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Diagnostic Value of 128-slice Spiral CT Combined with Virtual Colonoscopy for Colorectal Cancer*

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Summary: The objective of this study was to evaluate the diagnostic value of 128-slice spiral CT combined with virtual colonoscopy in diagnosis of colorectal cancer. We retrospectively analyzed 45 patients of colorectal diseases who underwent definition AS+128-slice spiral CT combined with virtual colonoscopy after bowel preparation and gas injection to evaluate the clinical diagnostic value of this technology. All the patients received electronic colonoscopy and were confirmed by pathology. In total, colorectal cancer was confirmed in 42 cases and inflammation in 3 cases. Diagnostic results shows: there were 17 cases of lump, 10 cases of infiltration, 6 cases of ulcer, 9 cases of mixed type, 4 cases of liver metastases, and 36 cases of lymph node metastasis. There was no significant difference between 128-slice spiral CT combined with virtual colonoscopy and electronic colonoscopy in detection, localization and characterization of colorectal tumors. CT virtual endoscopy has great advantages in observing the invasion around the lesion and the presence or absence of metastasis in distant organs and lymph node metastasis. It is also possible to understand the shape of the lesion in the intestinal lumen and the length of the lesion involving the lumen of the intestine.
Key words: 128-slice spiral CT; virtual endoscopy; colorectal cancer

Clinically, colorectal cancer is the third most common malignant tumors in digestive tract. The conventional detecting technique includes electronic colonoscopy and barium enema. Although electronic colonoscopy is considered as a minimally invasive endoscopic technique, it is unpleasant for most patients and has a particular risk of complications.

Spiral multi-slice computed tomography (CT), a noninvasive imaging modality, was increasingly used for diagnosis of gastrointestinal system disease. But the CT sectional image shows limited performance for colon cancer staging due to the special anatomy of the colon[1]. However, the advancement of computer technologies has given rise to an exciting technique: virtual reality imaging. The combination of virtual reality with high resolution CT imaging showed promise to improve the diagnostic method for colon disease[2, 3]. This new diagnostic method was first applied in clinic by Vining *et al*[1], which is now known as CT virtual endoscopy (CTVE).

CTVE is a new kind of non-invasive method which combines computer virtual reality technology with modern medical imaging modality[4]. The procedure of CTVE includes volume CT images acquisition and related post processing in the workstation. The colon virtual endoscopy simulation software with application of multi-plane reformation (MPR), shaded surface display (SSD) and Raysum technology, can display the intestinal condition, the lesion site and the relationships with surrounding organs vividly.

Recently, with the development of multi-slice spiral CT, higher resolution volumetric CT imaging is becoming possible, which shows the promise to further improve the performance of CTVE in colorectal cancer diagnosis. However, to our knowledge, no recent work was done to evaluate the performance of 128-slice high resolution CT imaging combined with CTVE base on volumetric CT images for diagnosis of colorectal tumors. The purpose of this study was to assess the diagnotic value of 128-slice spiral CT combined with virtual colonoscopy in detection, localization and characterization of colorectal tumors.

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1 MATERIALS AND METHODS

1.1 Patient Population

Our study retrospectively analyzed 45 patients of colorectal diseases, 27 males and 18 females (mean age of 47.5 years and age ranging from 21 to 74 years), who underwent definition AS+128-slice spiral CT combined with virtual colonoscopy after bowel preparation and gas injection from October 2013 to November 2014. All the patients received electronic colonoscopy and were confirmed by operation and pathology. Thirty-seven cases were diagnosed as colorectal cancer and 3 cases as inflammation. The main clinical symptoms of the patients were as follows: change of stool, bloody stool, alternation of diarrhea and constipation, abdominal distension, and anal pendant expansion. The inclusion criteria were as follows: patients with colon disease confirmed by pathology after CT virtual colonoscopy and electronic colonoscopy.

1.2 Examination Preparation

Bowel preparation is the crucial part of the whole examination procedure. On the day before examination, patients were required to only have a small amount of fluid diet for breakfast and lunch, and fast for dinner. Besides, each patient received mixture of 1500 mL water and Senna leaf 30 g during 9 o'clock to 15 o'clock on the day before examination. On the day of examination, from 12 o'clock to 2 o'clock in the morning, each patient drank electrolyte solution 3000 mL (concentration: 30 g electrolyte/3000 mL water) in 2 h. Since then, the patient should fast until the CT examination finished.

Another important preparation step is air injection into intestinal tract. First, patients lay on the left side on the examination table with knees bent, and were injected with about 450 mL of gas through the anus. Then, the patients turned to right side position with knees bent, and another 450 mL of gas was injected. During the injection process if the patients felt abdominal distention, the injection should be stopped for a while and the abdomen was gently massaged to alleviate the symptom. In our study, 900–1000 mL gas was required to inject into the intestinal tract for the examination preparation.

1.3 Acquisition Protocol

All patient images were acquired on a Siemens Definition AS+128-slice spiral CT scanner (Siemens Healthcare, German) at 120 Kv, 150 mA with a detector collimation of 64×0.6 mm, 0.33 s of rotation time and pitch of 1. Ultravist intravenous contrast medium was used to perform the enhanced scanning by using double-syringe power injector (MEDRAD Company, USA). The scan was performed in the supine position after injection of 1.5 mL/kg of ultravist contrast medium with the injection rate of 2.5–3 mL/s, and the scanning delay time was 25 s (arterial phase) and 45 s (venous phase) after the contrast agent injection. Finally the scan was performed in the prone position from the top of the diaphragm to the lower margin of the pubic bone. All the CT images were reconstructed as 1-mm slices with a 1-mm reconstruction interval, and transferred to post-processing workstation software called Colon (Multi-Modality Workplace, Siemens Healthcare, German). In Colon, we could observe the shape, size, involved scope and metastases of the intestinal lesion from different angles. The main image post-processing methods include CT virtual endoscopy (CTVE), SSD, Raysum, MPR, maximum intensity projection (MIP).

1.4 Interpretation

Both the sectional enhanced CT images and CTVE reconstructions of the 45 cases were analyzed by two experienced gastrointestinal radiologists independently. Final interpretations (including the detection, classification, location and surrounding conditions) were based on a combined evaluation of enhanced CT and CTVE (enhanced CT+CTVE). A consensus approach was used for the interpretation. In this study, surgical pathology was considered as the gold standard.

2 RESULTS

2.1 Lesion Detection

Of the 45 cases, by enhanced CT+CTVE, 40 cases were considered to be neoplastic lesions, 3 cases were normal, 2 cases were polyps. The comparison of the results of enhanced CT+CTVE and surgical pathology is shown in table 1. The detection sensitivity and specificity of 128-slice spiral CT combined with virtual colonoscopy post-processing method for the 45 cases were 92.9% and 66.7%, respectively.

Table 1 Enhanced CT+CTVE for colorectal cancer detection

Enhanced CT+CTVE	Pathological results		Total
	Positive	Negative	
Positive	39	1	40
Negative	3	2	5
Total	42	3	45

Of the 40 cases of neoplastic lesions that were detected by high resolution enhanced CT combined with CTVE, 17 cases were lump. The lesion was located on the side of the bowel wall, with a broad base or pedicled tumor protruding into the intestine, with irregular morphology and no obvious abnormalities in the proximal and distal intestinal wall (fig. 1A–1I). A total of 9 cases of infiltration were identified, the tumor grew along the intestinal wall, the intestinal tract was infiltrated in a longer distance, and the intestinal canal was irregular and narrow (fig. 2A–2G). In 5 cases of ulcer, the surface of the mass was unsmooth, and the intestinal canal was narrow slightly. Besides, in the 9 cases of mixed type, the lumen was lumpy, and the

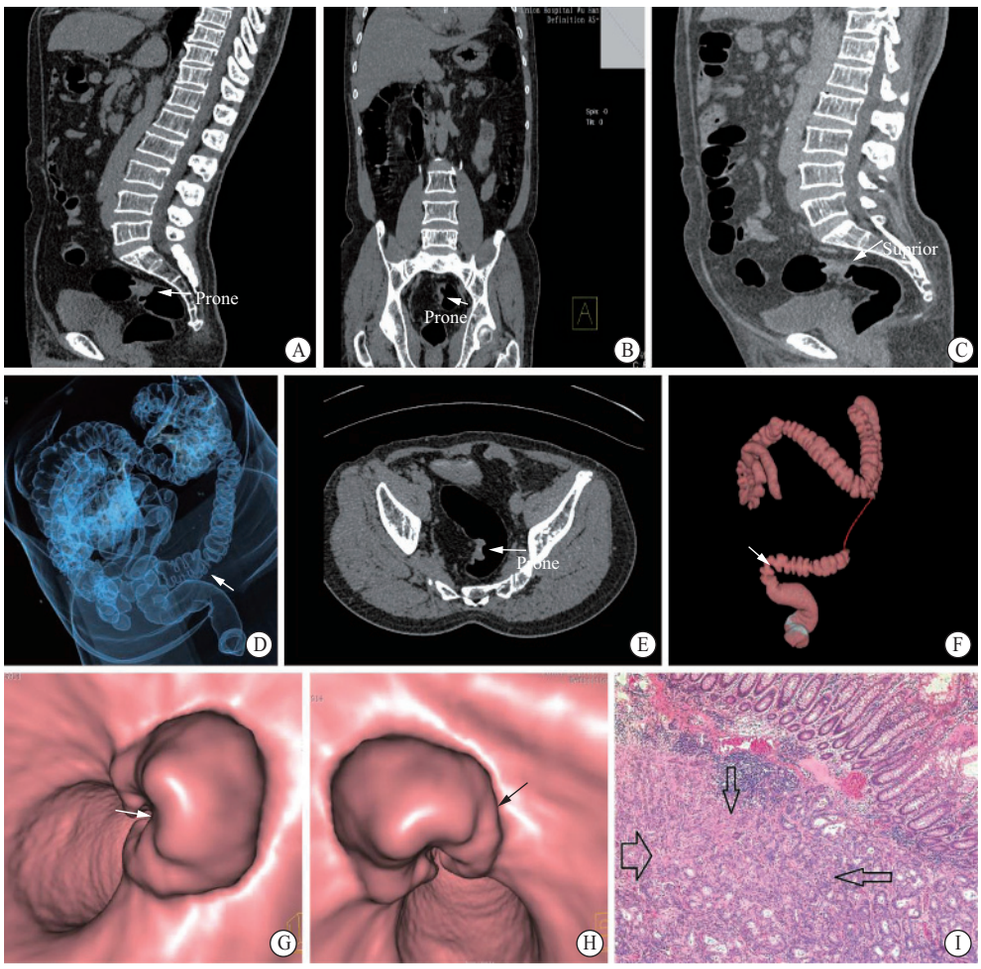

Fig. 1 Results of a 69-year male patient

Symptoms: Blood was found in the stool for more than six months, and abdominal pain for more than one month. Surgical pathological diagnosis: mass sigmoid colon cancer (highly differentiated adenocarcinoma) with mesenteric lymph node metastasis

A–C and E: coronal images in prone position, sagittal image, axial image and sagittal image in supine positions of the MPR reconstruction, respectively, showing the localized stenotic soft tissue on the right side of the distal wall of the sigmoid colon protruding into the intestine (arrow), the intestinal stenosis is not obvious, the fat gap around the lesion is turbid, and there is an increase in number of small lymph nodes. D: Transparent imaging (Saysum) shows localized stenosis of the distal of the sigmoid colon. The side of the intestine wall was obviously sunken, and the proximal and distal intestines of the lesion were stiff (arrow). F: Surface occlusion reconstruction (SSD) shows localized stenosis (arrow) of the intestine, approximately 13 cm from the anus. G, H: CTVE shows a mass with a wide base in the lumen of the intestine protruding into the cavity (arrow), about 2.5 cm in diameter. The surface of the lesion is smooth, located on one side of the intestinal wall, and the proximal and distal intestinal lumens are smooth. I: Pathological findings show irregular glandular infiltration of the muscular layer (arrows, HE staining×20).

intestinal canal was narrow or with the mass protruding into the canal (fig. 3A–3I).

The MPR method showed peripheral adipose space was fuzzy and muddy in 37 cases, with increasing number of small lymph nodes. Four cases were identified with liver metastasis, 35 cases with retroperitoneal and mesenteric lymph node metastasis.

2.2 Lesion Location

For the 40 cases of neoplastic lesions detected by enhanced CT+CTVE, the lesion location was shown as follows: 3 cases at descending colon cancer, 17 cases at rectal cancer, 5 cases at sigmoid colon cancer, 8 cases at ascending colon cancer, and 4 cases at transverse colon cancer. The comparison with surgical pathology results is shown in table 2.

2.3 Classification and Metastasis

Among the 45 cases, there were 42 cases of colorectal cancer and 3 cases of inflammation. Of the 42 colorectal cancer cases, there was lump in 17 cases, infiltration in 10 cases, ulcer in 6 cases, mixed type in 9 cases. In 40 cases, the peripheral adipose space was infiltrated. Four cases had liver metastasis, and 39 cases had lymph node metastasis. All cases were confirmed by operation and pathology. The comparison between the performance of enhanced CT+CTVE and pathological results is shown in table 3.

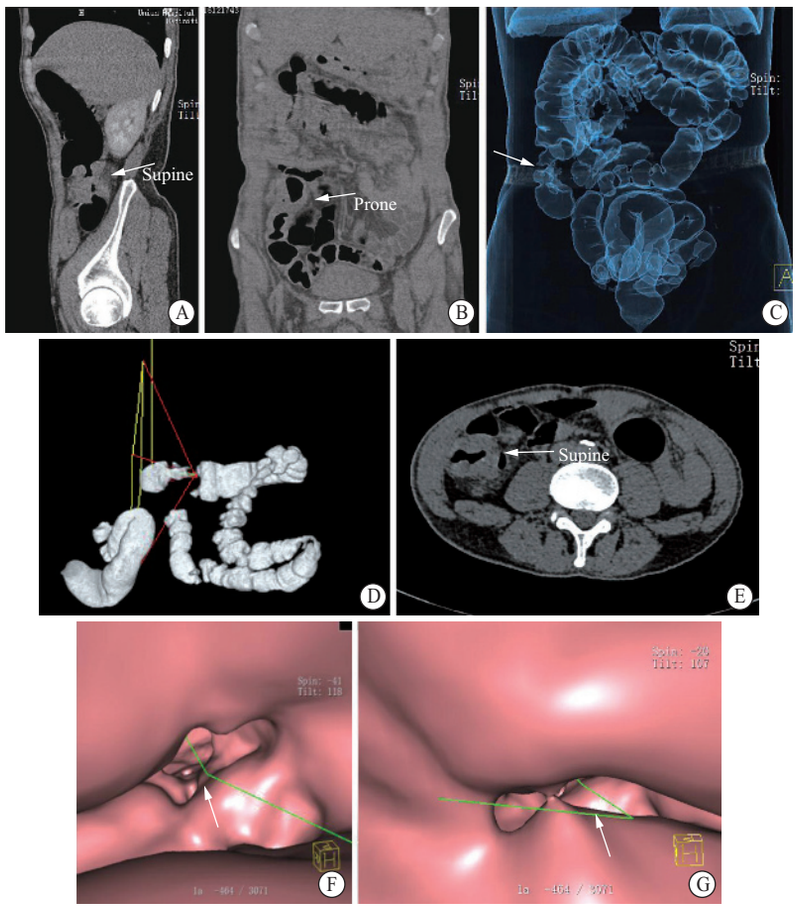

Fig. 2 Results of a 58-year-old male patient

Symptoms: the frequency of bowel movements increased by more than two months, and blood was found in the stool for more than one month. The pathological diagnosis of the operation was: invasive ascending colon cancer (medium differentiated adenocarcinoma), invading the whole layer of the intestinal wall and the extraintestinal fat gap, accompanied by mesenteric lymph node metastasis.

A, B, E: The sagittal image, axial image, and coronal image in supine positions of the MPR reconstruction, respectively show irregular annular thickening of the intestinal wall (arrow). The lesion is about 7–8 cm in length, and the range of involvement is wide. The fat gap around the lesion is turbid, and increased and enlarged lymph nodes could be seen. C: Transparent imaging (saysum) shows irregular concentric stenosis (arrow) in the lumen. D: Surface occlusion reconstruction (SSD) shows irregular stenosis (arrow) of the intestine, with a proximal stenosis of the lesion and local stiffness of the intestinal lumen. F, G: CT simulation endoscopy shows that the lumen of the intestine is obviously narrowed and the surface is uneven (arrow).

Table 2 Enhanced CT+CTVE for detecting colorectal cancer locations

Locations	Pathological results	Enhanced CT+CTVE	Accuracy (%)
Descending colon cancer	5	3	60.0
Rectal cancer	19	17	89.5
Sigmoid colon cancer	6	5	83.3
Ascending colon cancer	8	8	100.0
Transverse colon cancer	4	4	100.0
Total	42	37	88.1

Table 3 Performance of enhanced CT+CTVE for colorectal cancer with metastasis (compared with surgical pathology results)

Items	Pathological results (*n*)	CTVE (*n*)	Accuracy (%)
Colorectal cancer	42	37	88.1
Invasion of peripheral adipose space	40	36	90.0
Liver metastasis	4	4	100.0
Lymph node metastasis	39	35	89.7

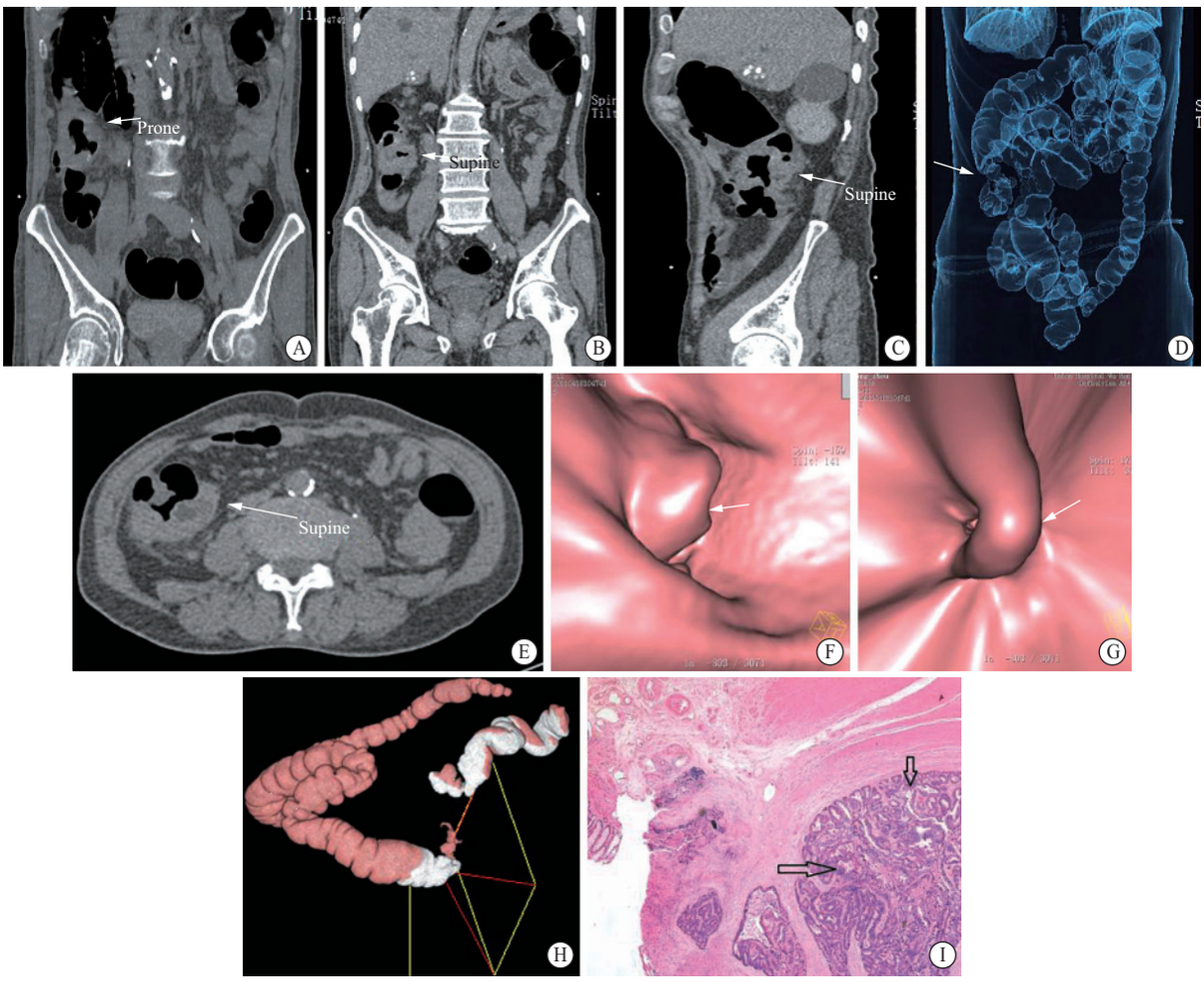

Fig. 3 Results of a 78-year-old male patient
His histopathological diagnosis was mixed ascending colon cancer (hypoplastic adenocarcinoma) accompanied by peripheral lymph node metastasis. The major complaint was intermittent upper abdominal pain over 2 years. MPR reconstruction of coronal images in prone positon (A) and supine position (B), sagittal (C) and axial images (E), shows the ascending colon proximal and back to the blind annular irregular thickening of the bowel wall (arrow), part images displayed the mass of tumor-like soft tissue protruding into the lumen of the intestine. The lesions invaded a wide range, with a length of about 7 cm. The fat gap of the perianal cavity was turbid with increased and slightly enlarged lymph nodes. D: Raysum image shows irregular narrowing (arrow) of the proximal intestine in the ascending colon. F, G: CTVE shows significant narrowing of the intestine, uneven surface, part of the cauliflower-like mass is protruding into the cavity (F, arrow), some lesions have a concave in the center, around the ring thickening, bulging (G, arrow); H: image with SSD reconstruction method displayed concentric stenosis of intestinal lumen, stiffness of intestinal wall. I: Pathological findings show irregular glands (arrows, HE staining×20).

3 DISCUSSION

The incidence of colorectal cancer has been rapidly increased in recent years, and the onset age is getting younger and younger. A younger age of onset of colorectal cancer has been observed. The common exam methods include electronic colonoscopy and barium enema etc. CTVE that combines computer virtual reality technology with 3-demensional CT imaging was first described by Vining *et al*[1] and applied in clinic. It is considered as a safe, non-invasive, time-saving method and easily accepted by patients. Therefore, it could been commonly used in clinical examination.

3.1 Preparation before CTVE and Post-processing Technique

Bowel preparation is the key step for successful CTVE examination. Intestinal tract after preparation should be clean with no fecal stone, no residual liquid, and the last excreta should be water; after gas injection, the ideal situation is that the whole colon is fully expanded, intestinal fold and colonic bag fully stretches[5]. If the intestine is not fully prepared, the remaining feces in intestine will be easily misdiagnosed as lesions. The residual water will block the navigator of CTVE when it observes the lesion. It can also cover the small lesion in the intestine. If the gas injected into the bowel is not enough, the bowel tract would

not be fully expanded, the colonic pouch wrinkles and does not stretch, it might be misdiagnosed as polyps or residual feces. CT topogram could evaluate whether gas injection is enough for diagnosis. Generally, after gas injection, if ileocecal bowel dilatation or intestinal tube dilatation was about 3 cm, the gas injection is well enough for diagnosis. Fully colon expansion by gas injection is helpful for lesion detection and delineation. Injecting too much or too little gas into intestine would influence the image post-processing, lesion detection and identification.

In this study, patients were scanned at both supine position and prone position on the 128-slice spiral CT scanner from the top of the diaphragm to the lower edge of the pubic symphysis. Change of the scanning position could shift the location of residual liquid and stool, thus it can decrease the chance of covering of the lesion and facilitate the identification of intestinal contents[6]. All the CT images were reconstructed as 1-mm thickness, and transferred to Siemens post-processing workstation. Through the colon virtual reality post-processing, we could observe the morphology, size, involved scope and metastases of the intestinal lesion from different angles. The post processing steps include: First, the SSD shows the whole colon intuitively and it can be rotated randomly. Through the SSD, we can observe the lesion's scope, location, and distance from the anus as well as the morphology of lesions. Second, Raysum, a method similar to double contrast barium enema, is used to display the entire colon, the intestine with or without the stenosis, the location and scope of lesion. It can also determine whether there are filling defects and changes in external pressure. Third, the anatomical view with 360° wide-angle shows unfold images of the colon; it helps reveal the lesion between the intestine folds or behind the folds. Finally, the navigator technique observes the growth and morphology of the intestinal tumor, it moves from the distal rectum gradually deep into the lumen, through the ileocecal junction; after finding the lesion, we can observe the general morphology of the tumor from the proximal and distal end, including surface situation and the relationship between the tumor base and the intestinal wall.

3.2 Clinical Value of Enhanced CT Combined with CTVE for Diagnosing Colorectal Cancer

For colorectal cancer diagnosis, the information of the location, size, classification and metastasis is necessary for clinician to select the proper treatment plan and evaluate the prognosis. In this study, we proved that enhanced CT combined with CTVE could provide high detection rate of rectal tumors. This is due to CT scans have high sensitivity and specificity for detection of colorectal cancer that penetrates the muscle layer. Besides, multi-planar reconstruction (MPR) of the original CT images enables multi-direction observation of lesion morphology, size, the relationship with surrounding tissues and presence of lymph node metastasis[7]. And combined with post-treatment CTVE we can further observe the shape of the lesion in the intestine, the invasion extent of the intestinal wall and the distance of the lesion from the anus. In this study, large lesions protruded into the cavity of 9 patients, resulting in severe stenosis of the intestine. These patients failed to do electronic colonoscopy examination as electronic colonoscopy could not pass through the severe stenosis intestines, so they were diagnosed by enhanced CT combined with CTVEA, which confirmed the clinical value of CTVE. In our study, the detection rate of colorectal cancer with liver metastasis was 100%, the detection rate of invasion of fat tissue around the intestinal wall was 90%, and the detection rate of lymph node metastasis was 89.7%. Enhanced CT scan can delineate intestinal contents and lesions to improve the detection rate of the lesions; for example, an enhanced nodular protrusion on the wall of the intestine indicates a large possibility of a lesion; for the nodule without enhancement, it is more likely to be intestinal contents. Besides, the tumor lesions showed obvious enhancement at artery phase, and reduction in the venous phase[8]. Another benefit is after CT enhancement, the maximum density projection (MIP) can also be used to clearly observe the vascular anatomy to understand the blood supply, which helps locate the lesion and understand the blood supply of the tumor. Combination of enhanced CT with CTVE greatly improves the diagnosis accuracy of colorectal cancer, and has important clinical value.

3.3 Clinical Value of Enhanced CT Combined with CTVE in the Localization and Qualitative Diagnosis of Colorectal Cancer

At present, surgical treatment is the first choice for colorectal cancer. It is very important to know the type of lesion, the specific location, the extent of invasion, the length of the lesion and the presence of metastasis before surgery, which is helpful for selecting the optimal treatment, surgical methods and evaluating prognosis. Our study showed that the diagnosis coincidence rate of mass type colorectal cancer between CT virtual endoscopy and pathological results was higher than that of invasive, ulcer and mixed types. The reasons is that CTVE is not restricted by intestinal stenosis to observe the shape of the lesion in the intestinal lumen[9], and it can display the mass in multiple directions and planes, thus is able to more objectively describe the overall shape of the lesion. Moreover, because CTVE cannot visually observe the color of the lesion, mucosal changes of the intestinal wall, and superficial ulcers, colorectal cancer of invasive, ulcer, and mix type is hard to be distinguished.

For positioning, enhanced CT combined with CTVE has obvious advantages and high accuracy. Through the coronal and sagittal images of MPR, the

specific location of the tumor, the fat spacing around the lesion, and the presence or absence of metastasis of other organs and lymph node can be identified. Combined with SSD and Raysum recombination images, it is possible to determine the length of the tumor involving the lumen and the distance from the anus. In this study group of 9 patients, the intestinal lumen was narrower due to the large lesion in the intestine, and the endoscope could not pass, so it is unable to measure the lesion length. However, the enhanced CT combined with CTVE could accurately determine the length and location of the lesion. In this study, we proved that CTVE can accurately evaluate the length of the mass, the extent of infiltration, the location, the classification and the presence or absence of other organ metastasis.

This study also showed misdiagnosis of colonic inflammation by CTVE. CT images showed that the fat gap around the lesion was blurred, the intestinal wall was slightly thickened, and there were enlarged small lymph nodes around it, but the diagnosis was neoplasm. However, after repeated review of the images, we consider the false positives may be due to edema of the intestinal wall, obscuration of the serosa caused by peripheral lymphangitis, and shadows in the surrounding fat gap. Repeated review of the images found that the colon bag and feces were misdiagnosed as polyps in 3 cases.

3.4 Advantages and Disadvantages of CTVE and Electronic Colonoscopy

CTVE is a safe, noninvasive, short-time and patient-friendly examination that requires no anesthetic or sedation. It could become the first choice to screen the colorectal cancer for the elderly and people who cannot undergo electronic colonoscopy. Moreover, the multi-slice spiral CT virtual endoscope has a large amount of data, which is easy to be stored, and can be repeatedly observed. The patients who are reviewed can be compared with the results of previous examination[6]. For cases that intestinal tumor is large or the intestinal wall is obviously thickened, resulting in a significant narrowing of the intestinal lumen, CTVE can also completely observe the shape and specific location of the lesion. But CTVE cannot observe the color and mucosa of the lesion, cannot obtain biopsy tissues; besides the false positive rate is higher if the intestinal preparation is not enough, and it lacks tissue specificity for detecting smaller polyps[10].

Electronic colonoscopy can visually observe the type of lesion and the color of the mucosa. The most important thing is that the biopsy tissues can be taken on the lesion and the suspected lesion during the examination. It can play a therapeutic role in small lesions. However, the electronic colonoscopy is an invasive method, and it can lead to a greater possibility of intestine perforation, which is generally intolerable in patients with weaker condition and older age; besides it is also intolerable for patients with intestinal obstruction and intestinal lumen stenosis. Six patients of the study group could not tolerate the pain during the electronic colonoscopy, so the detection was interrupted.

In conclusion, there are still shortcomings in CTVE technique, but with the development of computer technology, the defects of CTVE may be overcome, it shows great clinical value. Electronic colonoscopy is still considered as the gold standard tool in the assessment of colorectal cancer, but our study proves that the combination of CTVE with high resolution CT imaging have the advantages to identify the location, range, the scope of the surrounding infiltration, lymph node and/or the other organs metastasis, and provide more information about preoperative staging and prognosis of patients. Hence, the combined application of CT and electronic colonoscopy should become a routine clinical method for diagnosis of colorectal diseases, which can better guide the doctors to select the treatment plan comprehensively and objectively.

Conflict of Interest Statement

We declare that we have no conflict of interest.

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