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ORIGINAL ARTICLE

Abdominal wall reconstruction following resection of large abdominal aggressive neoplasms using tensor fascia lata flap with or without mesh reinforcement

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Abstract

Purpose Abdominal wall defects caused by neoplasms with large extended resection defects remain a challenging problem. Autologous flaps, meshes, and component separation techniques are effective in reconstructing these defects. We retrospectively reviewed and assessed the success of reconstruction using tensor fascia lata flap with or without meshes.

Methods 18 patients with abdominal wall neoplasms were identified during the period from 2007 to 2016. A retrospective review of office charts and hospital records was performed.

Results A total of 18 patients received corresponding treatment according to the degree of defects, with a mean age of 53.89 ± 14.56 years old, a mean body mass index (BMI) of 22.89 ± 4.09 kg/m^2, and a mean American Society of Anesthesiologist (ASA) score of 2.18 ± 0.75. Operative details included the mean defect size (303.44 ± 175.67 cm^2), the mean mesh size (265.92 ± 227.99 cm^2), and the mean operative time (382.33 ± 180.38 min). Postoperative wound complications were identified in 7 (39%) patients, including incisional infection, edema and thrombus. Neoplasm recurrence was observed in 2 (13%) primary neoplasms patients. No hernias were present in any patient.

Conclusions Abdominal wall defects caused by neoplasms should be repaired by autologous flaps combined with or without mesh reinforcement. Most type I defects should be primary sutured; type II or III defects should be repaired well by flaps, with or without mesh; if the incision is infected or contaminated, biological mesh or flaps are the best choice.

Keywords Abdominal wall defeats · TFL flap · Synthetic mesh · Biomaterial mesh

Introduction

Abdominal wall neoplasms are not only found in skin, subcutaneous tissue, muscles, fascia, and peritoneum, but also can be caused by direct spreading from gastric, gallbladder, and colorectal carcinomas. Neoplasms can be classified into benign, borderline, and malignant according to the pathological morphology. Fibromas, lipomas, and hemangiomas are the most common benign tumors, found in 26–40% of abdominal wall tumors. Malignant neoplasms, including fibrosarcomas, leiomyosarcomas, and lymphangiosarcomas, originate from soft tissue mesenchymal sarcomas (STSs) and account for 5% of abdominal wall neoplasms and 1% of all tumors [1]. The biological characteristics of borderline neoplasms, which fall somewhere between benign and malignant, include a lack of encapsulation, invasiveness, and slow growth that rarely result in distant metastases. Desmoid tumors and dermatofibrosarcoma protuberans are two common types of borderline neoplasms. Currently, surgery is the main treatment for abdominal wall neoplasms, and when defects are too large after tumor excision, surgeons should repair the abdominal wall defects using mesh reinforcement, component separation techniques (CST), or autologous flap repair to achieve a better result for the patients.

Autologous flaps, such as transverse rectus abdominis myocutaneous (TRAM) and tensor fascia lata (TFL) are common techniques for reconstructing abdominal wall defects. Among these, TFL is the most common muscle flap procedure, which can cover a donor area up to 40 × 25 cm^2. It eliminates complications and makes it good for abdominal wall defect repair. However, the recurrence rate of hernia

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using TFL alone is up to 40% because of the poor mechanical strength of the tissue [2]. Therefore, in clinical practice, we combine autologous flap repair with prosthetic or biological materials to increase the mechanical strength of abdominal wall, and reduce the risk of postoperative hernia.

Mesh plays important roles in the process of reconstruction of the abdominal wall. Polypropylene (PP) could significantly reduce the recurrence; however, its non-absorbable characteristic can cause infection and chronic pain in some situations [3, 4]. It can even cause serious complications, such as bowel adhesion, obstruction, and fistula formation [5–7]. Therefore, composite mesh or biological mesh is more often used in abdominal wall reconstruction.

Compared with prosthetic mesh, biological mesh offers better biocompatibility and reduced susceptibility to infection. In the United States, biological mesh, such as pig small intestinal submucosa (PSIS), pig skin acellular dermal matrix (PADM) and human skin acellular dermal matrix (HADM) have been available for over 10 years for use in abdominal wall reconstruction, and each material shows promising results in the repair of these defects. Because acellular mesh, both SIS and ADM, are mainly comprised of collagen, which provides a three-dimensional structural environment allowing adhesion, growth, and migration of the host cell. Many glycoproteins and proteoglycans in SIS contain specific sites on their protein portions that facilitate host-derived cell attachment within the three-dimensional structure, and thereby contribute to the repopulation of the matrix and the cellular processes necessary for remodeling into mature functional tissue. ADM has also been promoted to encourage collagen deposition and neovascularization, which potentially reduces infection rates [8] and are widely used in treatments of recurrent hernias, dural repair, and abdominal wall reconstruction [9–11].

Given the advantages above, SIS and ADM mesh are often combined with synthetic meshes to repair abdominal wall defects, especially for complex cases with or without infection.

In our study, 18 TFL flaps with or without mesh were used to reconstruct full-thickness abdominal wall defects caused by abdominal wall neoplasms. Our patients had favorable results during follow-up; so, we herein gathered and assembled our experiences.

Patients and methods

We retrospectively reviewed 18 patients with aggressive neoplasms invading abdominal wall partially or fully. Between March 2007 and October 2016, the patients underwent radical resection with a one-stage abdominal wall reconstruction using a TFL flap. All patient information was retrospectively collected in a record review, including basic patient information, preoperative examination, surgical treatment, pathological results, and postoperative results (general complications, length of stay, and long-term follow-up).

Preoperative examination

Computed tomography (CT) offers a clear delineation of the size of defect, surrounding organs, the extent of invasion into adjacent vital structures, and the presence of enlarged lymph nodes. Therefore, CT scans should be conducted for every patient. Magnetic resonance imaging (MRI) is not ideal because it is less capable of delineating tumors originating from the abdominal wall.

Preparation of TFL and operative details

According to CT results, we precisely described the location, size, and degree of the abdominal wall tumor using our previously described classification standards [12]. Patients were intubated under general anesthesia and placed in the supine position with a Foley urethral catheter inserted. A circumferential mark was made both around and 3 cm over the border the abdominal wall tumor. We then measured the maximum and minimum diameters of the oval mark and marked the same size onto the projection plane of the TFL flap on the same side of the tumor. If the tumor was located in the lower abdominal wall, creating a pedicle TFL flap achieved better reconstruction results than other flaps. After completing extensive full abdominal wall resection, the pedicle TFL flap should be separated entirely, including the skin, fat tissue, muscle, and fascia.

A circumferential incision was made into the deep fascia and the lateral circumflex femoris artery was found where it passes between the rectus femoris and the vastus lateralis, at the point where it spreads to the transverse branch and pierces the TFL muscle. The large perforating vessel traversing the vastus lateralis muscle was dissected back to its origin from the descending branch of the lateral circumflex femoral artery, which created a vascular pedicle (approximately 14 cm long). This was followed by dividing the iliotibial tract distally and raising of the fascia lata and vastus anterolateralis muscle from the underlying muscles using proximal progression. Finally, the pedicle was separated after confirming its viability [14]. To avoid displacement between different layers, the side of the flap was sutured. After the ascending branch of the lateral femoral circumflex artery was carefully separated, the abdominal wall defect was repaired using the pedicled flap; the range was from the start of the blood vessel to the center of the tumor, and the angle was at a 100°–180° rotation.

Postoperative follow-up

Postoperative data were obtained through telephone follow-ups and evaluations were performed using a standardized questionnaire with patients. Patients with any syndromes or complications were encouraged to return to the clinic for a further examination. Hernia recurrences were defined by self-report of the hernia repair site, physical examination, and CT scan.

Data analysis

Continuous and categorical variables were summarized using means (standard deviations) or number (percentage). *T* tests and Chi-squared tests were used when appropriate. Data analysis was carried out using SPSS 20.0 software. A *P* value of less than 0.05 was considered statistically significant.

Results

Preoperative characteristics

In this study, 18 patients underwent radical tumor excision and immediate abdominal wall reconstruction. 7 of 18 patients were female. The mean age of all patients was 53.89 ± 14.56 years old, and the body mass index (BMI) was 22.89 ± 4.09. In addition, the mean American Society of Anesthesiologist (ASA) score was 2.18 ± 0.75 (Table 1).

Perioperative outcomes

The mean size of the abdominal wall neoplasm was 201.39 ± 197.18 cm^2, which induced an area of abdominal wall defects of approximately 303.44 ± 175.67 cm^2. A mean mesh size of 265.92 ± 227.99 cm^2 was used to repair abdominal wall defects, and the mean operative time was 382.33 ± 180.38 min. The primary surgical treatment was extensive full abdominal wall resection combined with synthetic or biological mesh repair or related flap transplantation. The details of surgical treatment, mesh types, and pathology results are described in Table 1.

Postoperative results

During the study period, the mean hospital stay and follow-up time of all patients was 32.72 ± 7.11 days and 22.8 ± 34.38 months, respectively. (The longest follow-up time is 87 months). All patients underwent extensive resection and flap transfer and some patients involved in multiple organ resection or incisional infection before surgery causes the long hospital stays (Table 1). Two patients developed neoplasm recurrence. One patient developed a recurrence 20 months postoperatively and received secondary surgery with extensive tumor resection with biological mesh and a latissimus dorsi flap. However, the patient unfortunately developed another recurrence after 48 months, and the family withdrew treatment. The other patient developed a neoplasm recurrence 5 months postoperatively and received secondary surgery with extensive tumor resection with synthetic and biological mesh. 9 of 13 primary abdominal wall neoplasm patients died. The mean survival time was 22.80 ± 24.38 months. Five patients had secondary abdominal wall neoplasm and three died because the primary tumor included gallbladder and colon cancer. The mean survival time was 14.22 ± 10.76 months.

Case 1

A 50-year-old man suffered from a recurrent schwannoma in the right back for 10 years, and underwent six abdominal wall tumor resections in a local hospital. At the time of examination, the tumor was approximately 6 × 5 × 4 cm, and had invaded the fatty tissue around the kidney and intercostal space between the 9th and 10th ribs. With the help of a chest team, we undertook an extensive resection resulting in a 9 × 8-cm abdominal wall defect. We chose biological mesh and free TFL flaps to reconstruct and repair the defect, which healed 2 weeks after flap transplantation. His condition remained favorable without postoperative complications at follow-up of 4.5 years after surgery (Fig. 1).

Case 2

A 44-year-old man who had had a gallbladder carcinoma excised 1 month previously presented with abdominal wall metastasis. The tumor was approximately 10 × 10 × 5 cm, and had invaded a 5 × 5 × 6-cm volume of liver. The range of the operation was 5 cm over the tumor's edge and the left lobe of the liver. Wide excision resulted in a right upper abdominal wall defect measuring 20 × 20 cm. Two sheets of 10 × 8-cm human acellular dermal matrix (ADM) were sewn together and inserted as an underlay patch, and covered with a right anterolateral thigh (ALT) flap. The patient recovered uneventfully and received chemotherapy. However, the patient died 15 months after surgery because the gallbladder carcinoma had metastasized to other tissues (Fig. 2).

Discussion

Abdominal wall defects are caused by events such as trauma, infection, surgery, and abdominal wall neoplasms. The best treatment method is aggressive resection with adequate clear margins, which may generate a large, complex abdominal

Table 1 Patient characteristics, surgical procedure, and outcomes

Case	Sex	BMI	ASA	Infection before surgery	Defect size	Operative time	Hospital stay	Surgery treatments	Pathologic types	Complications
1	F	21.77	3	No	270	435	29	Tumor extensive resection + prosthetic mesh + TFL + skin transplantation	Dermatofibrosarcoma	Primary tumor death
2	M	25.3	2	No	400	430	36	Tumor extensive resection + HADM + TFL + skin transplantation	Malignant schwannoma	Primary tumor death
3	M	20.3	3	Yes	300	720	50	Infection extensive resection + TFL	Metastatic adenocarcinoma	Incisional infection after surgery and secondary tumor death (exist infection preoperative)
4	M	22	3	No	208	660	27	Tumor extensive resection + TFL	Dermatofibrosarcoma	Incisional infection and dressing change 3 months
5	M	21.8	3	No	160	255	26	Tumor extensive resection + TFL + skin transplantation	Dermatofibrosarcoma	Primary tumor death
6	F	22.2	2	Yes	784	285	32	Tumor extensive resection + HADM + TFL	Dermatofibrosarcoma	Incisional infection after surgery and primary tumor death (exist infection preoperative)
7	F	21.6	1	No	301	345	39	Tumor extensive resection + HADM + TFL	Dermatofibrosarcoma	Incisional infection and dressing change 7 months
8	M	28.7	2	No	72	185	45	Tumor extensive resection + ribs resection + PSIS + TFL	Dermatofibrosarcoma	Thrombus of leg and edema recovery three months later
9	M	20.1	2	Yes	400	190	33	Tumor extensive resection + TFL	Metastatic adenocarcinoma	Primary tumor death
10	M	20.9	2	Yes	126	345	22	Tumor extensive resection + TFL	Squamous carcinoma	Primary tumor death
11	M	21.3	3	Pus	378	300	33	Tumor extensive resection + HADM + TFL + skin transplantation	Dermatofibrosarcoma	Incisional infection after surgery and primary tumor death (exist pus preoperative)
12	F	25.1	3	Yes	143	120	24	Tumor extensive resection + ribs resection + PSIS + TFL	Dermatofibrosarcoma	Normal

Table 1 (continued)

Case	Sex	BMI	ASA	Infection before surgery	Defect size	Operative time	Hospital stay	Surgery treatments	Pathologic types	Complications
13	F	22.2	2	Yes	374	382	30	Tumor extensive resection + prosthetic mesh + TFL	Clear cell carcinoma	Incisional infection after surgery and primary tumor death (exist infection preoperative)
14	M	22.1	1	No	475	590	30	Tumor extensive resection + PSIS + TFL	Metastatic adenocarcinoma	Primary tumor death
15	F	20.5	2	Yes	225	700	33	Tumor extensive resection + ribs resection + PSIS + TFL	Metastatic adenocarcinoma	Secondary tumor death
16	M	21.3	1	Yes	162	205	36	Tumor extensive resection + TFL	Skin Bowen's disease	Normal
17	M	22.2	3	Yes	378	390	33	Tumor extensive resection + TFL + HADM + skin transplantation	Dermatofibrosarcoma	Normal
18	F	20.4	3	Pus	270	345	31	Tumor extensive resection + PSIS + TFL	Dermatofibrosarcoma	Normal

wall defect. If the neoplasm invades surrounding tissues, such as bone, large vessels, or organs, especially when combined with infection or heavy contamination, the defect can be even greater. In such cases, reconstruction becomes extremely complex, presenting a formidable challenge for surgeons. Generally, large defects (> 6 cm in diameter) should be reconstructed using synthetic or biological mesh or autologous flaps [13] In our study, 12 patients used the mesh and 6 patients did not. According to our surgical treatment proposal (Fig. 3), not all abdominal wall defects require mesh placements. Moreover, both the size of the defect and the type of the flap should be considered during reconstruction. When the defects are small, the application of a flap alone can provide sufficient mechanical strength for repair.

Polypropylene (PP), a typical synthetic material, can dramatically reduce the rate of hernia formation by providing sufficient strength for an abdominal wall repair [3, 4]. It bridges the defect and allows a low-tension or tension-free repair because of its stability, strength, inertness, and handling characteristics. However, synthetic mesh can lead to serious complications, such as infection, chronic pain, and bowel adherence or even obstruction [5, 6, 14, 15]. In particular, when a synthetic mesh is applied to contaminated wounds, its removal is required in 50–90% of cases [16]. In addition, when placed in contact with the bowel, the PP mesh tends to promote adhesions to the bowel, which sometimes result in fistula formation. Therefore, many meshes have been developed by encapsulating a bio-resorbable layer to physically separate the PP mesh from the underlying tissue and organ surfaces, thus minimizing tissue attachment and reducing adhesions.

The introduction and recent popular use of biological mesh consisting of human (allograft) and animal (xenograft) products have given the surgeon an alternative for hernia repair. Many studies have reported that there is enough clinical evidence to support biological meshes being used safely with a lower recurrence rate of infected or contaminated fields where synthetic meshes are contraindicated [17]. Thus, the use of biological mesh in these types of repair has become the preferred method. Biological mesh consists of an extracellular collagen matrix that gradually resorbs and remodels, and deposits new collagen and regenerates tissue. During this process, these biological meshes are thought to offer a collagen framework to allow cellular regeneration, neovascularization, and potentially fascial replacement [18]. Commercially available biological mesh for abdominal wall reconstruction can be derived from human and porcine dermis, porcine small intestinal submucosa, or bovine pericardia. According to the literature, porcine small intestinal submucosa (SIS) and human acellular dermal matrix (ADM) meshes have been commonly and successfully used for abdominal wall reconstruction with successful hernia repair and resistance to infection in contaminated fields

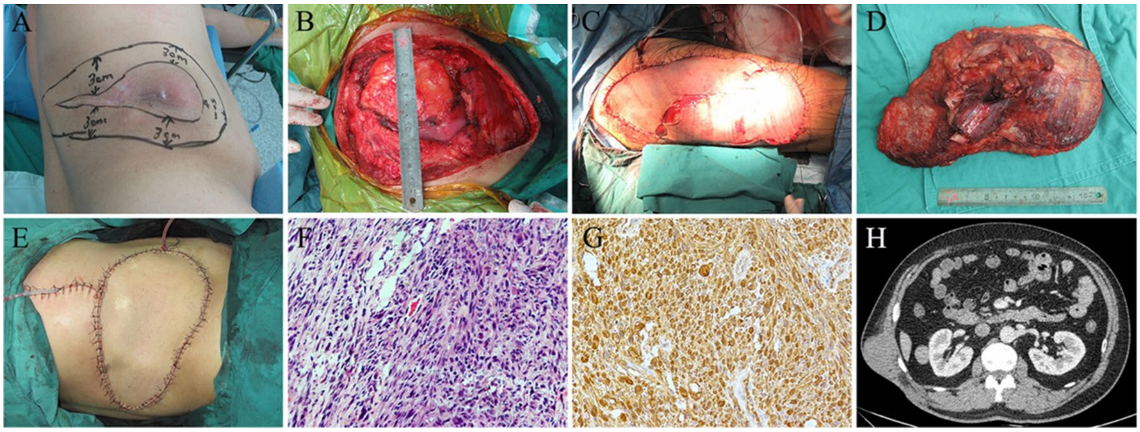

Fig. 1 The reconstruction of abdominal wall defect (type III) caused by primary abdominal wall neoplasm. **a** The primary abdominal wall neoplasm in right lumbar with one tube operated in local hospital; **b** the abdominal wall defect about repaired with biological mesh; **c** the free tensor fascia lata flap was achieved and preparing to reconstruct the abdominal wall. **d** Extensive resection abdominal wall neoplasm; **e** reconstructing the abdominal wall; **f** HE staining of abdominal wall neoplasm and showed necrotic tumor cells; **g** immunohistochemical (Ki 67) staining of abdominal wall neoplasm; **h** CT examination results of abdominal wall neoplasm

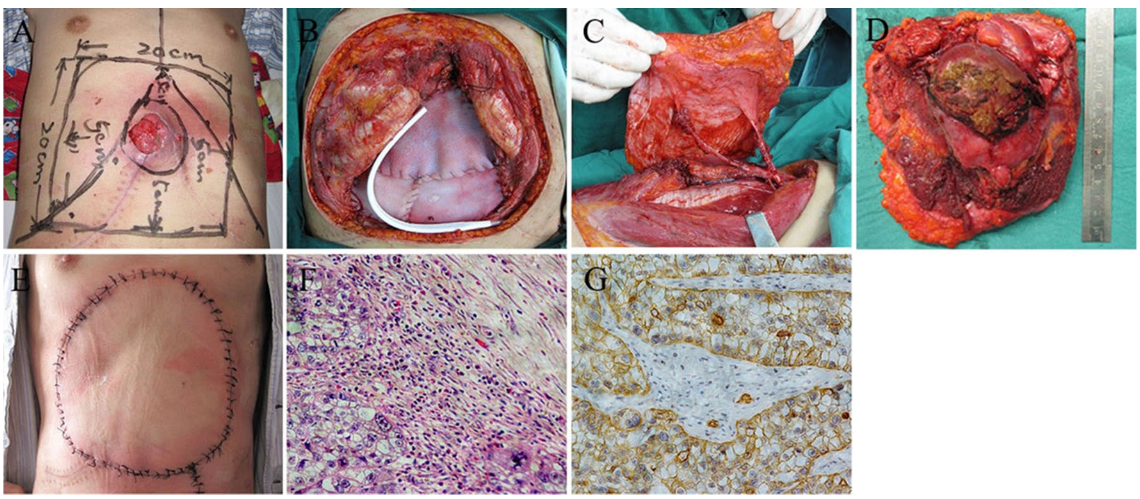

Fig. 2 The reconstruction of abdominal wall defect (type III) caused by secondary abdominal wall neoplasm. **a** The secondary abdominal wall neoplasm in upper abdominal wall; **b** the abdominal wall defect was repaired by biological mesh after extensive resection; **c** the pedicled tensor fascia lata flap was achieved and preparing to reconstruct the abdominal wall. **d** Extensive resection abdominal wall neoplasm; **e** reconstructing the abdominal wall with TFL flap 1 month; **f** HE staining of abdominal wall neoplasm and showed the tumor cells and the invasion of the liver tissue; **g** immunohistochemical (CK) staining of abdominal wall neoplasm; **h** CT examination results of abdominal wall neoplasm

[19]. Helton et al. reported a retrospective case series of 53 patients having eight-ply SIS mesh repair or ventral abdominal hernia in clean, clean-contaminated, and dirty fields with a mean follow-up of 14 months. There was a 17% recurrence (78% in dirty wounds), 11% mesh reaction, and 21% partial dehiscence rate, which concluded that SIS was safe for clean and clean-contaminated hernia repair [20]. Garvey et al. conducted a retrospective study to evaluate the safety and efficacy of abdominal wall reconstruction using ADM in 359 patients. There were no significant differences between clean and combined contaminated cases with regard to surgical site infection (8.8 vs. 8.0%), hernia recurrence (9.9 vs. 10.1%), and mesh removal rates (1.2 vs. 1.1%) during follow-up over a 9-year period [21]. These data support the use of biological mesh and suggest that it may offer better safety and efficacy in reconstructing abdominal wall defects with clean or clean-contaminated wounds, while worse results are obtained with contaminated or dirty-infected wounds. In this study, PSIS and HADM were used in 10 patients, 7

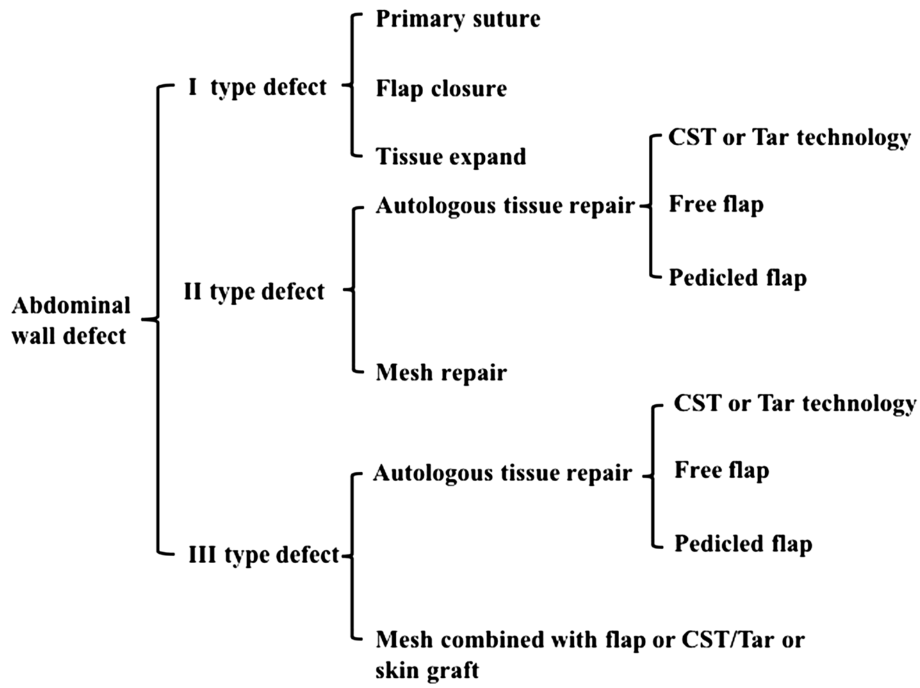

Fig. 3 Surgical treatment proposal of abdominal wall defect

of whom had incisional infection before surgery; only one patient caused incisional infection.

The abdominal wall is a multilayered structure composed of several different tissues. Therefore, defects can be quite diverse. We categorized the defects into three types, according to the defective components of the abdominal wall. Most type I defects were easily repaired, and none of these cases are described in this article. A type II defect was caused by a defect of the myofascial layer, which is the major supportive part of the abdominal wall, necessary to protect the abdominal contents and allow dynamic function. Many methods, including synthetic or biological mesh, autologous flaps, and CST techniques, can be chosen for reconstruction. We believe that mesh should be the base of the CST or flaps. If mesh is used, especially synthetic mesh, the rate of hernia formation is significantly lower; however, a synthetic mesh is not suitable for contaminated or dirty wounds because of the high complication rates in a chronic situation with sinus formation or loss of the synthesis. In contrast, biological mesh and/or an autologous flap are/is the best choice for contamination cases. No hernia or incisional hernia was observed in these patients because of the short follow-up time (22.8 ± 34.38 months). In our experience, synthetic mesh achieved sufficient mechanical strength to restore abdominal wall integrity and prevented hernia formation or bulging of the intra-abdominal contents. Biological mesh, as an extracellular matrix, is shaped and transformed continually within the body to maintain the function of the abdominal wall.

There are two ways to reconstruct an abdominal wall defect with mesh: the suture bridge technique, and the mesh reinforced technique. Both are recommended for all kinds of defects because of lower recurrence rates and less incision complications. Deerenberg has reported that mesh reinforced techniques to repair incisional hernia displayed better recurrence rates (< 3.6%) and hazards (< 0.5%) than techniques without mesh reinforcement (12–44%) by 55 articles and 3954 incisional hernia repairs [22]. In our study, the suture bridge technique was used for three patients because of large defects covering nearly the entire abdominal wall (425 ± 43.3). Regardless of the CST, abdominal organ resection or other methods, it is impossible to close the defect. In a large abdominal wall defect such as this, the only way is to use the suture bridge technique to repair the defect.

Generally, we placed different tubes in different locations during the operation to achieve sufficient drainage. One tube was placed in the pelvic cavity, two tubes were located between the synthetic and biological mesh, and one tube was located above the biological mesh. If the peritoneal defect is repaired with biological mesh, then one tube should be placed above the mesh. If the subcutaneous tissue is extensively manipulated or CST is performed during the operation, one or two tubes should also be placed. Adequate drainage is very important for patients with mesh or flaps, and reduces the risk of postoperative infection. In our study, two patients with hematomas ultimately developed wound infections, mostly because the large defect caused relatively inadequate drainage. The onlay (placing the mesh above the rectus muscles and anterior sheath), sublay (placing the mesh under the rectus muscles and anterior to the posterior sheath and peritoneum), and intraperitoneal onlay mesh (IPOM) (placing the mesh under the peritoneum inside the abdominal cavity) methods can also be used for repairs. Successful repair requires effective mesh bridging or augmentation of the abdominal wall. De Vries Reilingh et al. retrospectively reviewed midline incisional hernia repair performed on 53 patients using either open inlay, sublay, or onlay techniques. They observed that the onlay technique had significantly more complications, while the inlay mesh technique should be avoided because of the higher reherniation rate (44, 12, 23%). Thus, the underlay technique seemed to be the best technique [23]. Eriksson et al. [24] analyzed 14 studies and showed the results of giant incisional hernias after repair and found that the inlay technique and repair without a mesh should be avoided, and mesh augmentation was preferable in the sublay position.

Type III abdominal wall defects, both myofascial and skin coverage defects, should be repaired by myocutaneous flap, such as TFL, latissimus dorsi flap, external oblique flap, internal oblique flap, rectus femoris flap, or omental flap. The latissimus dorsi flap is widely used for breast or chest wall reconstruction; internal oblique flaps are small, and dissection can be bloody and tedious [25]. Rectus femoris flaps may cause significant knee weakness [26]. TFL is the most often used and is the most appropriate flap for abdominal wall reconstruction because of two advantages: its collagen fibers are strong enough to resist intra-abdominal pressure, and the skin and muscle can cover defects with full blood supply and nerve distribution. Fast revascularization and preservation of its physical properties after implantation make it nearly ideal for fascial substitute. Although the wound complication rate was high, up to 40%, no graft was lost and the recurrence rate was similar to CST [27]. However, the abdominal wall defects caused by extended resection of the tumor were usually too large for one flap to repair. Therefore, the denervated muscle cannot resist the intra-abdominal pressure, which results in bulging of the abdominal wall over time, and application of muscular flaps alone for large abdominal wall defects is not advised.

Overall, in our opinion, most type I defects should be primary sutured; type II or III defects should be repaired well by flaps, with or without mesh; if the incision is infected or contaminated, biological mesh or flaps are the best choice. Given the nature of abdominal wall tumors, especially for secondary tumors, the mean survival time of patients was very short. Regrettably, we could not obtain the long-time follow-up record to verify the feasibility of surgical methods.

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Compliance with ethical standards

Conflict of interest ZCS, DCY, JJY, XN, JGW, HS, YG declares no conflict of interest.

Ethical approval All the work described in our paper has been carried out in accordance with the code of ethics of the world medical association.

Human and animal rights Human Experimental Ethical Inspection was approval by ethics committee of Shanghai Ninth People's Hospital affiliated to shanghai JiaoTong University, School of Medicine

Informed consent For this type of article informed consent is not required.

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