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Original Article

Surgical strategies for abdominal wall invasion and implantation of colorectal cancer

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Abstract: Background: Abdominal wall invasion and implantation (AWII) of colorectal cancer leads to complex complications and poor prognosis, which has a low efficacious treatment. We present our surgical strategies, which led to a relatively good outcome. Methods: Nineteen cases between February 2006 and July 2018 in our department were enrolled. Operations were divided into extensive resection and palliative resection, which was to eradicate the tumor and to mitigate tumor complications, respectively. The surgical strategies present included reasonable patient enrollment, precise classification of abdominal wall defect and appropriate repair technique for abdominal wall reconstructions. Results: Surgical treatments for AWII of colorectal cancer in our study proved as good methods to mitigate tumor complications and eradicate tumors. The immediate abdominal wall reconstructions were successful in all cases using the reinforcement repair technique (14 cases) and the double patch bridging repair technique (5 cases). Patients with type II abdominal wall defects after tumor resection had shorter operation times, shorter hospital stays and fewer postoperative complications than those with type III abdominal wall defects. The follow-up period ranged from 1 to 40 months. Only two patients developed abdominal wall hernias caused by tumor recurrence. Patients who had undergone extensive resection had a better long term survival time after surgery. Conclusion: Appropriate surgical treatment could be a good choice to prolong survival time and improve the quality of life for patients with AWII of colorectal cancer.

Keywords: Colorectal cancer, abdominal wall invasion, abdominal wall implantation, abdominal wall defect, abdominal wall reconstruction

Introduction

Colorectal cancer is the sixth most common malignancy and the fifth leading cause of cancer-related death in China [1, 2]. Abdominal wall invasion and implantation (AWII) of colorectal cancer have a relatively low incidence and a poor prognosis [3-6], which can cause gastrointestinal obstruction, ulceration in the abdominal wall, wound infection and other complications. Patients suffer severely from these complications, and their quality of life is seriously affected. Moreover, there is a lack of effective treatments or guidelines for such diseases in China and abroad.

This research group has long been engaged in clinical and scientific research on colorectal cancer and abdominal wall defects [7, 8]. Our surgical strategies for AWII of colorectal cancer can benefit certain patients.

Methods

Patients enrollment

Nineteen patients were treated for AWII of colorectal cancer in our department between February 2006 and July 2018. Surgery was approved by the hospital Review Board and the Ethics Committee of the Medical Faculty at the Shanghai Jiao Tong University, China. Inclusion criteria were as follows: (1) Abdominal wall defects with an area ≥ 100 cm^2 after resection of tumors, in accordance with the definition of a large complex abdominal wall hernia [9, 10]; (2) Immediate functional repair of complex abdominal wall defects; (3) Patients had no benefit from chemotherapy, radiotherapy or biological therapy before they accepted the surgery. Exclusion criteria were as follows: (1) AWI-GI patients had an unresectable distant metastasis

beyond the abdominal wall; (2) AWI-GI patients had severe dysfunction of the heart, lung, brain, kidney, bone marrow or other systems, and cannot tolerate long-term surgical treatment; (3) AWI-GI patients had extensive intraperitoneal tumor dissemination with ascites formation.

The clinical data of these 19 cases were recorded (**Table 1**). There were 12 men and 7 women aged from 35 to 82 years (median, 62 years). Patients suffered from tumor complications, such as wound infection (7 cases), intestinal obstruction (2 cases), wound infection plus intestinal obstruction (2 cases) and mobility limitation due to massive abdominal wall tumor (1 case). They all expressed strong surgical intentions and gave consent to undergo surgical treatment.

Resection range and operation purpose

According to a thorough preoperative and intraoperative assessment, including CT, MRI, and in some cases PET-CT, surgery was divided into extensive resection (12 cases) and palliative resection (7 cases). Extensive resection was defined as no tumor remaining either under the naked eye or with microscopy after surgery. The tumor was widely resected in blocks 3-5 cm beyond the margin, and completeness of clearance was ascertained using frozen sections. The purpose of this operation was to eradicate the tumor.

Palliative resection is defined as residual tumor that can be seen at the incisional margin by gross or pathological examination. The purpose of this operation was to solve tumor complications, such as wound infection, intestinal obstruction or mobility limitation caused by massive abdominal wall tumor.

Whether extensive resection and palliative resection was performed depends on the condition of the primary tumor in the abdominal cavity. Extensive resection was performed when the primary tumor was confined to the surrounding mesentery. Otherwise, Palliative resection was taken when the primary tumors invaded important abdominal vessels, such as the portal vein, superior mesenteric vessels and submesenteric vessels or involved the liver, kidney, multi-segmental small intestine, or stomach, etc.

Classification of complex giant abdominal wall defects after tumor excision

The accurate classification of abdominal wall defects is the basis for selecting appropriate surgical procedures and the prerequisite for the evaluation of postoperative efficacy.

The size of the defects after tumor excision ranged from 100 to 450 (mean 260.6 ± 123.4) cm^2. We categorized the defects into three types [7, 8]: type I, defects involving only the loss of skin; type II, myofascial defects with intact skin coverage (13 cases, 68.4%); and type III, myofascial defects without skin coverage (6 cases, 31.6%).

Bounded by lateral borders of the bilateral rectus abdominis and horizontal plane of the umbilicus, abdominal wall defects were divided into three zones in our study: abdominal wall defects in the midline (Zone M), abdominal wall defects in the outer upper quadrant (Zone U), and abdominal wall defects in the outer lower quadrant (Zone L). Then, Zone M was averaged into M_1, M_2 and M_3. All the abdominal wall defects in our research covered more than two zones (**Table 1**).

Technologies used for the repair of abdominal wall defects

Based on many years of treatment experience, the reinforcement repair technique (14 cases) and double patch bridging repair technique (5 cases) were adopted for the patients in this study (Figure S1).

In the reinforcement repair group, we used the repair materials based on the defect type. For type II defects, the defects were repaired by the combined repair technique of patch repair technology and autologous tissue transplantation as follows: biological mesh and components separation technique (CST) (7 cases, 36.8%) (Figure S2); biological meshes and omentum flap (1 case, 5.3%). For type III defects, the biological mesh was used to repair the peritoneum and followed by the tissue flap technique to repair the abdominal wall: biological mesh and advanced skin flap (2 cases, 10.5%); biological mesh, bilateral CST and advanced skin flap (1 cases, 5.3%); biological mesh and free anterolateral thigh flap (ALTF) (1 cases, 5.3%); biological mesh and bilateral pedicled TFL plus ALTF flap (1 cases, 5.3%) (Figure S3); and biological

Table 1. Clinical details of patients in our research

ID	Sex	Age (years)	Tumor pathology	Abdominal wall tumor location	Wound infection	Defect location	Defect size (cm)	Defect type	Reconstruction procedure	Resection	Operation time (minutes)/hospital stay (days)	Tumor free survival (months)	Total survival (months)
1	M	62	Sigmoid colon adenocarcinoma	Left lower quadrant	No	M_3 + left L	10 × 10	II	Underlay HADM + omentum flap	Extensive	360/24	18	28
2	M	57	Rectal adenocarcinoma	Right lower quadrant	No	M_2 + M_3 + right L	20 × 15	II	(SIS + PP mesh) double patch bridging	Extensive	250/23	15	24
3	M	65	Ileocecal adenocarcinoma	Right lower quadrant, primary sinus	Yes	M_2 + right L + right U	10 × 15	II	(SIS + PP mesh) double patch bridging	Extensive	270/19	21	28
4	M	50	Ileocecal adenocarcinoma	Right lower quadrant	No	M_2 + M_3 + right L + right U	20 × 12	II	(Physiomesh + SIS) double patch bridging	Extensive	280/22	20	26
5	F	63	Ascending colon adenocarcinoma	Primary incision	Yes	M_2 + M_3 + right L + right U	20 × 20	II	Underlay SIS + CST	Extensive	310/21	> 30	> 30
6	F	65	Sigmoid colon adenocarcinoma	Left lower quadrant	No	M_2 + M_3 + right L	19 × 13	II	(SIS + PP mesh) double patch bridging	Extensive	220/30	24	30
7	M	35	Ascending colon adenocarcinoma	Primary incision	No	M_1 + M_2 + left U	10 × 10	II	Underlay SIS + CST	Extensive	330/20	21	30
8	F	78	Transverse colon adenocarcinoma	Epigastrium	No	M_1 + M_2	14 × 12	II	Underlay HADM + CST	Extensive	340/21	26	40
9	F	81	Transverse colon adenocarcinoma	Right lower quadrant	No, but limitation of activity	M_2 + M_3 + right L	20 × 20	II	(SIS + PP mesh) double patch bridging	Palliative	280/22	/	9
10	F	73	Rectal adenocarcinoma	Peripheral stoma	No, but intestinal obstruction	M_2 + left L	10 × 10	II	Underlay SIS + CST	Palliative	350/35	/	1
11	M	82	Sigmoid colon adenocarcinoma	Primary sinus	Yes	M_2 + M_3	13 × 17	II	Underlay SIS + CST	Palliative	320/24	/	24
12	M	58	Sigmoid colon adenocarcinoma	Left lower quadrant	Yes, plus intestinal obstruction	M_3 + left L	15 × 11	II	Underlay SIS + CST	Palliative	350/26	/	17
13	F	48	Ascending colon adenocarcinoma	Primary incision	No, but intestinal obstruction	M_3 + right L	15 × 8	II	Underlay SIS + CST	Palliative	370/20	/	20
14	M	66	Transverse colon adenocarcinoma	Primary incision	Yes	M_2 + M_3 + right L	15 × 15	III	Underlay SIS + advanced skin flap + VAC	Extensive	450/61	> 10	> 10
15	M	50	Ileocecal adenocarcinoma	Primary incision	Yes	M_2	15 × 25	III	Underlay SIS + bilateral CST + advanced skin flap + relaxation suture	Extensive	510/50	> 14	> 14
16	M	58	Ascending colon adenocarcinoma	Primary incision	Yes	M_1 + right U + left U	15 × 30	III	Underlay SIS + advanced skin flap + relaxation suture	Extensive	500/60	> 14	> 14
17	F	54	Ascending colon adenocarcinoma	Right up quadrant	No	M_1 + M_2 + right U + right L	20 × 22	III	Underlay SIS + PP mesh + omentum flap + regional rotation flap	Extensive	520/52	> 20	> 20

18	M	54	Rectal adenocarcinoma	Primary incision	Yes, plus intestinal obstruction	$M_2 + M_3 + L$	18 × 25	III	Underlay SIS + bilateral pedicled TFL and ALTF	Palliative	600/32	/	5
19	M	71	Colon adenocarcinoma	Primary incision	Yes	$M_1 + M_2$ + right U	15 × 20	III	Underlay HADM + free ALTF	Palliative	490/48	/	5

PP, polypropylene; HADM, human acellular dermal matrix; SIS, porcine small intestinal submucosa (HADM and SIS are the biological meshes); CST, component separation technique; Physiomesh, a type of anti-adhesion mesh; PCO, a type of anti-adhesion mesh; VAC, vacuum assisted closure; TFL, tensor fasciae latae; ALTF, anterolateral thigh flap.

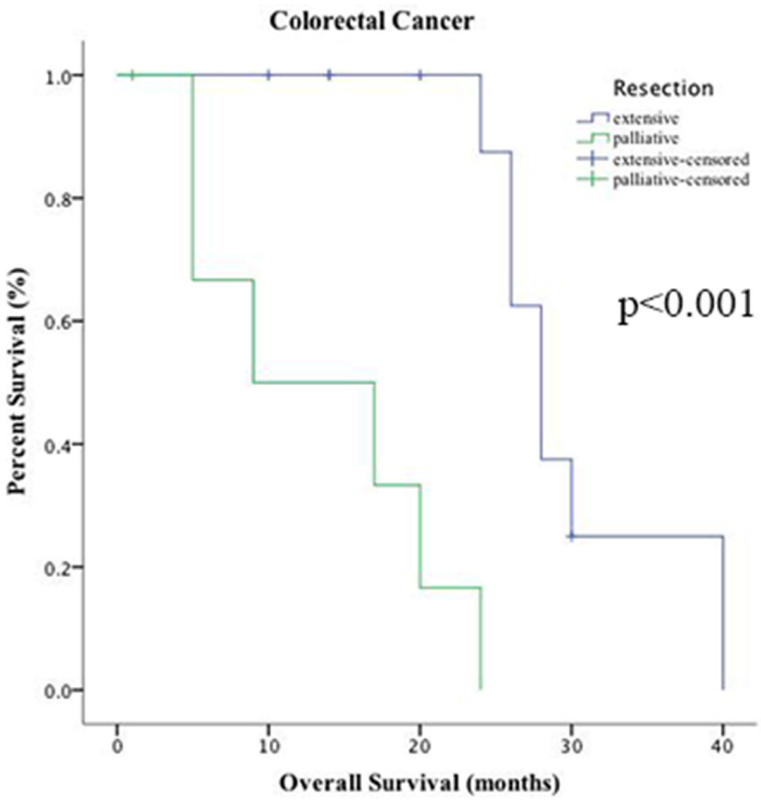

Figure 1. Survival curves of patients with abdominal wall invasion and implantation of colorectal cancer after different tumor resection.

mesh, PP mesh, omentum flap and regional rotation flap (1 case, 5.3%).

The double patch bridging repair technique is a novel improvement of the bridging repair technique, which has not been reported before. Two kinds of patches, biological mesh and synthetic mesh, were placed in a bridging interposition fashion, where the fascia was defect. These patches were directly fixed to the edges of the defects, which were required to cover beyond the edges of the defect by 3 cm. In this research, there were four cases (21.1%) using biological mesh as an under layer and PP patches as an upper layer. Meanwhile, one other case (5.3%) used anti-adhesion mesh as an under layer and biological mesh as an upper layer. These cases were all type II defects (Figure S4).

Statistical analysis

SPSS 13.0 software was used to analyze the data in this study. The Kaplan-Meier method was used for survival analysis. The level of statistical significance was defined as $P < 0.05$.

Results

Surgery was performed successfully in one stage and solved the main problems the patients suffered

Clinical details are listed in **Table 1**. All immediate reconstructions of the abdominal wall were performed successfully after tumor resection. Most patients had a smooth recovery and their main problems such as tumor burden, wound infection, intestinal obstruction or mobility limitation were solved. They could return to normal life.

Patients with type II defects had shorter operation times, shorter hospital stays and fewer postoperative complications than those with type III defects. The average operation time and hospital stay for type II defect group was 310.0 ± 44.5 minutes (from 220 minutes to 370 minutes) and 23.6 ± 4.3 days (from 19 days to 35 days), while it was 511.7 ± 45.2 minutes (from 450 minutes to 600 minutes) and 50.5 ± 9.6 days (from 32 days to 61 days) for the type III defect group.

The short-term complications in the type II defect group included one patient dying from surgery-related abdominal infection and myelosuppression and one patient developing a seroma. However, group III included one patient developing intestinal anastomotic leak and four patients suffering flap necrosis combined with infection in patients with type III defects. These complications were cured through drainage, debridement, vacuum assisted closure or tissue flap repair.

The long-term complications included two patients developing abdominal wall hernias at 26 months and 12 months caused by tumor recurrence, respectively. Other patients had no signs of herniation or AWII recurrence.

Extensive resection could prolong survival time of patients

The medium survival time of patients in the extensive resection group was 26 months (from 2 months to 40 months) compared to 9 months (from 1 month to 24 months) in the palliative resection group. Survival statistics revealed that patients in the extensive resection group had a significantly longer survival time (X^2 = 19.548, P < 0.001) (**Figure 1**).

There was no significant different of tumor free survival between type II defects and type III defects in the extensive resection group (X^2 = 0.434, P = 0.510).

Discussion

Characteristics of AWII of colorectal cancer

AWII assumes a variety of morphological appearances, with single or multiple violet to flesh-colored, firm, freely mobile, painless nodules on the skin [11, 12]. Subcutaneous metastatic lesions are the most common phenotype and some masses present as inflammation or ulcers [4-6, 13]. In our study, all the abdominal metastases were adenocarcinoma, with partial mucous adenocarcinoma and signet-ring cell carcinoma, which was in accordance with the primary cancer types. Tumors were moderately differentiated or poorly differentiated, but none were well differentiated. The time of AWII formation after primary surgery ranged from 2 weeks to 3 years. However, the vast majority of cases developed within 1 year.

The exact cause of abdominal wall tumor secondary to colorectal cancer remains unclear; however, iatrogenic implantation, direct invasion, lymph node metastasis and blood supply may be the main causes [14-17]. According to our study, iatrogenic implantation and direct invasion are the two leading reasons. Among the 19 cases, 8 cases (42.1%) were considered to be iatrogenic implantation. Four cases (21.1%) were considered to be direct abdominal wall violation of malignancies. Two cases (10.5%) were confirmed as recurrent tumors violating the abdominal wall. The other five cases (26.3%) had no clear cause of disease. Therefore, the principles of tumor-free surgery should be strictly adhered to in order to reduce the incidence of iatrogenic implantation [18].

Surgical strategies for AWII of colorectal cancer patients

At present, treatment on AWII of colorectal cancer mainly depends on palliative methods such as symptomatic treatment, chemotherapy, radiotherapy and so on. However, the overall prognosis of such patients is not ideal. The treatment concept of AWII is now changing and more and more reports can be found with surgical treatment of AWII [19-25].

In our study, patients in the extensive resection group had a significantly longer survival time. In terms of patients in the palliative resection group, the main problems of disturbance to them were resolved, which improved the quality of life and preserved the dignity of the patients. Furthermore, the prognosis may be better if the patients undergo surgery earlier. For case 18, the gentleman endured AWII of rectal cancer 21 years before accepting surgical treatment by our department, although he saw a number of doctors already. The extensive resection of AWII may cause huge abdominal wall defects, however, it is necessary. In our research, with the exception of two patients who developed abdominal wall hernias at 12 months and 26 months, other patients had no signs of herniation or AWII recurrence. By contrast, patients developed AWII recurrence in 2 weeks, 3 months, 4 months, 5 months and 9 months, respectively, after AWII local excision in other hospitals before coming to our department (data not shown).

Immediate functional reconstruction of the abdominal wall after extended resection of AWII of colorectal cancer

A full evaluation of the general condition and previous medical history of patients should be made before surgery. Accurate classifications and zones of abdominal wall defects after tumor resection are very important. The principles of abdominal wall defect repair can be summarized into two categories: reinforcement repair technique and bridging repair technique.

The reinforcement repair technique was mentioned many times in our previous paper and other reviews [7, 8, 26-28]. Furthermore, we defined a novel improvement of the bridging repair technique, which is called the double patch bridging repair technique. The biological patch, which can promote the growth and self-

organization, will be replaced by self-organized tissues eventually. The tension stress of the synthetic patch is strong and the synthetic patch cannot be absorbed. The combination of these two patches avoids the high recurrence rate of hernias, which is a disadvantage of the bridging repair technique. In our study, five cases underwent this method and presented with no hernia in the follow up. We believe that this technique is simple, easy to teach, has a short learning curve, short operative time, and causes few complications. In addition, the present data has demonstrated promising curative effects. This technique is suitable for elderly and infirm patients in a poor general condition, as well as for hospitals that lack experience on flap techniques. However, the long-term effects of the double patch bridging repair technique need to be verified through large-sample cases.

Conclusions

Surgical treatment for AWII of colorectal cancer could be a good choice, which depends on the problems suffered by patients, in terms of whether to eradicate the tumor or to solve complications of the tumor. The appropriate surgical treatment may prolong survival time and improve the quality of life for patients with colorectal cancer.

Acknowledgements

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Disclosure of conflict of interest

None.

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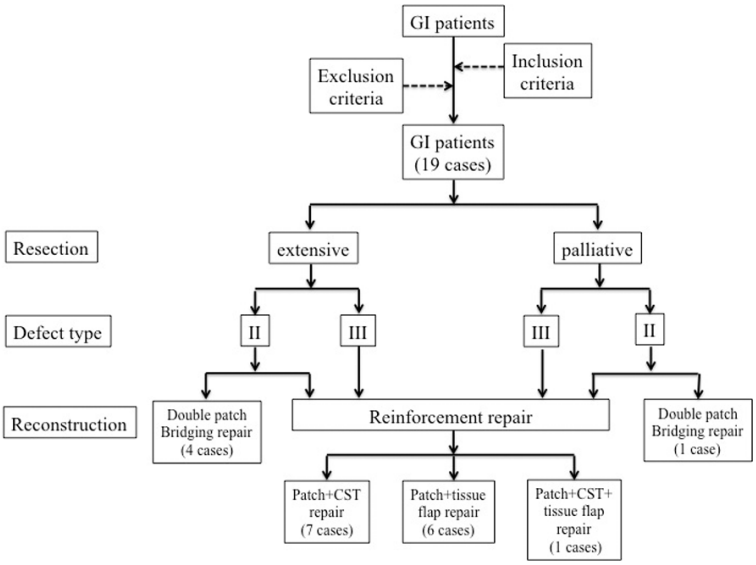

Figure S1. Graphical abstract for patients included and methods applied.

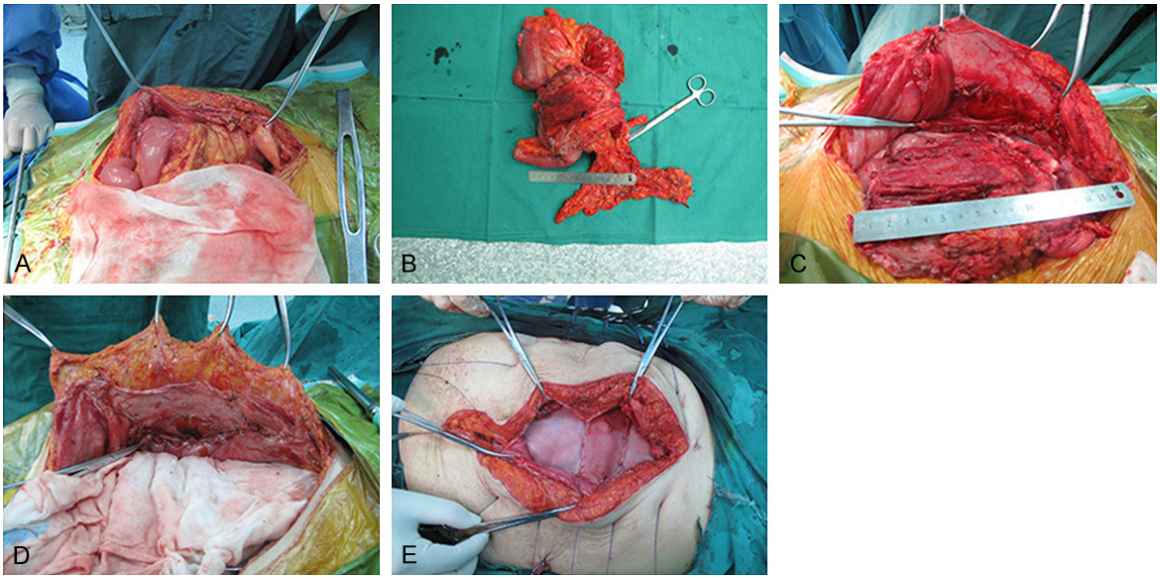

Figure S2. Combined repair technique of biological patch and components separation technique (case 8, type II defect). Note: a 78-year-old women saw a doctor due to "masses on the middle-upper abdominal wall". Further examination revealed the abdominal metastasis was from colon cancer. A large mass with a size of 10 × 8 × 8 cm was observed on the transverse colon near the hepatic flexure of the colon during surgery, which infiltrated into the peritoneum and rectus abdominis (A). Radical enlargement surgery (extensive resection) of the carcinoma of the transverse colon was performed (B). Type II abdominal wall defect with a size of 14 × 12 cm was created (C), and then was repaired using the combined repair technique of biological patch (HADM, underlay) and CST (D, E). The patient had a smooth recovery. Recurrence of abdominal tumors invading the abdominal wall caused an abdominal wall incisional hernia 26 months later.

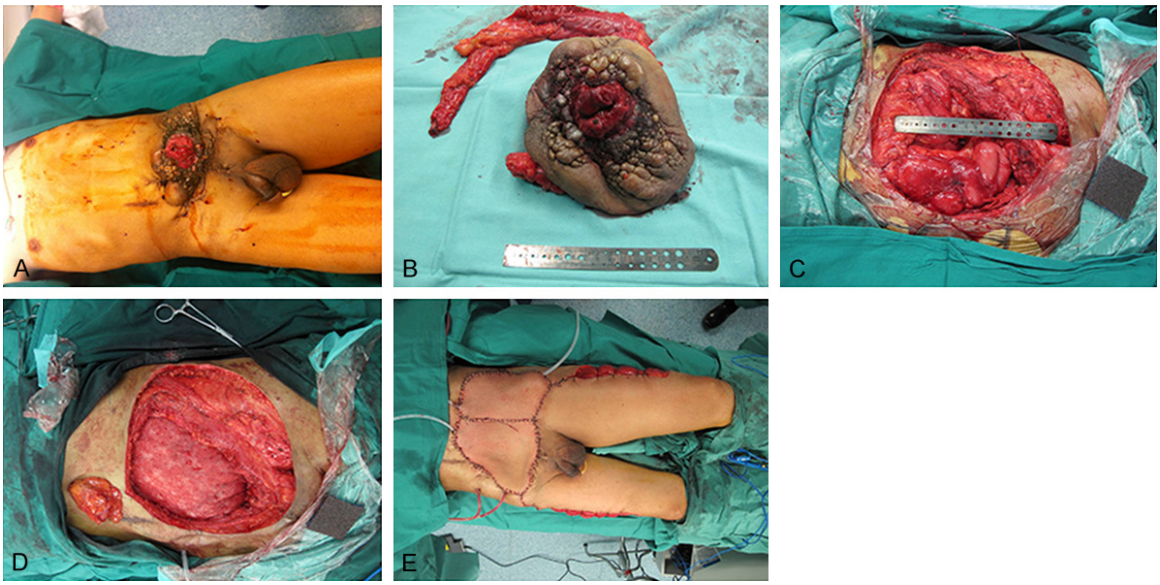

Figure S3. Combined repair technique of biological patch and tissue flap (case 18, type III defect). Note: A 54-year-old man underwent radical resection of a rectal carcinoma (Miles resection) in 1990. Tumor growth began to occur around the stoma three years after surgery and increased rapidly, combined with tingling and defecation difficulties one year before hospitalization. The biopsy revealed a poorly differentiated adenocarcinoma and the PET-CT indicated that lymph node metastases had occurred in the retroperitoneum and the left groin. The masses were not responsive to chemotherapy. The examination performed in our hospital revealed that there were dozens of masses with a hard texture and no swelling around the stoma of the sigmoid colon (A, B). During surgery, it was found that the mass was approximately 22 × 16 × 8 cm and invaded outward to the iliac spine, and downwards to the symphysis pubis. Several enlarged lymph nodes were found in the root of the mesentery. Palliative resection was performed, and the location of the colostomy was changed. Type III abdominal wall defect with a size of 18 × 25 cm was created (C), and then was repaired by the combined repair technique of biological patch (SIS, underlay) and bilateral pedicled TFL plus ALTF flap (D, E). The patient had a smooth recovery, but died of pulmonary metastasis due to rectal carcinoma without hernia 9 months later.

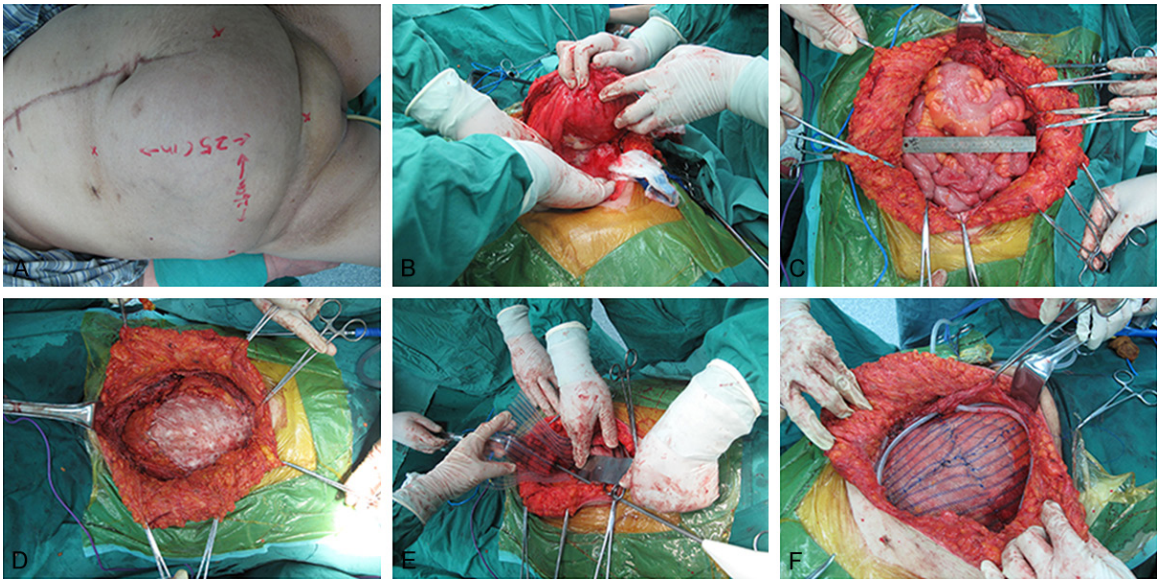

Figure S4. Double patch bridging repair technique (case 9, type II defect). Note: Palliative resection of the tumor was performed 31 months after primary surgery due to activity limitation caused by a recurrent huge mass (A). A large mass with a size of 25 × 25 × 13 cm was observed in the abdominal cavity during surgery, and had widely infiltrated into the peritoneum, rectus abdominis and symphysis pubis (B). Type II abdominal wall defect with a size of 20 × 20 cm was created (C). The double patch bridging repair technique was used to repair defects (SIS were inlaid in the under layer, and PP patches with large meshes were inlaid in the upper layer) (D-F). The patient had a smooth recovery, but died of primary tumors without hernia 9 months after the second surgery.