far.

Unlike CTC, CTWE has received little attention in recent radiological literature: a few works concerned the role of this modality in the detection and staging of colorectal cancer and polyps [9-11]. CTWE requires retrograde colonic distension using water associated with mural enhancement by administration of intravenous iodinated contrast medium, providing optimal visualization of the intestinal wall, the hypodense lumen and the pericolonic fat. In fact, CTWE can be part of a fully diagnostic contrast enhanced CT of the abdomen and/or the chest. It can also be associated to small bowel enteroclysis, providing an optimal distension of both small and large bowel and allowing an accurate evaluation of vascular and inflammatory conditions affecting the bowel, including the last ileal loops. In addition, CTWE requires simpler acquisition in the supine position only (possibly with more compliance in old patients) and a shorter learning curve for post-processing imaging, when compared to CTC.

In our institution CTC and CTWE were mainly used as control of each other in patients with doubtful clinical context or in patients presenting anemia, diverticulosis, a positive OBFT and/or contraindication to optical colonoscopy. Many of these patients were old and/or frail patients. In some cases CTWE was associated to contrast enhanced CT of the abdomen for other clinical indications (i.e. evaluation of liver parenchyma or abdominal aorta).

In our work the results of the per segment analysis showed that an adequate distension of rectum, transverse colon, ascending colon and coecum was achieved in similar proportion of patients using CTC-S, CTC-P and CTWE. With regard to sigmoid colon, an adequate distension was more frequently achieved by means of CTC-P and CTWE compared to CTC-S (p<0.05), and the same trend, with the lack of statistical significance, was observed in descending colon. Considering the quantitative analysis, distension of the left colon was better achieved using CTC-P and CTWE compared to CTC-S (p<0.01 and P=0.03, respectively, for the sigmoid colon; p=0.01 and p=0.03, respectively, for descending colon). It is important to notice that these differences could have important clinical implications, since in risk stratification of pathological conditions for the single patient (i.e. colorectal cancer) the GI evaluations consider right vs left colon rather than a single segment, which still represents an important landmark in population study.
However, the specific order of acquisitions performed at our institution can be a confounding factor: indeed, in all CTC examinations, supine acquisition was performed previous to prone acquisition, leading to possible redistribution of air in the large bowel during the movements of the patients modifying their decubitus. Despite other recent studies confirmed that the prone position was better distended with the room air technique compared to CO2 insufflation, the use of an automatic carbon dioxide insufflator to obtain colonic distention may overcome these limitations by providing a more constant and homogeneous in both CTC-S and CTC-P acquisition [13]; furthermore, CO2 insufflation could bring the double advantage of pain reduction (due to faster resorption) and reduced risk of complications like peritonitis in case of perforation [14]: more studies, even with larger cohorts of patients, are required to clarify these aspects.

Performance in achieving sigmoid colon distension becomes crucial when considering diverticulosis. Large bowel diverticular disease is an extremely common condition, affecting over 50% of the population over 65-years-old and predominantly involves the sigmoid tract: indeed, this pathological entity was a quite common finding in our small cohort of patients. Diverticulosis may in some cases be the cause of an incomplete optical colonoscopy and CTWE can help to visualize the distribution of diverticular disease and to explore the entire length of colon. Common findings in uncomplicated diverticulosis are represented by fluid- or air-filled diverticular outpouchings of the colonic wall, often associated with mural thickening [15]. In our small series of patients, as previously discussed, an adequate distension of the sigmoid colon was more frequently achieved by means of CTC-P and WE compared to CTC-S (p<0.05): in addition, CTC-P and especially CTWE, with the added value of parietal enhancement, better delineated the appearance of diverticular disease, providing an optimal assessment both of the degree and the extension of colon mural thickening as well of the evaluation of extraluminal inflammatory findings (Fig. 2).

The administration of iodinated contrast medium is particularly useful in cases of dolichocolon: in these patients, with equal bowel distension, CTWE showed better performance compared to CTC, particularly in the assessment of sessile tumors (Fig. 5).

In one case CTC resulted false positive, presenting a doubtful thickening of the walls of the terminal ileum with associated enlarged ileocecal lymphnodes. CTWE often allows the evaluation of the terminal ileum as well as the large bowel, due to hyoscine-N-butylbromide-induced ileocecal valve incompetence permitting retrograde distension of the terminal ileal loops: in this case, indeed, no significant abnormality was observed at CTWE (Fig. 6). On the other hand, CTC showed a superior ability in the evaluation of polyps compared to CTWE, with a more precise delineation of the polyp, especially with the aid of fecal tagging and of post-processing three-dimensional reconstructions (Fig. 3).

A possible limitation of our study is that the quantitative analysis performed measuring the widest diameter is a surrogate of the real distension of the single bowel segment, since currently there are no qualified methods allowing a comprehensive measurement of the exact volume for a single segment of interest on CTWE images: however, the
quantitative findings were in agree with those obtained with the qualitative evaluation, thus supporting the validity of the overall assessment.

In conclusion, considering similar degrees of distension obtained with the three different protocol, CT studies of the large bowel should be customized to fulfill the clinical query: CTC can be reliably used for the detection of polyps and uncomplicated diverticulosis, while CTWE could be preferred in those patients who require an accurate evaluation of the intestinal wall (i.e. inflammatory diseases) and for systemic staging of colorectal cancer, since the use of iodinated contrast medium can make the difference regarding the assessment of extracolonic findings.
Fig. 2: CTC in supine (A) and prone (B) position and CTWE (C) axial images of the same patients. The sigmoid colon showed a better overall distension in CTC-P and CTWE compared to CTC-S acquisition; mural enhancement provided by CTWE allows an accurate evaluation of the intestinal walls, while delineation of diverticular outpouchings is equally confident with CTC-P images.

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