Open components separation and underlay repair using biological mesh for the treatment of planned ventral hernia after open abdomen surgery

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Abstract: Objective: There are no standard surgical methods for planned ventral hernia (PVH). This paper discusses the possibility of using “open components separation + underlay repair using biological mesh” as a preferred surgical method for PVH. Methods: We retrospectively analyzed the clinical data of PVH patients who received open components separation and underlay repair using biological mesh. Results: Five PVH patients underwent this surgical method from June 2014 to April 2015. All patients were males with an average age of 43.6 ± 17.3 years, body mass index (BMI) of 23.1 ± 2.3 kg/m², and skin graft width of 15-17 cm. Four patients received a sliding myofascial flap of bilateral musculus rectus abdominis + underlay repair with biological mesh (Biodesign®, Cook Medical, Inc., Bloomington, IN, USA), and 1 patient received a sliding myofascial flap of unilateral musculus rectus abdominis + underlay repair with biological mesh. There was one case of incisional infection and 1 case of abdominal sinus formation 2 weeks after discharge. Both patients were cured using vacuum sealing draining (VSD) for 4 to 5 months without removal of the biological meshes. Five patients were followed up in an outpatient clinic after discharge, and the follow-up time ranged from 13 to 23 months. Abdominal incisions healed well, and abdominal computed tomography (CT) indicated no hernia recurrence in all patients. Conclusions: The “open components separation + underlay repair using biological mesh” method is a safe and feasible treatment method for PVH with good outcomes.

Keywords: Hernia, reconstructive surgical procedures, surgical mesh

Introduction

Open abdomen (OA) technology has been used in the fields of trauma, general surgery and vascular surgery for more than 30 years [1]. OA is a key technology for “damage control” (DC) to effectively reduce morbidity and mortality. Most patients complete abdominal wall reconstruction 2-3 w post-surgery, but 9% to 25% [2, 3] of the patients are unable to complete definitive abdominal wall reconstruction within the short term, and these patients require skin grafts to form planned ventral hernia (PVH).

Abdominal wall reconstruction for PVH is a challenge that is faced by trauma surgeons, and the causes for PVH formation include severe trauma, pancreatitis, peritonitis, abdominal vascular emergencies, and abdominal compartment syndrome (ACS) [4]. Patients often undergo one or multiple surgeries, and intra-peritoneal contamination, infection and colostomy are the common complications. Definitive abdominal wall reconstruction surgery often includes a high risk of infection. The hernia grading system recommended by Breuing et al. states that PVH is in grade 3 (possible contamination) or grade 4 (infection) [5]. The reported repair methods include components separation (CS) technology [6, 7] meshes [4] and vascularized flap [8]. However, a long-term follow-up study on the outcomes of these technologies indicated a less than ideal result [2]. The authors compared the hernia recurrence rate of PVH repairing using different methods of primary fascial closure (PFC) after open abdomen and reported a hernia recurrence rate of 18.8% in (3/16) PVH patients and 8.5% (8/94) in PFC patients (P = 0.199).
PVH is often a huge hernia with a large area of abdominal wall defect, and it has a higher risk of infection than incisional hernia. CS technology is an effective method for definitive abdominal wall reconstruction [3], but the sole use of CS technology leads to a high hernia recurrence rate [9]. The 2015 European Hernia Society guidelines suggest the use of prophylactic mesh augmentation in high-risk patients [10]. The type of mesh for treating PVH is controversial, but mesh type may determine the clinical effects and recurrence rates following hernia surgery.

This paper discussed the possibility of using “open components separation + underlay repair using biological mesh” as a preferred surgical method for PVH based on the complexity of PVH. Our institution adopted this technique for the treatment of five patients from June 2014 to April 2015 and achieved good results.

Materials and methods

Patients

Our institution received five PVH patients from June 2014 to April 2015 who underwent intra-abdominal volume increment (IAVI) (7) after severe trauma (Figure 1). All patients were males with an age range from 28 to 64 years and an average age of 43.6 ± 17.3 years. Body mass index (BMI) ranged from 20.0 to 26.1 kg/m² with an average of 23.1 ± 2.3 kg/m². The trauma causes included traffic injuries in 2 cases, a falling injury in 1 case, a penetrating stab injury in 1 case, and a blunt abdominal boxing injury in 1 case. The reasons for PVH formation included ACS in 3 cases and intra-abdominal hypertension (IAH) in 2 cases (Table 1). These patients were complicated with diseases, including sigmoid colostomy in 1 case, ileostomy in 1 case, postoperative pelvic fracture healing in 1 case, and abdominal sinus formation in 1 case. According to the classification of hernia grading system [5], these patients were all grade 3 (possible contamination, previous wound infection or stoma present). The abdominal skin graft width was 15-17 cm, with an average of 16 ± 1 cm, which were huge hernias [11]. Axial abdominal computed tomography (CT) images revealed that the defect size in the muscle fascia ranged from 8.7 to 18.0 cm with an average of 15.2 ± 3.8 cm. The time from PVH to definitive abdominal wall reconstruction was 6 months in 4 cases and 9 months in 1 case (Table 2). All patients were treated using “open components separation + underlay repair using biological mesh”. One patient underwent resection of the infected right rectus abdominis due to peritonitis at first admission, which slid the myofascial flap of the unilateral musculus rectus abdominis. The remaining four patients underwent a sliding of the myofascial flap of the bilateral musculus rectus abdominis.

Preoperative preparation

Hernia patients should engage in moderate activities, such as walking exercise, to restore organ function, and they should avoid vigorous activities, such as weight lifting and running. These patients should eat a balanced and healthy diet and avoid excessive weight increases. Hernia contents were placed back into the abdominal cavity 1 and 2 weeks before surgery and gradually bandaged using abdominal belts. Adaptive exercises were performed to adapt to postoperative increases in intra-abdominal pressure (IAP). Chest X-ray and blood gas analysis were performed after admission to evaluate heart and lung function. Abdominal CTs assessed the muscular fascia defect size of the abdominal wall with hernia, and the integrity and availability of the abdominal muscular layer of the rectus abdominis was determined. The “hand twisting method” was also used. Doctors used their hands to pinch the split thickness skin graft from the underlying abdominal vis-
Open components separation and underlay repair

Table 1. Demographics of PVH patients before definitive abdominal wall reconstruction

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (y)</th>
<th>Trauma causes</th>
<th>Diagnosis of open abdomen surgery</th>
<th>Reasons for PVH formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Male</td>
<td>38</td>
<td>Traffic injury</td>
<td>IAH</td>
</tr>
<tr>
<td>Case 2</td>
<td>Male</td>
<td>61</td>
<td>Traffic injury</td>
<td>ACS</td>
</tr>
<tr>
<td>Case 3</td>
<td>Male</td>
<td>28</td>
<td>Falling injury</td>
<td>IAH</td>
</tr>
<tr>
<td>Case 4</td>
<td>Male</td>
<td>28</td>
<td>Penetrating stab injury</td>
<td>ACS</td>
</tr>
<tr>
<td>Case 5</td>
<td>Male</td>
<td>64</td>
<td>Boxing injury</td>
<td>ACS</td>
</tr>
</tbody>
</table>

Table 2. Demographics of PVH patients with definitive abdominal wall reconstruction

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (y)</th>
<th>Trauma causes</th>
<th>Diagnosis of open abdomen surgery</th>
<th>Reasons for PVH formation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Male</td>
<td>38</td>
<td>Traffic injury</td>
<td>IAH</td>
</tr>
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<td>Case 2</td>
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<td>Case 3</td>
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</tr>
<tr>
<td>Case 5</td>
<td>Male</td>
<td>64</td>
<td>Boxing injury</td>
<td>ACS</td>
</tr>
</tbody>
</table>

Surgical procedures

Step 1: Patients with sigmoid colostomy and ileostomy underwent stoma closure surgery, and pelvic fracture patients with bone healing first underwent internal fixator removal. The stoma of patients who simultaneously underwent stoma closure surgery was first disinfected to minimize contamination during the process of abdominal wall reconstruction. Annulliform incision was used on the skin around the stoma, and the stoma was continuously sutured to close. Abdominal wall reconstruction began after hand washing, disinfection, and surgical coat and surgical instrument replacement.

Step 2: A skin-fold incision less than 0.5 cm was made in the central graft area to enter the abdominal cavity. The skin was carefully separated from the subcutaneous omentum and bowel to avoid damage to the intestine and minimize the possibility of contamination. Adhesions among the omentum, intestine, and abdominal wall on both ends of the incision were freed until no adhesions were found at an 8-10 cm distance from the inner edge of the fascia (convenient for a mesh overlap of 5-8 cm) or the peritoneum of the anterior abdominal wall without adhesions. The stoma intestine was freed from the abdominal wall and placed back in the abdominal cavity. Ileoleostomy or sigmoidorectostomy were performed to complete the stoma closure surgery.

cera and if they did not bring up unsclerotic intestinal loop. Then the adhesions below the skin was released to adopt a definitive abdominal wall reconstruction and determine the mesh size.

The stoma was checked in the 2 colostomy patients before surgery, and normal bowel movement and skin intactness were confirmed. Barium enemas via the anus confirmed the integrity, morphology, distant and near end distance of the intestinal tract, and the presence of stenosis and fistula. Patients with pelvic fractures received X-ray examinations before surgery to determine fracture healing. Patients with abdominal sinus formation underwent abdominal angiography before surgery. All five patients underwent preoperative bowel preparation and trans-bladder measurements to measure IAP before surgery. The antibiotic cefazolin (1 g) was administered 30 min before laparotomy.
Figure 2. Case 2, components separation. A. Cutting central skin graft region; B. Separating the skin from subcutaneous omentum and bowel; C, D. Cutting the sheath 0.5 cm within the inner edges of the rectus abdominis; E, F. Sliding myofascial flap of musculus rectus abdominis.

Table 3. Intra-operative information on definitive abdominal wall surgery

<table>
<thead>
<tr>
<th>Primary incision of abdominal wall before operation</th>
<th>Other diagnosis</th>
<th>Surgical methods</th>
<th>Operation time (min)</th>
<th>Bleeding volume (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Paramedian incision</td>
<td>Sigmoid colostomy</td>
<td>Stoma closure + sliding myofascial flap of bilateral musculus rectus abdominis</td>
<td>180</td>
</tr>
<tr>
<td>Case 2</td>
<td>Paramedian incision</td>
<td>Pelvic fracture with postoperative bone healing</td>
<td>Removal of internal fixator + sliding myofascial flap of bilateral musculus rectus abdominis</td>
<td>240</td>
</tr>
<tr>
<td>Case 3</td>
<td>Paramedian incision</td>
<td>Abdominal wall sinus tract</td>
<td>Sliding myofascial flap of bilateral musculus rectus abdominis + sinus tract debridement</td>
<td>270</td>
</tr>
<tr>
<td>Case 4</td>
<td>Paramedian incision</td>
<td>Ileum stoma</td>
<td>Stoma closure + sliding myofascial flap of left rectus abdominis</td>
<td>210</td>
</tr>
<tr>
<td>Case 5</td>
<td>Median incision</td>
<td>None</td>
<td>Sliding myofascial flap of bilateral musculus rectus abdominis</td>
<td>300</td>
</tr>
</tbody>
</table>

Step 3. Open components separation (OCS): All incomplete skin in the skin-grafting area was excised. The superficial fascia was separated from the abdominal rectus fascia starting from the incision area to clear the abdominal wall layer along the sheath and tendinous membrane of the external oblique muscle of the abdomen and toward both sides to the anterior axillary line. The sheath was cut within 0.5 cm of the inner edge of the lateral rectus abdominis fascia, and the connection between the posterior sheath and endoabdominal fascia.
Open components separation and underlay repair

(below arcuate line) was separated along the posterior rectus abdominis. The superior and inferior epigastric arteries behind the abdominal wall were protected, and the bilateral rectus abdominis anterior sheath on the linea alba was opened from the lower edge of the costal arch to the pubic symphysis level. The myofascial flap of the freed bilateral or unilateral musculus rectus abdominis and sheath was slid. No. 4 silk line interrupted the sutures on the outer edge of the bilateral rectus abdominis anterior sheath and the inner edge of the posterior sheath (Figure 2). A single-cavity drainage tube was placed in the abdominal cavity, and the abdominal fascia reconstruction was completed (Table 3). The sliding of the myofascial flap of the bilateral or unilateral musculus rectus abdominis depended on the abdominal wall. The original incision was taken as the midline incision, and bilateral sliding was per-
formed if both sides of the rectus abdominis were intact. Unilateral sliding was conducted if only one side of the rectus abdominis was intact.

**Step 4. Underlay repair:** A 30 cm × 20 cm piece of biological mesh (8-layer Biodesign\textsuperscript{®}, Cook Medical, Inc., Bloomington, IN, USA) was used to perform the underlay repair. The silk suture was preset on the mesh, and a horizontal mattress suture with a needle distance of 2-4 cm and margin of 1 cm was used. Meshes were laid flat on the abdominal cavity, and a transfixion pin was used to pull the preset suture and

**Table 4. Patients' postoperative data**

<table>
<thead>
<tr>
<th>Postoperative abdominal wall drainage (ml)</th>
<th>Intra-bladder pressure (mmHg)</th>
<th>Incision healing</th>
<th>Discharge time (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>1180</td>
<td>6-8 Good incision healing</td>
<td>22</td>
</tr>
<tr>
<td>Case 2</td>
<td>1100</td>
<td>8-10 Escherichia coli infection on incision, incision opening + VSD drainage, healing after 4 months</td>
<td>36</td>
</tr>
<tr>
<td>Case 3</td>
<td>155</td>
<td>6-8 Good incision healing, healed abdominal wall sinus tract</td>
<td>22</td>
</tr>
<tr>
<td>Case 4</td>
<td>1015</td>
<td>7-8 Good incision healing, sinus formation occurred 2 weeks after discharge, healed after 5 months</td>
<td>23</td>
</tr>
<tr>
<td>Case 5</td>
<td>300</td>
<td>8-10 Good incision healing</td>
<td>25</td>
</tr>
</tbody>
</table>

**Figure 5.** Case 2, male patient, aged 61 years, incision was infected after abdominal wall reconstruction surgery without removal of biological mesh. A. Sliding myofascial flap of bilateral musculus rectus abdominis + underlay repair with biological mesh; B. Performing VSD to protect incision after suturing incision. C. Incision infection; D. After debridement + VSD treatment, the incision margin was gradually more close; E. Incision was healed after 4 months.
fix the mesh to the muscular fascia to ensure a 5-8 cm overlap of the mesh and muscular fascia. One side of the mesh was fixed, and the mesh was flattened. The other side of the mesh was fixed, and the preset sutures on the other side were adjusted if necessary. Interrupted suture was used to suture the mesh and fascia edge with a needle distance of 3 cm. The mesh was flattened to avoid uneven conditions and reduce fluid, infection and postoperative abdominal discomfort. The absence of bleeding on wounds was ensured, and the surgical area was washed. Four drainage tubes were inserted in the superior biological mesh and between myofascial flap and biological mesh, and subcutaneous tissue and skin were sutured without tension (Figures 3, 4). Intro-bladder pressure was continuously monitored during surgery.

Postoperative management

The patients’ vital signs and intro-bladder pressure was continuously monitored post-surgery, and the antibiotic cefazolin sodium was continuously used for 3 days. Abdominal wall drainage tubes were indwelled for 9-15 d, and they were removed when the daily drainage volume was less than 10 ml and ultrasonic examination indicated no subcutaneous effusion. Patients were encouraged to perform early bed activities after surgery, and get out of bed 2-3 d post-surgery. Intense activity and heavy physi-
cal labor were banned for 6 months after surgery, and athletic banding was wrapped for three months.

Results

The average operation time was 180-300 min (mean 230 ± 57 min), and the amount of bleeding was 200-400 ml (mean 290 ± 102 ml). Intra-operative bladder pressure was 6-10 mmHg, and the postoperative bladder pressure was 6-10 mmHg. The post-operative anal exhaust time was 3-5 d (mean 4.2 ± 0.8 d), and the postoperative time to get out of bed was 2-3 d (mean 2.6 ± 0.5 d). The volume of abdominal drainage was 155-1180 ml (mean 750 ± 483 ml), and the time for removal of the abdominal wall drainage tube was 9-15 d (mean 12.4 ± 2.4 d) after surgery. The time for stitches removal from abdominal incisions was 14-18 d (mean 16.4 ± 1.5 d), and the discharge time was 22-36 d (mean 25.6 ± 5.9 d) after surgery (Table 4). One patient had mild abdominal pain and exudation on the abdominal incision after surgery, and bacterial culture revealed an Escherichia coli infection, who underwent debridement + vacuum sealing draining (VSD) treatment for 4 months and healed without mesh removal (Figure 5). One patient occurred abdominal sinus formation 2 weeks after discharge, who was not cured by incision opening and VSD for 4 months, then injected with platelet-rich plasma (PRP) and cured after 1 month (Figure 6). Five patients were followed up for 13-23 months (mean 17.0 ± 4.1 months). All abdominal incisions healed well, and abdominal CT showed no hernia recurrence (Figure 7). The three youngest patients returned to work.

Discussion

OA technology has been used in the fields of trauma, general surgery and vascular surgery for more than 30 years [1]. Our institution used IAVI to prevent and treat traumatic ACS [7]. The occurrence of IAH and ACS after severe abdominal trauma is the indication for the application of OA, and definitive surgery and fascia closure must be performed as soon as possible. PVH is a management strategy that does not close the abdominal fascia, but covers the internal organs solely using original skin and grafts [12]. PVH is different from incisional ventral hernia (IVH). The peritoneum is missing on PVH patients, and the fascia is intentionally not sutured or is unable to be sutured. The skin layer is split-thickness skin graft (STSG), and the abdominal skin is not intact after removal (Table 5).

PVH can be treated using different surgical methods. However, a long-term follow-up survey found that the results of the above techniques were not ideal [2], and the authors compared the hernia recurrence rate of PVH repair

Table 5. Differences between PVH and incisional hernia

<table>
<thead>
<tr>
<th></th>
<th>PVH</th>
<th>Incisional hernia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peritoneum layer</td>
<td>Missing</td>
<td>Possibly being intact</td>
</tr>
<tr>
<td>Fascia muscular layer</td>
<td>Actively opening or being unable to suture</td>
<td>Incomplete healing after suture</td>
</tr>
<tr>
<td>Skin layer</td>
<td>STSG</td>
<td>Intact skins</td>
</tr>
</tbody>
</table>
after open abdomen surgery using different methods. A hernia recurrence rate of 18.8% was reported in (3/16) PVH patients and 8.5% (8/94) in PFC patients (P = 0.199). The reasons for this difference may be as follows: PVH patients had many huge hernias; the abdominal defect was enormous; patients often underwent one or several contaminated abdominal surgeries that were often combined with stomas (e.g., there were 2 patients with combined abdominal stoma among the 5 patients in our study); and the stoma closure and abdominal wall reconstruction surgery may be potentially contaminated. Basta et al. [13] reported that wound infection was a risk factor (OR value of 22.1, P = 0.017) for hernia recurrence, that some patients exhibited a more difficult CS because of infections and the absence of fascia after trauma, and different mesh types would lead to different outcomes. Beale et al. [14] systematically reviewed 29 studies on the outcome of different types of biological meshes and demonstrated that the hernia recurrence rate was lowest using Surgisis® biological meshes. (Note: The Biodesign is modified based on the Surgisis). They concluded that the hernia recurrence rates of allograft acellular dermal matrix meshes were higher than xenograft products. Therefore, this paper discusses the possibility of using “open components separation + underlay repair using biological mesh” as a preferred surgical method for PVH.

Ramirez et al. [6] first used CS techniques to repair hernias, which separated the oblique externus abdominis from obliquus internus abdominis plane with no vessels and connected the compound muscle flaps on the oblique externus abdominis and obliquus internus abdominis. Scholars then proposed modified CS techniques, such as the Memphis modification [15], posterior component separation with transverses abdominis muscle release (PCS/TAR) technology [16], and minimally invasive component separation [17]. The CS technology has the following advantages: (1) it uses the patient’s own fascia muscular layer for abdominal wall reconstruction, which avoids the potential infection risk of artificial implants; (2) the size of PVH defects is large, which can not be repaired simply using meshes, but CS technology can free the bilateral muscular fascia based on the size of the defect; and (3) CS can reconstruct linea alba and close the median line, which encases the abdominal wall in functional muscular fascia like normal anatomy. Abdominal muscular fascia provides dynamical support for the re-distribution of IAP through the innervated tissues. DiCocco et al. [3] conducted a long follow-up in 114 patients with abdominal wall reconstruction after PVH, and reported that the hernia recurrence rate was only 5% using the modified components separation techniques. They concluded that the modified components separation was the treatment of choice for huge abdominal hernia. Our institution has adopted methods similar to the Memphis modification. However, our method freed the rectus abdominis posterior sheath from the inner edge of the lateral rectus abdominis sheath, and the myofascial flap of the bilateral musculus rectus and sheath were slid toward the midline, and the linea alba was reconstructed. The blood of rectus abdominis and rectus abdominis sheath was primarily supplied from the superficial superior epigastric artery and deep lower abdominal artery, and damage to these two arteries must be avoided during surgery. This caution underlies the reason that the rectus abdominis sheath is separated from the posterior rather anterior during the CS technology.

The abdominal wall defect of PVH is huge, and closing the median line when the muscle fascia can not be sufficiently freed may cause IAH, which increases postoperative risk. It is necessary to find the right mesh to strengthen the repair, and long-term follow-up results demonstrated a high recurrence rate of complex huge hernias that were treated only using CS [9]. Suitable meshes would not erode intestine or cause excessive adhesions have a low possibility of contamination. Common synthetic materials exhibit a high-risk of infection, and surgeries must be performed to remove them once infection occurs. Surgeries for PVH mostly exhibit a high potential for contamination, and thus require biological meshes.

Biological meshes are divided into human acellular dermal matrix (HADM) and animal small intestine submucosa (SIS) according to the material source, and these meshes can be divided into cross-linked and non-cross-linked according to the production technology. Common meshes, such as HADM, have complications of laxity or eventration [18], and they exhibit a huge hernia recurrence rate as high as
17.1-21.8% [19, 20]. These problems occur because the HADM contains large amounts of elastin, which is easily stretched, and not enough strength. SIS primarily contains collagen fibers with a strength that is 100 times greater than elastin. Cross-linked technology primarily aims to reduce immunogenicity and increase the resilient ability in the contamination condition. The non-cross-linked technology primarily aims to promote tissue regeneration and remodeling. Biodesign mesh is non-cross-linked, and it is derived from the extracellular matrix (ECM) of porcine SIS, which is comprised of non-collagenous and collagenous proteins and numerous biological information molecules, such as glycosaminoglycans, proteoglycans and glycoproteins. These bioinformation molecules actively attract body cells and nutrients to infiltrate the implantation site and surrounding tissues. Biodesign mesh is a very good repair material that provides a scaffold for host cells to promote the formation of new blood vessels during early stages and accelerate cells to differentiate and mature to the host’s own ECM components, which gradually remodels the tissue into structures that are similar to the implantation tissues. The Biodesign mesh provides sufficient mechanical strength during this process to support the organization of these new structures. Biodesign mesh also exhibits powerful anti-inflammatory effects, especially in a variety of infections and potentially contaminated surgeries, including rectourinary fistula [21], rectovaginal fistula [22], foregut fistula [23], high infection-risked hernia repair [24, 25] and huge abdominal hernia reconstruction [26]. Our institution used an 8-layer Biodesign® biological mesh based on the characteristics of the biological mesh.

Biodesign mesh exhibits the following main advantages: (1) having superior resistance to infection and not hindering the body’s own immune system and local anti-infective mechanism; (2) stimulation and strengthening of blood vessels to grow the recycled materials, stimulation of cell regeneration, rebuilding of complex organizational structure, achieving the functional repair of the abdominal wall, and leaving no foreign objects in the body after degradation; (3) carrying a biomolecular signal that actively attracts body cells and nutrients to infiltrate in the implant site and surrounding tissue; and (4) a gradual regeneration of healthy tissue after implantation that increases in intensity daily. Therefore, Biodesign is particularly suitable for PVH. This mesh does not require removal even in the event of infection. One case in our study experienced an incision infection after surgery, and one case occurred abdominal sinus formation 2 weeks after discharge, but the biological mesh was not removed. The patient with infected incision underwent debridement + VSD treatment for 4 months and healed without mesh removal; the patient with abdominal sinus formation was treated by incision opening and VSD for 4 months, then injected with PRP and cured after 1 month. These results support the strong anti-inflammatory effects of the Biodesign mesh. PVH patients are primarily young patients who have high functional requirements of the abdominal wall after surgery. Biodesign also provide enough muscular fascia support and aids in the recovery of abdominal wall function.

The location of biological mesh placement does not have a common standard. Albino et al. [27] systematically reviewed the literature and found that the hernia recurrence rate was highest when the mesh was placed in onlay and inlay positions, and the infection was highest when the mesh was placed in an inlay position. The incidence of seroma was lowest when the mesh was placed in a sublay position. They concluded that the hernia recurrence rate was lowest when the mesh was placed in a sublay position. They compared three different repair methods (onlay, inlay and underlay), and followed up patients for an average of 30 months. They found that the hernia recurrence rates for the onlay, inlay and underlay methods were 23%, 44%, and 12% (P = 0.03), respectively. They concluded that the underlay repair technology was the best method. Rosen et al. [29] followed up 128 patients for an average follow-up of 15.9 months who received biological meshes in infected and contaminated abdominal wall reconstruction surgery. They found that the OR value of incision complication was 0.31 (P = 0.006) when the mesh was placed in a sublay position, and the hazard ratio (HR) value for time to recurrence was 0.54 (P = 0.063). These results indicate that placing the mesh in sublay position is favorable for patients. PVH patients do not have a hernia sac, and it is hard to put the mesh in sublay position. Therefore, it is
often necessary to place the mesh in an underlay position. Our department placed the biological mesh in an underlay position for the repair of PVH.

Additionally, PVH formation resulted from increased IAP caused by trauma, pancreatitis, peritonitis and ACS. Therefore, we should avoid IAH while performing definitive abdominal wall reconstruction and continuously monitor IAP preoperatively, intra-operatively and postoperatively to ensure the safety of the surgery.

Our study has some limitations. This study reached conclusion from our clinical experience and a comprehensive literature search. The number of patients was few, and it was a single-center study. A large sample in a multi-center prospective randomized controlled study is needed to provide better references for evidence-based medicine.

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Disclosure of conflict of interest

None.

Authors’ contribution

LPY carried out the studies and drafted the manuscript. LD participated in the design of the study and performed the statistical analysis. ZLY and SSJ conceived of the study, and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

Abbreviations

PVH, planned ventral hernia; VSD, vacuum sealing draining; CT, computed tomography; OA, open abdomen; DC, damage control; CS, abdominal compartment syndrome; CS, components separation; PFC, primary fascial closure; IAVI, intra-abdominal volume increment; IAP, intra-abdominal pressure; OCS, open components separation; IVH, incisional ventral hernia; STSG, split-thickness skin graft.

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