Int J Clin Exp Med 2017;10(7):9954-9962
www.ijcem.com /ISSN:1940-5901/IJCEM0053930

Original Article

Application of postoperational CT scan in the early diagnosis of incisional surgical site infections in elective colorectal surgery

Jinfu Zhuang[1,2], Jianxin Ye[1,2], Yongjian Huang[1,2], Wei Zheng[1,2], Shugang Yang[1,2]

[1]Department of Gastrointestinal Surgery 2 Section, The First Hospital Affliated to Fujian Medical University, Fuzhou 350004, Fujian, China; [2]Key Laboratory of Ministry of Education for Gastrointestinal Cancer, Fujian Medical University, Fuzhou 350004, Fujian, China

Received March 27, 2017; Accepted May 10, 2017; Epub July 15, 2017; Published July 30, 2017

Abstract: Background: Surgical site infection (SSI) is a potentially morbidity and costly complication following colorectal operations. It is difficult to detect the wound infection through the patient's symptoms and signs in the early stage of incisional surgical site infections. However, there are few studies about the Early identification and diagnosis of patients with incisional SSI. The aim of this study was to assess the application of postoperational CT in the early diagnosis of incisional surgical site infections in elective colorectal surgery. Methods: Using our SSI surveillance database, we analyzed retrospectively 342 patients who underwent colorectal surgery between 2012 and 2016. There were two groups. The study group included 171 patients who had the incisional surgical site infections. The control group also included 171 patients who had the same location of the tumor (Right hemicolon, Left hemicolon and Rectum) and the thickness of subcutaneous fat was similar (The difference is less than 0.5 cm). Recorded clinical parameters included the average CT Attenuation Value (CAV for short) of the area where CAV changed obviously. The transverse diameter of the area where CAV changed obviously, C-reactive protein (CRP) levels, incisional pain and tenderness, localized swelling and redness, the treatment of the incisional surgical site infections. Then statistical analysis was carried out to get the difference of two group. Results: In the superficial incisional SSI group, the average CAV of the incision in the infected group was -0.21±19.60, and -51.00±27.35 in the normal group. T was 15.32, and P was 0.000 ($P<0.05$). In the deep incisional SSI group, the average CAV of the incision of the infected group was 19.72±8.40, and 39.97±5.74 in the normal group. T was -16.415, and P was 0.000 ($P<0.05$). The transverse diameter of the area where CAV changed obviously was divided into 4 group, $D<0.5$ cm, 1.0 cm$>D\geq$0.5 cm, 2.0 cm$>D\geq$1.0 cm and $D>2.0$ cm. There were 13 (7.6%), 21 (12.3%), 53 (31.0%) and 84 (49.1%) respectively in the infected group, and 126 (73.7%), 26 (15.2%), 13 (7.6%) and 6 (3.5%) respectively. The χ^2 was 184.238, P was 0.000 ($P<0.05$). There were 46 cases whoes CT scan showed obvious low density or liquid dark area (Figure 9), and we used the 5 ml or 10 ml syringe to puncture the low density or liquid dark area under the CT image guiding. 38 cases could be punctured pus, then we opened the incision for further treatment. Conclusions: Testing the incision CAV and the transverse diameter of the area where CAV changed obviously is an effective diagnostic method for the early incisional SSI. CT combining with puncture Contribute to early diagnosis and treatment for the incisional SSI, reduce the pain of patients and medical expenses.

Keywords: Colorectal operations, postoperative complication, incisional surgical site infections, computed tomography scan (CT scan)

Introduction

Surgical site infection (SSI) is a potentially morbidity and costly complication following major abodominal resection. Moreover, colorectal operations are associated with a higher incidence of incisional SSI than are upper gastrointestinal procedures because the target bacteria are gramnegative enteric bacilli, principally Escherichia coli, and anaerobic bacteria, including Bacteroides spp. In recent years, there has been growing attention placed on the accurate monitoring of such surgical site infection and their costs, measured in terms of increased morbidity to patients and increased financial costs to society. However, although the development of various perioperative management techniques has contributed to a decrease in

Figure 1. The superficial incisional SSI. The red circle was 0.94 cm^2. The average CAV 11.3 (HU).

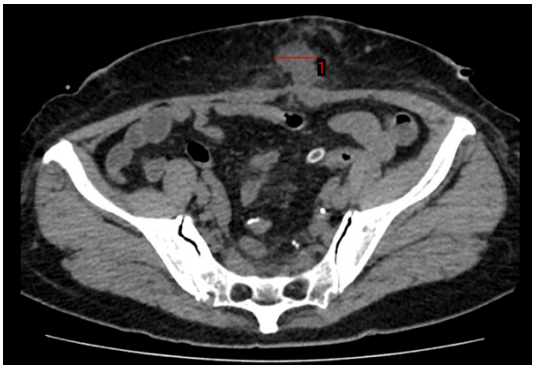

Figure 2. The transverse diameter of the area CAV changed obviously. It was 2.81 cm.

postoperative complications [1, 2], elective colorectal surgery still has a high incidence of I-SSI (5-30% in China) [3].

Early identification and diagnosis of patients with incisional surgical site infections may lead to a decrease in morbidity and financial costs to society. It is difficult to detect the wound infectiong through the patient's symptoms and signs in the early stage of incisional surgical site infections. However, there are few studies about the Early identification and diagnosis of patients with incisional surgical site infections. Computed tomography (CT) is currently the most readily available imaging in the work-up of major complications [4-6]. Moreover, in the study conducted by Eckmann et al., CT-scan imaging showed a sensitivity of 97% [7]. Another recent study established CT-scan imaging as the preferred modality in diagnosis of anastomotic leakage [8]. There are few studied about the application of postoperational CT in the diagnosis of incisional surgical site infections in elective colorectal surgery. In the study here presented, we assessed the CT-scanning in the early diagnosis of incisional surgical site infections in elective colorectal surgery.

Materials and methods

The present study was approved by the Institutional Review Board of the first Hospital Affiliated to Fujian Medical University, and informed consent was obtained according to institutional regulations. Written informed consent for further clinical research was obtained from participants for their clinical records.

Since May 2012, we have been conducting prospective SSI surveillance according to the CDC guidelines [9] for all patients who undergo elective colorectal surgery at the Institute of Department of Gastrointestinal Surgery 2 Section, The First Hospital Affliated to Fujian Medical University. In the present retrospective study, attending physicians or nurses observed all operative sites at least once a day until patient discharge from the hospital. Post-discharge SSI surveillance was carried out in the outpatient clinic, and all patients were followed up for 30 d postoperatively. The diagnosis of SSI was made after discussion among attending physicians and nurses.

Using our SSI surveillance database from May 2012 to December 2016, a single-institutional retrospective statistical analysis was performed. There were two groups, 342 patients in total. The study group included 171 patients who had the incisional surgical site infections in elective colorectal surgery and CT was performed 3-5 days after the operation. Patients whoes infected incisions were opened for drainage before postoperaional CT were excluded. Using a paired method according to the thickness of subcutaneous fat and the location of the tumor, 171 patients whoes incisions were recovered well and CT was performed 3-5 days after the operation were secected as the control group. The patients in the control group had the same location of the tumor (Right hemicolon, Left hemicolon and Rectum) and the thickness of subcutaneous fat was similar (The difference is less than 0.5 cm).

Recorded clinical parameters included the average CT Attenuation Value (CAV for short) of the area where CAV changed obviously

Table 1. The basic data and incisional characteristics of the patients in the superficial incision group (n = 206)

Variable	Superficial incisional SSI (103)	Superficial normal incision SSI (103)	T/χ^2	*P* value
Gender			1.257	0.262
Male	61 (59.2%)	53 (51.5%)		
Female	42 (40.8%)	50 (48.5%)		
Age (years old)	57.63±11.27	58.85±10.207	-0.816	0.415
CAV[a] of the incision	-0.21±19.60	-51.00±27.35	15.32	0.000
CRP[b]	42.98±13.36	39.48±12.29	1.098	0.276
Incisional pain and tenderness			9.667	0.002
Positive	34 (33.0%)	15 (14.6%)		
Negative	69 (67.0%)	88 (85.4%)		
Localized swelling and redness			3.102	0.078
Positive	25 (24.3%)	15 (14.6%)		
Negative	78 (75.7%)	88 (85.4%)		
Purulent drainage from the incision				
Positive	17 (16.50%)	0 (0%)	----	----
Negative	86 (83.50%)	103 (100%)		

[a]CT Attenuation Value. [b]Only 43 cases in the superficial incisional SSI and 27 cases in the superficial normal incision SSI.

(**Figure 1**), The transverse diameter of the area where CAV changed obviously (**Figure 2**), C-reactive protein (CRP) levels, incisional pain and tenderness, localized swelling and redness, the treatment of the incisional surgical site infections. The incisional SSI included both superficial and deep infections as defined by the CDC (the U.S. Centers for Disease Control and Prevention guidelines for patients) criteria. Specifically, incisional SSI was defined as an infection that occurred at the incision site within 30 d after surgery and was characterized by at least one of the following: Purulent drainage from the incision; an organism isolated from a culture of fluid from the incision; incisional pain, tenderness, localized swelling, redness, or heat with opening of the incision; and diagnosis by the surgeon or attending physician [9]. Superficial incisional SSI involves only the skin or subcutaneous tissue of the incision, whereas deep incisional SSI involves the deep soft tissues (e.g., fascial and muscle layers) [9]. Postoperative pain level was evaluated with the use of the visual analog scale (VAS) with scores ranging from 1 to 10. It is positive when patients' pain is greater than 3. When incisional surgical site infections were the only complication, the CRP and WBC which were tested 3-5 days after the operation were included. When CRP was more than 90 mg/L, we took 90 for Statistics. It is positive when patients' WBC was more than 30% of its preoperaional level.

Statistical analysis

Statistical analysis was conducted in SPSS version 17.0 (SPSS Inc. Chicago, IL, USA). Continuous variables with normal distributions were presented as means and standard deviations. Medians and interquartile ranges were used as central tendency for continuous variables with non-normal distributions. Categorical data were expressed with percentage frequencies. Effects between two groups were further examined with a Student's t-test. χ^2-test was used for comparing categorical variables as appropriate. A value of $P<0.05$ was considered statistically signifcant.

Results

A total of 342 patients were enrolled, 171 cases in the study group, and 171 cases in the control group. All patients had the CT or MRI examination before operation for clinical tumor TNM stage, and were examined with CT after 3-5 days Part of the patients had the CRP test. According to the depth of infection (superficial incisional SSI and deep incisional SSI), 171 cases of incisional SSI were divided into 2 groups, 103 cases in the superficial incisional

Figure 3. The superficial normal incision. The red circle was 1.28 cm^2. The average CAV-94.7 (HU).

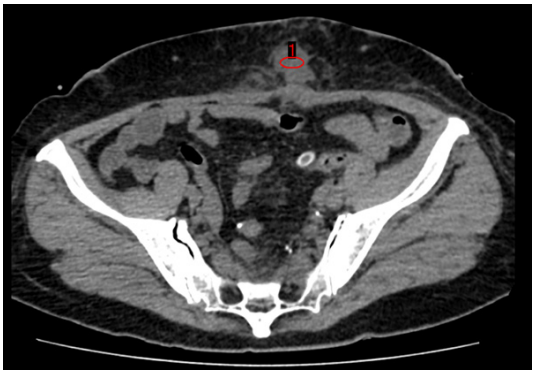

Figure 4. The superficial incisional SSI. The red circle was 1.09 cm^2. The average CAV 9.6 (HU).

Figure 5. The incision after purulent drainage from the incision of **Figure 4**.

SSI and 68 cases in the deep incisional SSI. All patients were followed up for more than 1 month and no missing cases.

In the superficial incisional SSI group (**Table 1**), 61 (59.2%) cases were male, and 42 (40.8%) cases were female; And in the normal incision group, 53 (51.5%) cases were male, and 50 (48.5%) cases were female. χ^2 was 1.257, P was 0.262 (P>0.05). The mean age was 57.63±11.27 years in the infected group, and 58.85±10.207 years in the normal group. T was -0.816 and P = 0.415 (P>0.05). The average CAV of the incision in the infected group was -0.21±19.60, and -51.00±27.35 in the normal group. T was 15.32, and P was 0.000 (P<0.05). There were only 43 cases who had the CRP test in the infected group, the mean CRP was 42.98±13.36 mg/L; And 27 in the normal group, the mean CRP was 42.98±13.36 mg/L. T was 1.098, and P was 0.276 (P>0.05). There were 34 (33.0%) cases who had the incisional pain and tenderness, and 15 (14.6%). χ^2 was 9.667, P was 0.002 (P<0.05). There were 25 (24.3%) cases who had the localized swelling and redness, and 15 (14.6%). χ^2 was 3.102, P was 0.078 (P>0.05) (**Figures 3**-**5**).

In the deep incisional SSI group (**Table 2**), 39 (57.4%) cases were male, and 29 (42.6%) cases were female; And in the normal incision group, 43 (63.2%) cases were male, and 25 (36.8%) cases were female. χ^2 was 0.491, P was 0.483 (P>0.05). The mean age was 58.63±12.64 years in the infected group, and 55.13±8.78 years in the normal group. T was 1.875 and P = 0.063 (P>0.05). The average CAV of the incision of the infected group was 19.72±8.40, and 39.97±5.74 in the normal group. T was -16.415, and P was 0.000 (P<0.05). There were only 36 cases who had the CRP test in the infected group, the mean CRP was 50.75±13.84 mg/L; And 23 in the normal group, the mean CRP was 37.87±15.78 mg/L. T was 3.300, and p was 0.002 (P>0.05). There were 26 (38.2%) cases who had the incisional pain and tenderness, and 9 (13.2%). χ^2 was 9.667, P was 0.002 (P<0.05). There were 15 (22.1%) cases who had the localized swelling and redness, and 7 (10.3%). χ^2 was 3.470, P was P = 0.062 (P>0.05) (**Figures 6**-**8**).

The transverse diameter of the area where CAV changed obviously was divided into 4 group (**Table 3**), D<0.5 cm, 1.0 cm>D≥0.5 cm, 2.0 cm>D≥1.0 cm and D>2.0 cm. There were 13 (7.6%), 21 (12.3%), 53 (31.0%) and 84 (49.1%) respectively in the infected group, and 126 (73.7%), 26 (15.2%), 13 (7.6%) and 6 (3.5%) respectively. The χ^2 was 184.238, P was 0.000 (P<0.05). There were 46 cases whoes CT scan

Table 2. The basic data and incisional characteristics of the patients in the deep incision group (n = 136)

Variable	Deep incisional SSI (68)	Deep incisional SSI (68)	T/χ^2	*P* value
Gender			0.491	0.483
Male	39 (57.4%)	43 (63.2%)		
Female	29 (42.6%)	25 (36.8%)		
Age (years old)	58.63±12.64	55.13±8.78	1.875	0.063
CAV[a] of the incision	19.72±8.40	39.97±5.74	-16.415	0.000
CRP[b]	50.75±13.84	37.87±15.78	3.300	0.002
Incisional pain and tenderness			11.119	0.001
Positive	26 (38.2%)	9 (13.2%)		
Negative	42 (61.8%)	59 (86.8%)		
Localized swelling and redness			3.470	0.062
Positive	15 (22.1%)	7 (10.3%)		
Negative	53 (77.9%)	61 (89.7%)		
Purulent drainage from the incision				
Positive	7 (10.29%)	0 (0%)		----
Negative	61 (89.71%)	68 (100%)		

[a]CT Attenuation Value. [b]Only 36 cases in the superficial incisional SSI and 23 cases in the superficial normal incision SSI.

showed Obvious low density or liquid dark area (**Figure 9**), and we used the 5 ml or 10 ml syringe to puncture the low density or liquid dark area under the CT image guiding. 38 cases could be punctured pus, then we opened the incision for further treatment; And the other 8 cased could be punctured nothing, then some days later, the pus out flowed from the incision. All of the cases were treated with drainage at the bedside.

Discussion

There are about 40,000,000 people in our province (Fu Jian province in china). As one of the largest gastrointestinal surgery in our province, there are about 800-1200 cases of colorectal surgery each year. Incisional SSI is a common complication of colorectal surgery, therefore Prevention of incision infection, early diagnosis and early treatment, can reduce the pain of patients, mordility and medical expenses. In recent years, there has been growing attention placed on the accurate monitoring of such surgical site infecton and their costs, measured in terms of increased morbidity to patients and increased financial costs to society. Previous studies have reported numerous independent risk factors that are associated with the incidence of I-SSI after colorectal surgery. These risk factors include body mass index (BMI) [10-12], the American Society of Anesthesia (ASA) score [13-15], systemic steroid use [16], preoperative non-absorbable oral antibiotics use [16], preoperative skin preparation [17], wound classification [13, 14, 18], the length of the operation time [11-13], prophylactic antibiotic use [11, 19, 20], blood transfusion [15], laparoscopic surgery [13, 21], creation or closure of an ostomy [10, 14, 17], the suture material used for fascial closure [10, 23], the type of skin closure [24], the subcutaneous fat thickness [25], and postoperative hyperglycemia [26, 27]. However, although the development of various perioperative management techniques has contributed to a decrease in postoperative complications [1, 2], elective colorectal surgery still has a high incidence of I-SSI (5-30% in China) [3]. Early identification and diagnosis of patients with incisional surgical site infections may lead to a decrease in morbidity and financial costs to society. It is difficult to detect the wound infectiong through the patient's symptoms and signs in the early stage of incisional surgical site infections. However, there are few studies about the Early identification and diagnosis of patients with incisional surgical site infections. Computed tomography (CT) is currently the most readily available imaging in the work-up of major complications [4-6]. Moreover, in the study conducted by Eckmann et al., CT-scan imaging showed a sen-

Figure 6. The deep normal incision. The red circle was 1.36 cm^2. The average CAV 46.0 (HU).

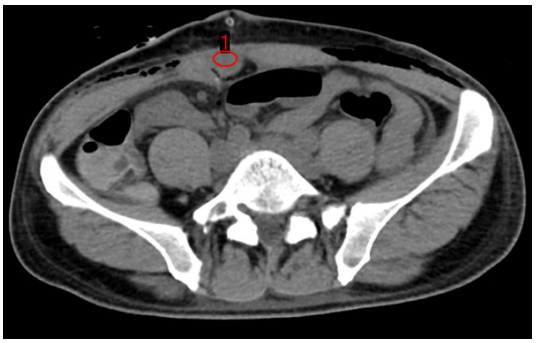

Figure 7. The deep normal incision. The red circle was 1.44 cm^2. The average CAV 24.5 (HU).

Figure 8. The incision after purulent drainage from the incision of **Figure 7**.

sitivity of 97% [7]. Another recent study established CT-scan imaging as the preferred modality in diagnosis of anastomotic leakage [8]. There are few studied about the Application of postoperational CT in the diagnosis of incisional surgical site infections in elective colorectal surgery.

Traditional diagnosis for incisional SSI include purulent drainage from the incision; an organism isolated from a culture of fluid from the incision; incisional pain, tenderness, localized swelling, redness, or heat with opening of the incision. However, when the infection is diagnosed, it always spread widely, and the patient's pain and medical expenses are increased. In our study, when the patients performed the CT scan only 34 (33.0%) cases felt incisional pain and tenderness, 25 (24.3%) cases had incisional localized swelling and redness, and 17 (16.50%) in the superficial incisional SSI. There were 26 (38.2%), 15 (22.1%), and 7 (10.29%) respectively in the deep incisional SSI. Therefore the positive rate was low. The CRP in the deep incison was different between two group (χ^2 = 3.300, P = 0.002). However it was the marker of infection, so it was difficult to distinguish the incisional infection and other infection. The above parameters contributed to the diagnosis of wound infection, but the sensitivity is low. With the number of obese patients increasing, the incidence of the incisional SSI is increasing. There are several proposed mechanisms that could explain why increased fat at the site of the surgical incision may increase risk of SSI. These include increased technical difficulty, increased tissue trauma, increased tension on the wound, decreased circulation and oxygenation at the local wound site, and local immunosuppression related to large populations of adipocytes [28-30]. Because the incision of the obese patient is deep, especially the deep incisional SSI, it is difficult to diagnose in the early stage. Our study showed that before the incisional SSI were dignosed the CAV of the incision changed obviously 3-5 days after operation. Therefore CT scan was more effectvie than the symptoms, signs and blood test for the diagnosis of the incisional SSI.

Different tissues have CAV. The fat is -80-120 (HU), muscle is 35-50 (HU), pus is more than 18 (HU), inflammation is 0-20 (HU). In our study,

Table 3. The relationship of the transverse diameter and the infection

D[a]	171	171	184.238, P = 0.000
D<0.5 cm	13 (7.6%)	126 (73.7%)	
1.0 cm>D≥0.5 cm	21 (12.3%)	26 (15.2%)	
2.0 cm>D≥1.0 cm	53 (31.0%)	13 (7.6%)	
D>2.0 cm	84 (49.1%)	6 (3.5%)	

[a]The transverse diameter of the area where CAV changed obviously.

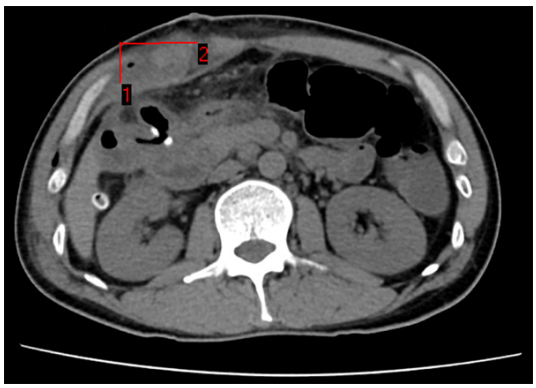

Figure 9. Line 1 which was 2.25 cm was the vertical distance from skin to pus cavity. Line 2 which was 4.24 cm was the horizontal distance from skin to pus cavity. Along line 1 for puncture was safe, because there was no bowel inside the abdominal wall.

we selected a size of about 1.0-1.5 cm^2 area where CAV changed obviously from the CT images, and tested its average CAV. In the 1.0-1.5 cm^2 area, it mixed fat, scar, pus, inflammation or muscle, so different incision and different part of the incision showed different CAV. However, the average CAV was similar to the main component In the 1.0-1.5 cm^2 area. Because the verage CAV of the fat, inflammtion (or pus) and muscle are so different, according to the verage CAV, it is easy for us to distinguish the infected incision and the normal incision. Our study showed that the verage CAV of superficial incisional SSI was -0.21±19.60, superficial normal incision was -51.00±27.35, deep incisional SSI was 19.72±8.40, and deep normal incision. The difference was significantly different. The transverse diameter of the area where CAV changed obviously was a sensitive parameter for diagnosing the infection. From our study, the larger the diameter, the higher the infection rate.

Computed tomography (CT) is currently the most readily available imaging in the work-up of major complications. Therefore CT become more and more common. When the patients accept the CT for the work-up after the colorectal operation, we should take more attention to the image of incision. When the patient has the Risk factors of incisional SSI (such as: high body mass index (BMI), great subcutaneous fat thickness, intraoperative incision contamination, long operation time, or creation of an ostomy), or when the patient's incision shows unnormal (such as: feeling incisional pain and tenderness, the localized incisional swelling and redness, high CRP) after operation, CT is a better choice for the diagnosis of the incisional SSI.

CT combining with puncture is more effective for the diagnosis of the incisional SSI. When we see the area where CAV changed obviously, especially Obvious low density or liquid dark area in the CT image, we can assess the location and depth from the CT image, and use the 5 ml or 10 ml syringe to puncture it.If we can puncture the pus, the infection diagnosis is sure. If we can puncture nothing, but the CT image shows the possibility of incisional infection is high, we should take more attention on the Incision follow-up. In our study, there were 46 cases whoes CT scan showed Obvious low density or liquid dark area, and we used the 5 ml or 10 ml syringe to puncture the low density or liquid dark area under the CT image guiding. 38 (82.6%) cases could be punctured pus. It showed that puncture was effctive for the diagnose of the incisional infection.

There are several limitations to this study. The first limitations is that it is difficult to diagnosis for the infection with CT scan when the pus is little. The second limitations is that the CT scan is a little expensive for the diagnosis of the incisional SSI, especially for the poor country.

In conclusion, this study had demonstrated that testing the incision CAV and the transverse diameter of the area where CAV changed obviously is an effective diagnostic method for the early incisional SSI. CT combining with puncture Contribute to early diagnosis and treatment for the incisional SSI, reduce the pain of patients and medical expenses. A prospective and more detailed investigation is necessary to establish the best strategy for diagnosis of the incisional SSI and minimizes the incidence of I-SSI following colorectal surgery.

Acknowledgements

The present study was supported by the Key Project of Science and Technology Research Program in Fujian Province (no. 2012B002), the Backbone Teacher Project of Fujian Medical University (no. JGG200716), a Ministry of Health Medicine Science and Technology Development and Research grant (no. W2013-FZ08) and the National Clinical Key Specialty Construction Project (General Surgery) of China.

Disclosure of conflict of interest

None.

Address correspondence to: Jianxin Ye, Department of Gastrointestinal Surgery 2 Section, The First Hospital Affiliated to Fujian Medical University, 20 Cha-Zhong Road, Fuzhou 350004, Fujian, China. E-mail: zhuangliu19860129@163.com

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