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Impact of contrast-enhanced computed tomography colonography on laparoscopic surgical planning of colorectal cancer

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Abstract

Aim: To evaluate the impact of contrast-enhanced computed tomography colonography (CE-CTC) on laparoscopic surgery planning in patient with stenosing colorectal cancer.

Materials and methods: Sixty-nine patients with endoscopically proven colorectal cancer underwent CE-CTC, after incomplete conventional colonoscopy. Two experienced radiologists evaluated site, length, and TNM staging of colorectal cancers on three-dimensional double contrast enema-like views, 2D axial and multiplanar reconstructions. All the patients underwent colorectal resection and surgery bulletin, pathology of surgical specimens, and radiological follow-up at about 8 months were used as reference standard.

Results: The detection rate of colorectal cancer was 100 % (75/75); CE-CTC allowed for a diagnosis of a synchronous colorectal cancer in five patients (7 %). CE-CTC correctly judged the site of the lesions in all the cases; clinically significant localization errors at conventional colonoscopy were noted in 3 out of 69 patients (4 %). Additional colonic polyps greater than 6 mm in diameter were found in 21 out of 69 patients (30 %); in two patients (3 %) the surgeon performed an enlarged colectomy to include synchronous polyps proximal to colorectal cancer. Sensitivity, specificity, PPV, NPV, and accuracy were for T1–T2 vs. T3–T4: 96 %, 71 %, 92 %, 87 %, and 91 %, respectively; for N: 94 %, 42 %, 64 %, 86 %, and 70 %; for M: 100 %, 100 %, 83 %, 100 %, and 97 %. There were no complications associated with CE-CTC.

Conclusion: Information given by CE-CTC concerning colorectal cancer location and synchronous colonic cancers and polyps changed the laparoscopic surgical strategy in almost 14 % of patients.

Key words: Colon cancer—Rectal cancer—Computed tomography—Contrast-enhanced CT—CT colonography—Laparoscopic colorectal surgery

Colorectal carcinoma is a significant cause of death from cancer in the world, and early detection and treatment are critical. The only cure for colorectal cancer is surgery, which may or may not be combined with chemotherapy and/or radiation therapy. Laparoscopic surgery has gained wide clinical acceptance because of its advantages as compared to conventional open surgery [1–3], i.e., smaller surgical incisions, less intraoperative blood loss, faster recovery of the normal bowel function, and shorter hospital stay. Indications for colorectal cancer laparoscopic surgery are evolving, and now include also advanced lesions [4]. However, there are disadvantages to this approach, namely, the lack of entire view of operative field and of tactile sensation, leading to potential inaccurate localization of the colonic lesions [5, 6]. Computed tomography colonoscopy (CTC) nowadays represents a good alternative to optical colonoscopy in diagnosing

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polyps and colorectal cancers since it has been shown to have similar accuracy, a higher patient compliance, and a lower rate of complications [7–12]. Some authors [13–18] already described the usefulness of contrast-enhanced CT colonography (CE-CTC) in patients with known colorectal cancer and incomplete optical colonoscopy; most of these experience were done using a manual insufflator for distension and without fecal tagging. Moreover, to the best of our knowledge no papers focused on the impact of this examination on laparoscopic surgery. The aim of the work is to determine the percentage of patients in which the surgical approach changed due to the additional information pointed-out at CE-CTC.

Materials and methods

Population

This study was approved by our Institutional Review Board and written informed consent was obtained from all the patients. Seventy-nine patients with a known colorectal cancer diagnosed by an incomplete optical colonoscopy and pathologically confirmed, underwent CE-CTC between 2008 and 2010. From the consecutive series of 79 patients, 10 patients who had been surgically treated at institutions other than our hospital were excluded because of lack of complete information about pathological T staging. Thus, 69 patients (38 female; 31 male) entered the analysis; they were aged between 43 and 86 years (68 ± 9 years, mean ± standard deviation). Within 1 month from CE-CTC, all the 69 patients underwent surgery at our institution.

Bowel preparation

Bowel cleansing was achieved by ingesting 2 or 4 L of a polyethylene glycol electrolyte solution in a standard manner before the procedure in 31 patients, in 21 patients by half a bottle of laxative (Phospho-Lax®, Sofar, Milan, Italy) after dinner the evening before, followed by 1 L of water.

The 17 remaining patients used one sachet of mild laxative per os (Movicol®, Norgine Italia srl, Milan, Italy) after breakfast, lunch, and dinner during the 3 days before CE-CTC.

On the day of the examination, at least 2.5 h before the examination, approximately 50–60 mL of iodinated contrast medium (Gastrografin®, Bayer-Schering, Berlin, Germany) diluted in 500 mL of water was administered orally for fecal tagging.

CTC protocol

All examinations were performed using a 64-row multidetector CT (VCT, General Electric Healthcare, Wisconsin, USA). The CT protocol involved image acquisition with patients initially in prone position and subsequently in supine position, after obtaining an adequate colonic distension. Immediately before CT data acquisition, carbon dioxide was insufflated by an automated insufflators (PROTOCO2L colon insufflator and administration set, Bracco, Milan, Italy) through a small rectal catheter with a retention balloon.

Twenty milliliter of hyoscine butylbromide (Buscopan®, Boehringer Ingelheim, Florence, Italy) was intravenously injected before colonic distension in all but three patients who had contraindications (recent myocardial infarction).

Each patient was first placed in the left lateral decubitus position until about 1–1.5 L of carbon dioxide was insufflated, and then in the right lateral decubitus position to reach a total of approximately 2–3 L of carbon dioxide. Thereafter, the patient was rolled prone and a CT scout image was taken. If colon distension was deemed adequate, the volumetric CT data acquisition was initiated during end-expiration. The patient was rolled supine and a second scout was acquired. A volumetric CT data acquisition was then obtained 65–70 s after intravenous injection of 100 mL of non-ionic iodinated contrast material (Iomeron® 400, Bracco SpA, Milan, Italy) followed by 50 mL of saline flush, at a flow rate of 3 mL/s, obtaining images during the portal venous phase.

In 41 patients, an additional chest CT acquisition was performed 45 s after intravenous injection, before the abdominal study.

In all but five patients, we performed a delayed supine volumetric CT data acquisition, at about 180 s after contrast material injection. The rationale for the acquisition of delayed images consists both in a better characterization of liver lesions and a better opacification of ureters and urinary bladder, which permits to depict more clearly the relationship between the urinary tract and the colorectal cancers, particularly.

In five patients, with a sigmoid segment collapsed on either supine or prone view, the delayed acquisition was performed with the patient in the right lateral decubitus position. After the last CT data acquisition, carbon dioxide delivery was stopped, the cuff was deflated, and the rectal catheter removed.

The CE-CTC technical protocol was as follows: unenhanced CT data acquisition, prone position, 120 kVp (140 kVp in obese patients), 100 mA (300 mA in obese patients); contrast-enhanced CT data acquisition, 120 kVp (140 kVp in obese patients), mA ranging from 80 to 440, with an auto-mA setting. For both series: gantry rotation, 0.5 s; slice thickness, 1.25 mm; table speed, 27.5 mm; pitch: 1.375; reconstruction interval, 1 mm. Both series were acquired during end-expiration from the diaphragm to the pubic symphysis in craniocaudal direction. All the images, and in particular CTC images were processed using a dedicated software (Colon VCAR, Advantage Windows 4.4; GE Medical Systems). The total effective dose of this CE-CTC protocol, for a normal size patient, was about 15.0 mSv.

Image analysis

Two radiologists, with respectively 7 and 3 years of experience in CTC, evaluated in consensus the quality of bowel preparation on axial two-dimensional (2D) and multiplanar reformatted images, on the basis of the presence of fecal residuals and tagged fluids in the six segments of the colon, and rated it on a semiquantitative scale as poor, good, or excellent. The overall distension of the entire colon was also visually evaluated by the two radiologists in consensus and rated as poor, good, or excellent using double contrast enema-like views generated by prone and supine CTC datasets, freely rotating the three-dimensional (3D) views.

The presence, location, size, and morphologic features of colorectal cancers and polyps were assessed on both 2D axial and multiplanar reconstructions and 3D views. Tumor and node staging were based on the international TNM classification. For T staging, the two readers evaluated the degree of wall deformity (WD) on 3D transparent colon map generated by prone and supine CTC dataset, freely rotating the 3D views. The reader was to identify two different types of WD due to the colorectal cancer on the basis of the extent of the lesion in comparison with the lumen circumference, using a modified classification proposed by Utano et al. [19]: <50 % of the lumen and ≥50 % of the lumen (also called *apple-core* WD). Each category was thought to be associated with a T stage [19, 20] as follows: <50 % of the lumen, T1–T2 stages; ≥50 % of the lumen, T3–T4 stages. The evaluation of lymph nodes was performed on 1.25-mm venous phase contrast-enhanced 2D axial and multiplanar images. Lymph nodes were defined as positive if at least a cluster of three nodes was present, independent of their size, or if fewer than three lymph nodes were present, with at least one of them measuring at least 1 cm in long axis.

The assessment of extracolonic compartment metastases was performed on 1.25-mm venous and delayed phase contrast-enhanced axial and multiplanar images. The liver and the lungs were evaluated for metastasis; metastases were recorded as present or absent.

Reference standard

Within 1 month from CE-CTC, all the patients underwent surgery at our institution and colorectal cancer specimens were evaluated for pathological staging, which was used as the reference standard. All pathologic specimens underwent central pathology review and cases diagnosed before 2010 were restaged according to the 7th edition of the AJCC TNM staging system of colorectal cancer [21]. T pathological staging for synchronous colonic carcinoma was evaluated separately, for statistical analysis. For the liver metastases, intraoperative ultrasound with pathology and 1-year radiological and clinical follow-up were used as reference. For the lung metastases, 1-year radiological CT follow-up was used as reference. For identifying the colorectal cancers location, we use as standard of reference the indian ink used during the conventional colonoscopy performed before the CE-CTC and the surgical bulletins.

For polyps, the reference standard was pathology (optical colonoscopy's biopsies or surgical specimen for polyps close to the cancer).

Statistical analysis

Diagnostic performance for TNM staging was calculated in terms of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy.

Results

Colorectal cancer detection and location

CE-CTC allowed for a diagnosis of a synchronous double colorectal cancer in four patients and a triple colorectal cancer in another patient. Thus, the series included a total of 75 colorectal cancers in 69 patients. The detection rate of colorectal cancer was 100 % (75/75). Mean colorectal cancers largest diameter were 49 ± 20 mm (range 10–110), 19 mm for T1, 40 mm for T2, 52 mm for T3, and 64 mm for T4. CE-CTC correctly judged the site of the lesions in all the cases, correcting the mistaken optical colonoscopy report in three patients (4 %). Eight lesions were located in the rectum, 42 in the sigmoid colon, 5 in the descending colon, 9 in the transverse colon, 7 in the ascending colon, and 4 in the cecum.

Polyps detection

CE-CTC found in 21 out of 69 patients (30 %) had at least one additional synchronous polyp greater than 6 mm in diameter. All 25 polyps of 13 patients who underwent a referral optical colonoscopy (or surgery) were confirmed and pathology revealed: 6 adenomatous polyps with high-grade dysplasia, 12 adenomatous polyps with low-grade dysplasia, 1 fibroepithelial polyp, and 6 hyperplastic polyps. In two patients, six polyps were adjacent to the colorectal cancer.

Change of laparoscopic surgical management

Information given by CE-CTC changed the surgical strategy in 10/69 (14 %) patients. First of all, in five patients (7 %) this change was due to the CE-CTC diagnosis of synchronous unknown cancer proximal to the stenosing colorectal cancer. In particular, a 76-year-old woman with a triple synchronous colorectal cancer (Fig. 1) scheduled for a left laparoscopic hemicolectomy, underwent a enlarged right hemicolectomy. Concerning three patients with a double synchronous colorectal cancers: a 62-year-old

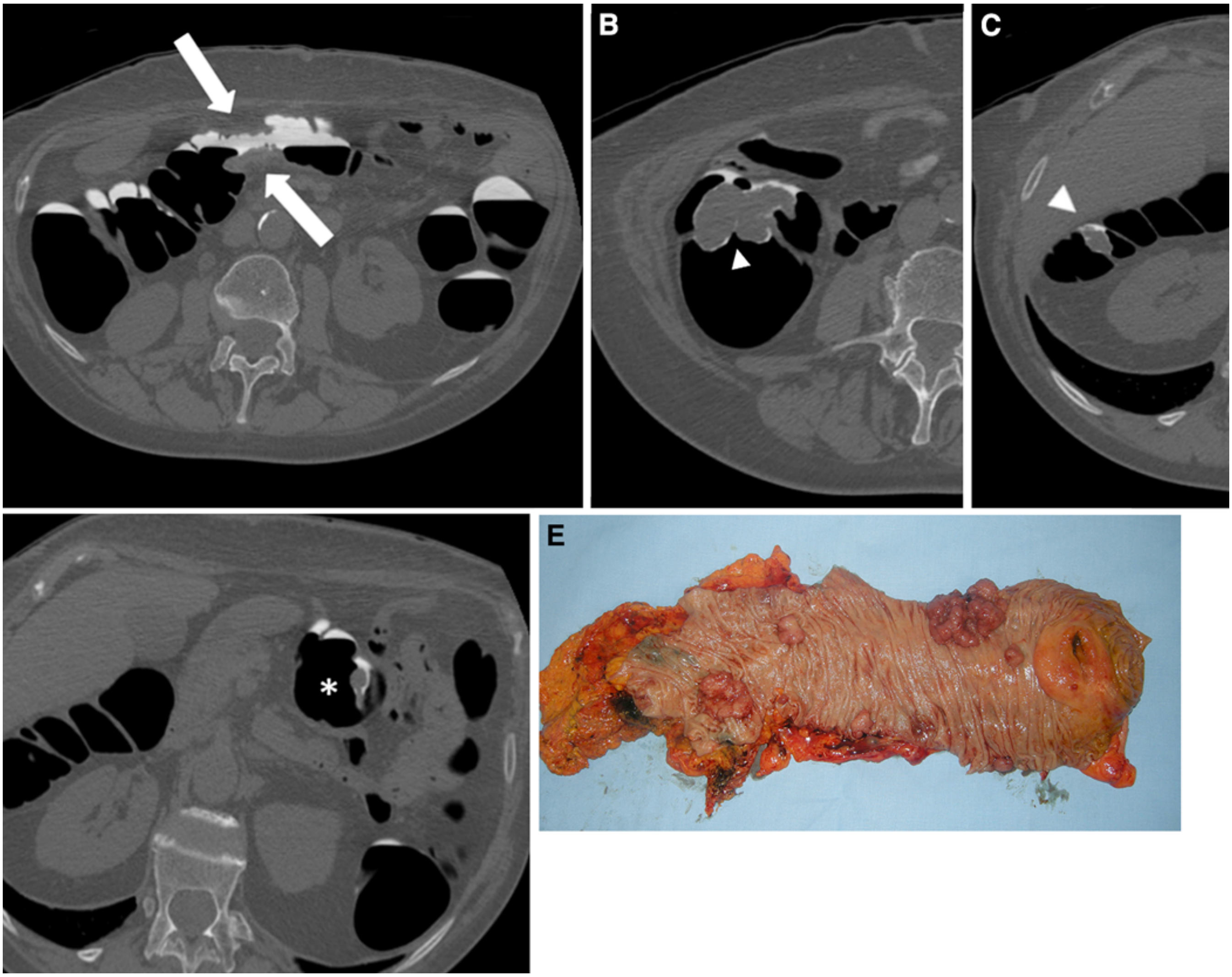

Fig. 1. Images in a 76-year-old woman with obstructive colon cancer in the mid transverse colon with two synchronous colorectal cancers in the ascending colon and additional polyps. Surgical extent was modified to include all the synchronous lesions, which could not be identified by optical colonoscopy. Axial image (**A**) shows the obstructive colon cancer in the mid transverse colon (*arrow*). Axial images (**B**, **C**) show the synchronous cancers (*arrowheads*) in the ascending colon. Axial image (**D**) shows an additional pedunculated polyp (*asterisk*) in the distal transverse colon surgical specimen of colectomy (**E**) showing all the synchronous lesions.

woman scheduled for a left laparoscopic hemicolectomy, underwent a subtotal colectomy; a 82-year-old man (Fig. 2), a 84-year-old woman, and a 83-year-old woman all scheduled for a left laparoscopic hemicolectomy, underwent an enlarged left laparoscopic hemicolectomy.

Three patients (4 %) underwent a different laparoscopic interventions, because CE-CTC clarified the exact site of the lesions, correcting the mistaken optical colonoscopy report.

In particular, in a 71-year-old woman the site of tumor has been corrected from sigma to distal transverse colon and finally she underwent an high left hemicolectomy instead of a scheduled left hemicolectomy; in a 43-year-old woman (Fig. 3) the site of tumor has been corrected from medium transverse to distal transverse colon and so she underwent an high left hemicolectomy instead of a enlarged right hemicolectomy; in a 62-year-old man, the site of tumor has been corrected from distal transverse to medium transverse colon and so he underwent an enlarged right hemicolectomy instead of an high left hemicolectomy.

Moreover, the surgeon modified the surgical strategy in two patients due to the CE-CTC diagnosis of unknown synchronous polyps greater than 6 mm, proximal to the cancer. In these two cases, the surgeon performed an enlarged laparoscopic colon resection to include the polyps.

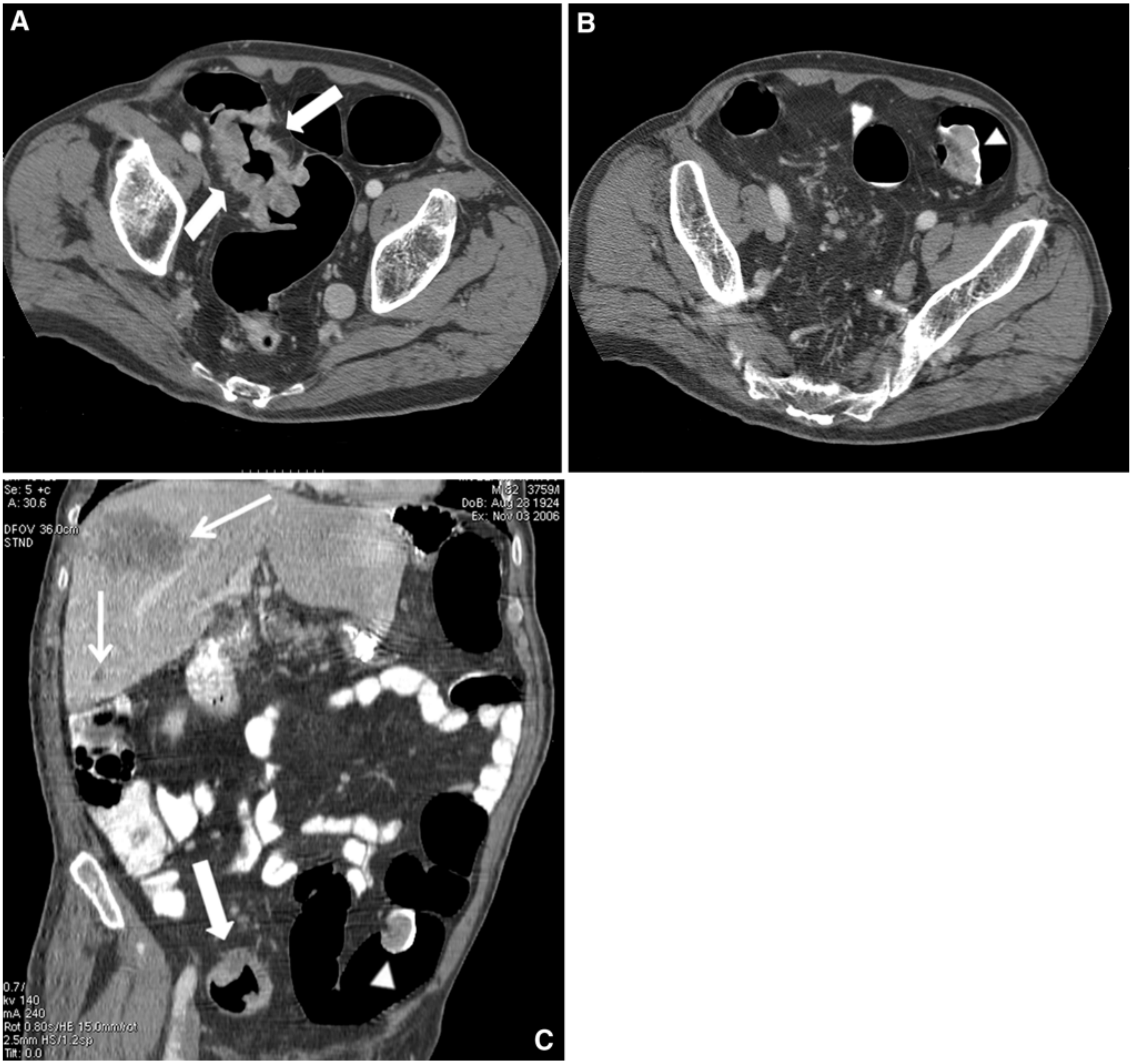

Fig. 2. Images in a 82-year-old man with obstructive colon cancer in the distal sigmoid colon with a synchronous colorectal cancer in the descending colon and liver metastases. The axial CE-CTC images (**A**, **B**) clearly show the obstructive sigmoid colon cancer (*arrows* in **A**) and a synchronous descending colonic lesion (*arrowhead* in **B**). Coronal multiplanar reconstructed CE-CTC image (**C**) shows the two synchronous colonic lesions (*arrow* and *arrowhead*) and the presence of two liver metastases (*thin arrows*).

TNM staging

Histopathologically, 6 were well-differentiated adenocarcinomas, 46 moderately differentiated adenocarcinomas, 22 poorly differentiated adenocarcinomas, and 1 mucinous carcinoma. At histopathologic examination T stage was T1 for 5 neoplasms, T2 for 12, T3 for 45, T4a for 8, and T4b for five. Thirty-three of sixty-nine (48 %) neoplasms were staged as pN0, 19 of 69 (27 %) as pN1, and 17 of 69 (25 %) as pN2.

Sensitivity, specificity, PPV, NPV of CE-CTC were for T1–T2 vs. T3–T4: 96 %, 71 %, 92 %, and 87 %, respectively; for N: 94 %, 42 %, 64 %, and 86 %; for M: 100 %, 100 %, 83 %, and 100 %. The overall diagnostic accuracies of CE-CTC for TNM staging of colorectal cancer were 91 %, 70 %, and 97 % for tumor, node, and metastasis, respectively.

The 76 metastatic liver lesions (diameter range 0.9 mm–11 cm), in twelve patients, were confirmed at

Fig. 3. Images in a 43-year-old woman with proven distal transverse colon cancer. The site of tumor has been corrected from medium transverse to distal transverse colon and so she underwent a high left hemicolectomy instead of a enlarged right hemicolectomy. The transparent 3D colon map (**A**) revealed an obstructive mass (*arrow*) in the distal transverse colon. The axial CE-CTC image shows the distal transverse colon lesion (*arrow* in **B**).

surgery by means of hepatic surface exploration and intraoperative US in all patients Follow-up CT data acquisition revealed no additional metastatic lesions.

Chest CT

Among the 41 patients who underwent also CT of the lungs, 12 patients (29 %) had at least one lung non-calcified nodule >5 mm, for a total of 24 nodules. At radiological CT follow-up, two patients with a rectal cancer, had lung metastases.

In eleven patients with advanced disease (liver and/or lung metastases), colonic surgery was performed to avoid the risk of acute intestinal obstruction; in these cases, chemotheraphy was planned after surgery.

Technical quality of CE-CTC

No patients had an inadequate diagnostic quality of the examinations.

The bowel preparation was considered adequate in 62/69 patients (90 %); in particular, the rating was good in 22/69 (32 %) and excellent in 40/69 (58 %). In seven patients (10 %), the bowel preparation was poor. The radiologists rated the colon adequately distended in 67/69 patients (97 %); in particular, distension was rated

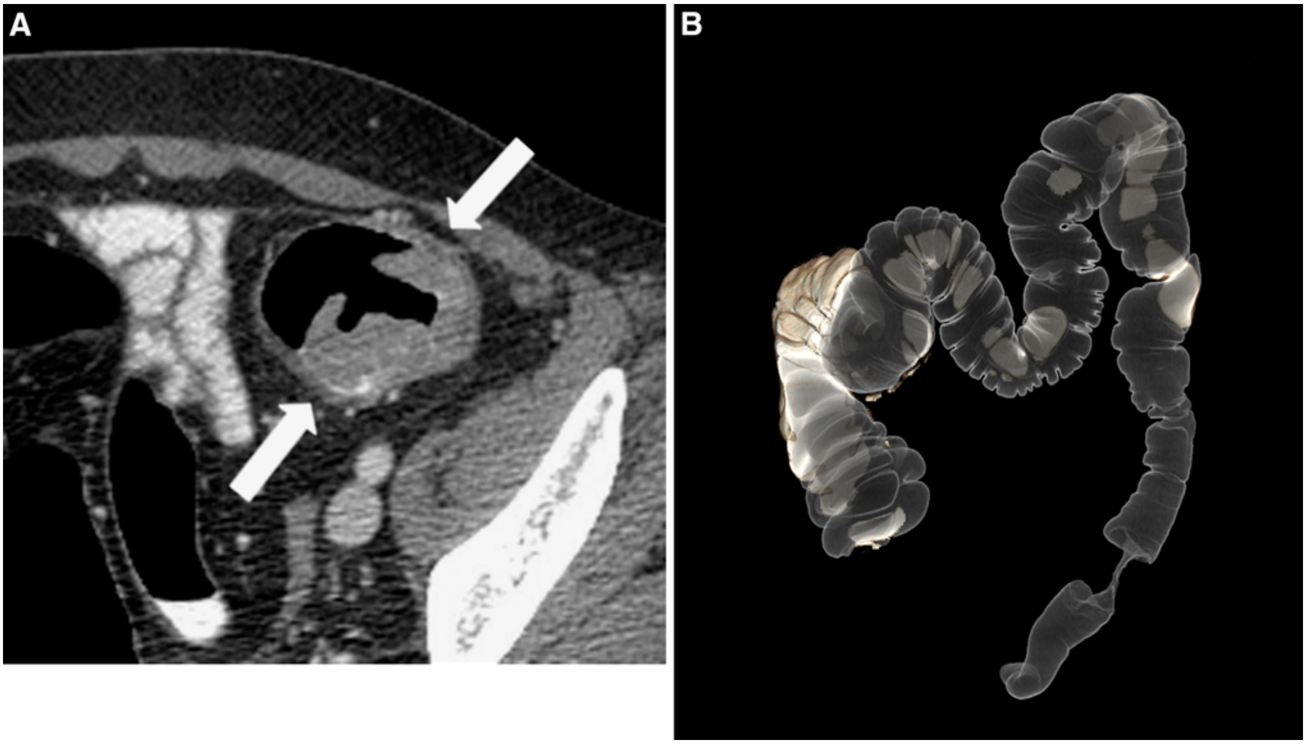

Fig. 4. Images in a 54-year-old woman with a proven proximal sigmoid colon cancer. The axial CE-CTC image (**A**) revealed a large enhanced fungating mass (*arrows*) in the proximal sigmoid colon. The transparent 3D colon map (**B**) clearly revealed the site of the lesion and the characteristic "apple-core" wall-deformity and an adequate distension of the whole colon proximal to the lesion.

good and excellent by both readers in 22 and 45 patients, respectively. In only two patients, the distension was rated as poor, but no patients were excluded for poor quality of CE-CT.

Discussion

CTC represents a valid alternative to optical colonoscopy due to the high accuracy in diagnosing polyps and colorectal cancer [9–12], as confirmed in a recent meta-analysis [22]. Patients with a colorectal cancer diagnosed on optical colonoscopy still benefit from a CTC if optical colonoscopy is incomplete [13–18]. Some authors [16–19, 23, 24] described the utility of CE-CTC in the preoperative staging of colorectal cancer, but without the state of the art technique and, in particular, in absence of a close correlation with laparoscopic management. Laparoscopic surgery for colorectal cancer is now widely used, also in case of advanced lesions, even if some limitations remain. Our purpose was to prospectively investigate the impact of state of the art CE-CTC on laparoscopic surgical planning, in patients with stenosing colorectal cancer.

In our study, the information given by CE-CTC changed the laparoscopic surgical planning in 14 % of the patients; in particular, this change was due to the correction of mistaken optical colonoscopy report about the site of the cancer in 4 % of the patients. Precise localisation of cancer is a critical aspect of laparoscopic approach; inaccurate localization of the colorectal cancer puts the patients at risk for inappropriate trocar placement, prolonged surgery and anesthesia, and inadequate colon resection. In particular, in a survey of the American Society of Colon and Rectal Surgeon [25] 6.5 % of responders reported the removal of the wrong segment of the colon during laparoscopic colorectal surgery. In our experience, information on colorectal cancer site was particularly useful in the cancer of transverse colon, also because the lack of standardized landmarks for the surgeon at this level. Moreover, the transverse colon is often increased in length (dolicocolon).

In association with the CE-CTC information, the endoscopic tattooing with indian ink, routinely used in our Hospital, represents a valid inexpensive tool helping the laparoscopist to identify the cancer intraoperatively [26].

Another crucial issue regarding patients with colorectal cancer is the occurrence of synchronous cancer, reported in the literature in 5–11 % of cases [27–29] and manifested in 7 % of patients in our experience. If synchronous cancer in a different anatomic segments is not diagnosed preoperatively, the second lesion requires additional future surgical treatment. In our experience, the transparent 3D colon map (Fig. 4) was particularly useful and preferred by both endoscopist and surgeon for a variety of reasons. The 3D colon map summarizes in a single image the precise location and number of colonic lesions, can easily be used in the operating room and is easily read as it closely resembles the familiar imaging of double contrast barium enema.

Conventional colonoscopy is regarded as the most sensitive and the most specific whole colon examination for identification of colorectal cancer; however, in patients with obstructive colorectal cancer, clearance of the colon proximal to the obstruction remains a problem. In these cases, we believe that CTC could be the most reliable method to assess the colonic segments proximal to the site of obstruction. In fact, CTC is superior to various techniques commonly performed in the recent past, such as barium enema, intraoperative palpitation, and intraoperative colonoscopy. In particular, barium enema has numerous disadvantages, already fully described [30, 31]; intraoperative palpitation might miss up to 40 % of synchronous lesions, while the main limitation of intraoperative colonoscopy concerns the technical difficulty [32]. Recently, some authors [33–35] suggested a promising role in this issue for a novel examination (PET-CT colonography); further studies with large populations are warranted to define the precise impact of this technique for patients with obstructive colorectal cancer.

The possibility to get information about the presence of additional polyps in the proximal colon not studied by optical colonoscopy is another advantage of CE-CTC vs. these techniques. The diagnosis of unknown additional polyps can change the surgical planning favoring an enlarged colonic resection; in our study, this issue changed the laparoscopic planning in 3 % of patients. Moreover, in case of additional polyps distant from colorectal cancer, the oncologist can opt for a tailored postoperative follow-up (i.e., earlier optical colonoscopy after surgery).

Some authors [18, 36] have reported changes to surgical plans based on CTC findings, with percentages different in synchronous lesions' prevalence; the impact on laparoscopic planning that we found (14 %) is very similar to that of Kim et al. [18] that reported changes to surgical plans in 16 % of cases.

The strengh of CE-CTC in diagnosing the exact site of colorectal cancers and synchronous colonic lesions rely on high technical quality of the examinations; in particular, we verified that the presence of an obstructive colorectal cancer did not affect at all the whole colon distension (Fig. 4), probably the most important factor for CTC quality. This result was probably facilitated by the use of an automated carbon dioxide insufflator, that has several advantages over room air manual insufflation [37], including a reduction of discomfort and pain. Moreover, the use of hyoscine butylbromide should also have favored the adequate whole colonic distension; although the use of spasmolytic agents is still controversial, hyoscine butylbromide improves bowel distension reducing colonic spasms, with less motion artifacts and less discomfort for the patients [38–40]. Even if this issue is not nowadays relevant for surgical planning, CE-CTC showed an excellent accuracy (91 %) in T staging; this result is definitively superior to previous MDCT results [41, 42] and to previous CE-CTC experiences [18, 36]. In particular, Kim et al. [18] reported an accuracy of 86 % for T staging, while accuracies for N and M (70 % and 80 %, respectively) were comparable to our results. The inclusion of the lungs in the CE-CTC acquisition protocol is controversial. Even if the small sample size limits our results, the depiction of lung metastases only in patients with rectal cancer and not in the ones with colon cancer should suggest to include the chest in the CE-CTC acquisition protocol only if the rectum is involved.

Some limitations of our study should be mentioned.

First, we did not evaluate the potential contribution to laparoscopic surgeon of an multiphasic contrast-enhanced CT protocol including the arterial phase; Matsuki et al. [43] in particular found important to perform a preoperative 3D assessment of the vascular anatomy with adjacent organs. This information seems to be very helpful for the laparoscopist before surgery, in particular to achieve the safe and rapid ligation of vessels and dissection of lymph nodes. Second, we preferred not to discuss the bowel preparation because we used in the study three different regimens of bowel preparation; it might be interesting in future to search for an ideal scheme of preparation for patients with obstructing colorectal cancer.

In conclusion, since contrast-enhanced CT is usually performed for colorectal cancer staging, added benefit can be obtained by converting the routine staging CT into a contrast-enhanced CT colonography instead. In particular, CE-CTC has revealed an excellent guide for laparoscopic surgeon avoiding the risks of incorrect choice of the colonic segment to be removed and the failure diagnosis of synchronous lesions.

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