Reconstruction of Complex Midline Abdominal Wall Defects, Is There a Gold Standard?

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Abstract

The management of patients with open abdomens is an evolving concept. Certain techniques for managing the open abdomen patients can be effective in treating ACS. The goal of therapy is to maximize tissue perfusion and minimize potential intra abdominal complications, such as fistulas and hernias. Meticulous care of the bowel, minimizing trauma from techniques or systems used to cover abdominal contents and protection of the bowel from exposure to the environment can reduce the complications associated with the open abdomen. A Temporal Abdominal Closure should not only protect the intra abdominal contents, but facilitate primary closure of the fascia and minimize the need for secondary repairs of ventral hernias and subsequent repair. Serial bladder pressure monitoring should be a part of post-operative management protocols in high-risk patients and decompression of the abdomen with a pressure of > 25-30 mmHg should be considered even without clear clinical evidence of ACS. While many closure techniques are reported in the literature, a dynamic closure technique, such as Vacuum pack appears to have an advantage in meeting most requirements for managing an open abdomen. IAH and ACS remain the most significant considerations for the management of the open abdomen. IAH and ACS are in part iatrogenic and can be minimized with the appropriate resuscitation protocols. Complications found in patients with open abdomens may be minimized with Vacuum pack Therapy resulting in early closure of the abdomen. Consideration for the type of closure is based on the patient’s clinical status with the optimal result of primary facial closure. When the fascia cannot be closed, skin over granulation tissue is preferred to skin grafting over granulation tissue to create ventral hernia. Several techniques have been described to repair created ventral hernias. In our work, three methods had been utilized for final reconstruction of complex midline anterior abdominal wall defects according to size of the defect and status of tissue bed; (I) repair with autologous tissue to bridge the fascial gap using components separation technique (CST), (II) prosthetic repair to bridge fascial defects and (III) Shoelace Darn Repair.

Keywords

Abdominal Wall; Complex Abdominal wall defects

Introduction

The open abdomen is an iatrogenic disease of modern abdominal surgery. Deliberately leaving a laparotomy wound open is now the standard of care in clinical situations that require either planned reoperations or decompression of intra-abdominal hypertension. Damage control surgery [1] and management of severe abdominal infection are examples of the former [2], while leaving the abdomen open after repair of a ruptured abdominal aortic aneurysm or for abdominal compartment syndrome are examples of the latter [3,4].

Less commonly, partial loss of the abdominal wall [5, 6] or septic dehiscence of a laparotomy incision prohibit immediate definitive closure and result in an open abdomen [7].

The “state of the art” in definitive abdominal closure is currently undergoing a quiet revolution. Until recently, the two options available to surgeons were either early closure within a week or so after the original operation, or allowing the wound to granulate (the so-called “planned ventral hernia”) with definitive closure 6-12 months later [8,9].

Reconstruction of complex defects of the abdominal wall is both challenging and technically demanding for surgeons. Therefore, it is imperative that the operating surgeon is knowledgeable of the etiologies, pertinent anatomy and proper postoperative care of these patients. Although these defects can be attributed to a many etiologic factors, the objectives in abdominal wall reconstruction are consistent and include the restoration of abdominal wall integrity, protection of intra abdominal viscera and the prevention of hernia or bulge formation while maintaining an aesthetically favorable result [7].

The aim of this work is to evaluate the outcome after different methods of reconstruction of difficult types of abdominal wall defects.
Patients and Methods

This is a prospective study on fifty two patients in different age groups ranging from nineteen to sixty seven years with complex anterior abdominal wall defects, in which primary closure is impossible, whom were managed by different techniques for closure and reconstruction of the defect.

Inclusion criteria

All the patients subjected to the study were complaining of a complex midline abdominal wall defect or large ventral incisional hernia defect, necessitating special techniques for closure or repair.

Patients were divided according to their presentation into two groups:

1. **Type 1 defects** with complex complete fascial defect (open abdomen) including thirty four patients.
2. **Type 2 defects** with intact or stable closed skin coverage over hernia defect (ventral hernia) including eighteen patients.

Methods

**General preoperative assessment:** Surgical planning for complex abdominal wall defects starts with a standard preoperative evaluation. Most patients with complex abdominal wall defects had a complex past medical histories that directly influence reconstructive options. Cardiac and pulmonary compromise can represent a significant associated risk during these surgeries. The risk of surgery is related not only to the reconstruction, but also to the hernia take down. It is hard to determine which aspect of the operation represents the greatest risk, but it is best to think of the risk in terms of the entirety of the case.

The preoperative evaluation included complete history, physical, general medical evaluation, basic laboratory work and other diagnostic or radiologic studies. The medication list was also carefully reviewed. Most patients with complex abdominal wall defects benefit from a CT scan of the abdomen with contrast to evaluate the extent of the defect, the anatomy and associated pathology (as infected mesh, abscess pockets and the extent of local inflammation and bowel adhesions). The CT scan also was used to evaluate the extent of loss of intra-abdominal domain.

Patients with evidence of pulmonary or cardiac compromise underwent preoperative pulmonary function tests and full cardiac evaluation, such as echocardiogram or cardiac stress test.

**Management of the open abdomen (type 1 defects):** Management had been based on the physiologic status of the patient. Recognizing the importance of long-term protection of the abdominal contents with the patient’s physiologic status as the main determinant, we had used Vacuum-Assisted Closure (V.A.C.) Technique for primary closure after the initial surgery.

Patients that had been stable could have a primary closure (early primary closure within three days was done in five cases, in addition to two died cases, and delayed primary closure within seven to ten days was done in ten cases in addition to four died cases). In the remaining thirteen patients who remained unstable, creation of ventral hernia with remote secondary repair had been utilized where vacuum pack therapy had been continued and was changed every 48 hours. The abdominal wall had been allowed to granulate until the skin was closed over the granulation tissue or a skin graft was to be immediately placed directly over the granulating abdominal contents. After wound closure, these patients were discharged when medically stable.

Regardless of the initial cause, the acute recovery period was managed by temporary abdominal wall closure with interposition mesh, followed by split-thickness skin grafting once granulation of the wound bed had occurred. Following stabilization of the patient and resolution of the inflammatory process, the skin graft can be removed from the wound bed, and definitive closure of the abdominal wall could be achieved using the components separation technique. Time to definitive closure of the abdominal wall varied from as little as 6 months to well over 2 years from the time of initial injury.

Vacuum pack closure technique: Vacuum pack had been tried in open defect cases especially those associated with massive trauma and subsequent tissue loss or with severe sepsis.

First, the omentum, if present, has been used to cover the small bowel and should be spread caudally and laterally to act as an abdominal apron.

Next, an absorptive layer (sterile towel 38 × 62 cm. or the polyurethane sponge of a commercially available vacuum-assisted wound management system) has been encased in an adhesive polyethylene plastic dressing (90 × 85 cm loban™ (Figure 1). This plastic-encased towel has been placed over the intestines and tucked under the fascial edges in a 360° fashion. It has been sized appropriately so as to not draw out from the edges of the abdominal wall and allow for evisceration (Figure 2).

Large bore, closed suction drains have been placed in the inferior or caudal end of the wound above the plastic encased towel in the deep subcutaneous gutters and brought out superiorly through long subcutaneous tunnels (10 cm) with exit sites over the lower chest (Figure 3). These subcutaneous tunnels have been important as they allow the next and outer layer of adhesive plastic to seal the wound. Drains resting on the skin allow air leaks once negative pressure is created and therefore the vacuum necessary for wound and intra-abdominal fluid removal is not created.

The abdominal closure has been completed with the placement of a second large loban™ sheet over the entire open abdomen (Figure 4). To ensure that the loban™ sticks securely to the skin, all abdominal wall hair, especially in the groin and suprapubic areas, has been shaved to promote adhesion.

Once the outer adhesive plastic is completely fixed to the abdominal skin, the drains have been placed to low continuous suction to create a vacuum effect, seal the wound, and remove excess fluid and blood (Figure 5).

**Figure 1:** Sterile towel is covered on one side with adhesive plastic dressing (loban)

**Figure 2:** The towel is placed over the intestines and tucked under the fascial edges
increase the risk of fistula formation. Drains were placed in this layer to apply the negative pressure.

The outer layer consisted of a bio-occlusive adhesive sheet (Ioban) that was secured laterally to the flank skin and provided enough integrity to the abdominal wall.

Methods used in definitive repair of abdominal wall defects in created ventral hernia in open cases and in closed defects: The determination of when to perform the definitive abdominal closure is crucial. The reconstruction is undertaken when the skin graft can be lifted from the underlying viscera without evidence of adhesions. Three procedures had been used in our series including:

- Component Separation technique (in eight cases)
- Shoelace Darn Repair (in ten cases)
- Polypropylene mesh Repair (in thirteen cases)

All patients received general anaesthesia for definitive repair of their abdominal wall defect. Prophylactic intravenous antibiotics were administered and prophylaxis for venous thrombosis with sequential compression devices was instituted.

Abdominal wall components separation

Preoperative assessment: A careful history and physical examination are critical to ascertain what components of the anterior abdominal wall remain undisturbed from prior surgical procedures, tumors, infection or trauma. If the clinical examination cannot identify an intact rectus abdominis muscle and fascia, CT scan, or magnetic resonance imaging can be useful for identifying remaining anatomic structures.

This technique had been used in present work for repairing large midline defects less than 20 cm in diameter. Exclusion criteria for a rectus abdominis muscle advancement flap include:

- Compromised vascular supply (as superior epigastric artery, deep inferior epigastric artery) to the rectus flap.
- Extensive destruction of the components of the abdominal wall.
- Reconstruction in a contaminated field.

Operative steps (10)

The first surgical step is to remove skin graft or the skin and subcutaneous tissues from the underlying fascia, extending from the costal margin cephalad to the pubis caudally, and to the anterior axillary line and iliac crest laterally (Figures 6 and 7a). Skin flaps are raised to expose the rectus and external oblique junction. Blunt dissection along the semilunar line was then carried out in a caudad direction. This dissection was done to preserve the periumbilical perforators from the rectus muscle to the skin, as well as decrease the amount of skin undermining, thereby minimizing seroma formation.

The viscera are freed from the abdominal wall to allow the abdominal wall to be mobilized medially. This may include extensive enterolysis and/or reversal of skin level ostomy.

A three-layered technique was used; the inner layer that faced the viscera consisted of a fenestrated inert sheet (IV bag or ISO 1010 Drape) covering the entire viscera to the bilateral paracolic gutters to prevent adhesions of viscera to the overlying peritoneum. The middle layer was made of Kerlex, lap sponges, gauze, or blue towels designed to provide the suction media for the NPA. It is imperative that the middle layer does not contact the underlying viscera, as it would protect the bowel from the negative pressure. A three-layered technique was used; the inner layer that faced the viscera consisted of a fenestrated inert sheet (IV bag or ISO 1010 Drape) covering the entire viscera to the bilateral paracolic gutters to prevent adhesions of viscera to the overlying peritoneum. The middle layer was made of Kerlex, lap sponges, gauze, or blue towels designed to provide the suction media for the NPA. It is imperative that the middle layer does not contact the underlying viscera, as it would increase the risk of fistula formation. Drains were placed in this layer to apply the negative pressure.

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An incision is made in the external oblique aponeurosis 2 cm lateral to the semilunar line and extending from the costal margin to the inguinal ligament (Figure 7b).

The external oblique muscle is bluntly dissected from the underlying internal oblique muscle (Figure 7c). Meticulous care is taken not to disrupt the internal oblique musculature and the neurovascular supply. This should result in approximately 5 cm of advancement in the upper third of the abdomen, 10 cm in the mid-abdomen, and 3 cm in the lower third of the abdomen.

If there is insufficient advancement of the musculofascial flap to the midline, the rectus muscle may be dissected free of its posterior sheath (Figure 8). This secondary release should produce an additional 2-4 cm of flap advancement. Thus, in the middle third of the abdomen, a total of 20 cm of advancement is often possible (Figure 9).

Debridement until viable fascial edges with bleeding rectus muscle was carried out. The fascia was then closed recreating the midline. Closed suction drains were left at each semilunar line and also in the midline.
Excess skin was then excised allowing primary skin closure. No special effort was made to preserve the umbilicus. Drains are almost universally employed in an effort to prevent seromas that can occur beneath the skin flaps and adjacent to prosthetic material if used.

The patients were mobilized on postoperative day 1 and dietary intake was advanced as tolerated. The patient was deemed ready for discharge when normal bowel function and adequate pain control were present.

Prosthetic Repair; Retro Rectus Approach

The essential steps are as follows:
1. Under general anesthesia, the old scar is excised and the hernia sac dissected free down to the myoaponeurotic edges of the hernial opening,
2. The sac is then opened and its contents inspected,
3. All adherent loops of bowel are freed and returned to the peritoneal cavity,
4. The excess sac is excised and the peritoneum and sac are closed with a running absorbable synthetic suture; where there is insufficient peritoneum to close the sac, the omentum is sutured to the edges of the residual defect so that the prosthetic non-absorbable mesh for the actual repair will not come in contact with bowel for fear of adhesions, sepsis, and fistula.
5. The bed for the permanent prosthesis is prepared by slitting open the medial edge of each rectus sheath along the hernial defect and for 8 to 10 cm above and below it, and
6. The rectus muscles are separated from the posterior rectus sheaths up to the whole length of the lateral edge of the sheath.

A sheet of propylene mesh is cut longer than the length of the defect and wide enough to stretch from one lateral edge of the rectus sheath to the other. This sheet then is fixed under slight tension with a few non-absorbable monofilament synthetic sutures. Thus, it will lay on the closed peritoneum and posterior rectus sheaths and will stretch above and below the defect and also from one lateral edge of the rectus sheath to the other, and in the plane behind the rectus muscles. The sutures are passed through the edge of the mesh and then along the line of the lateral edges of the rectus sheath (linear semilunaris), from inside the sheath, through the whole thickness of the abdominal wall and out through stab holes in the skin, using an Aneurysm needle (Figure 10). Each limb of the suture is passed through the abdominal wall separately but through the same stab wound. In some patients, when the abdominal wall is not too fatty, a stitch with a straight needle may be passed through the abdominal wall from the skin to the retro muscular space (Figure 11).

The passage of each end of the suture through the muscle must be separated by at least 1.5 cm. If they are closer, the muscle fibers may be cut by the knot.

The sutures are tied so that the knots come to lie on the outer surface of the external oblique muscle and each stab wound is closed with a suture.

The upper and lower edges of the mesh are sutured in a similar fashion. When the hernia defect reaches the upper part of the abdominal wall, the upper edge of the mesh is passed down to lie under the diaphragm.

The transfixing sutures are placed clockwise along each semilunar line (Spiegel line) and at each extremity of the laparotomy. Usually 12 transfixing sutures are sufficient but in the patient with a huge incisional hernia, up to 21 sutures may be used. Sutures are tied on one side and then the other side of the defect. Tailoring of the prosthesis is important so that sutures result in some tension of the prosthesis to re-establish the lateral muscle function that was lost because of their midline detachment.

In the lower abdomen, below the arcuate line of Douglas, the graft comes to lie in the pre-peritoneal plane and should be long enough to hang into the pelvis in the retropubic space of Retzius and in the spaces of Bogros.

Figure 6: Component separation technique, skin flap dissection

Figure 7: Component separation technique, plane of dissection

Figure 8: Component separation technique, rectus muscle elevation; When additional advancement is needed while performing the technique, the muscle can be elevated from the posterior sheath in its entirety.
In this case, it should be fixed with a few sutures to the back of the pubis and along the pectineal lines. Two vacuum drains are laid on the graft and brought out through separate stab wounds. The two anterior rectus sheaths then are sutured together along their cut medial edges with a continuous synthetic absorbable or non-absorbable monofilament suture. The excess skin is excised and the wound is closed.

Postoperative care: Respiratory physiotherapy is resumed as soon as possible after surgery. Aspiration drains are monitored and usually removed on the third or fourth postoperative day. Anti-thromboembolism therapy must be used.

Technique of Shoelace Darn Repair (12): A vertical elliptic incision is used, excising the old scar. In obese patients with a large apron of fat hanging below the pubis, panniculectomy and abdominoplasty are combined with repair of the hernia. In this case a long transverse incision is used at the level of the supra-pubic crease and is extended almost to the back, curving up at its lateral ends. The skin and fat of the apron and of the abdominal wall are freed upward off the musculoaponeurotic layer to well up onto the anterior chest wall. After repair of the hernia the apron and the excess skin and fat of the lower abdominal wall, usually up to the level of the umbilicus, are excised. Should it become necessary, an inverted midline V of the remaining skin and fat is excised to create a tucked in waistline (Figure 12A).

In the usual case, the skin and fat are dissected off the sac of the hernia, as well as off the rectus sheath on each side (Figure 12B). The anterior rectus sheaths should be exposed sufficiently to allow for splitting off of the medial ribbon, as well as for suturing the second layer. Time need not be wasted on accurate delineation of the medial edge of the rectus sheaths or on leaving an absolutely clean surface on the hernial sac. With the first continuous suture for construction of the new midline, the sac, together with the adherent bits of scar tissue and even old sutures that cannot be easily removed, are returned to the abdominal cavity.

The new linea alba is now constructed, using a vertical strip 1 to 1.5 cm wide split off the medial edge of each anterior rectus sheath as follows:

1. the abdominal wall around the hernial opening is defined,
2. an incision is made in each anterior rectus sheath about 1 cm or more from its medial edge to confirm the presence of rectus muscle
3. the incision is extended up and down the entire length of the hernial opening and for about 2 cm beyond, keeping the ends of the incision away from and parallel to the midline, above and below the hernia (Figure 13), and

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With narrow or moderately wide hernias the edges of the anterior rectus sheaths may be approximated by this suture line. In the usual case of a large hernia, a gap of at least a few centimeters remains, with the continuous pliable to-and-fro shoelace suture adjusting itself to the differing widths and tension across the fascial defect and thus functionally substituting for the missing anterior rectus sheaths (Figure 15C and D). Excess skin and fat are excised.

A vacuum drain is placed on either side, and each is brought out through a separate stab. The incision is closed with automatic staples or a continuous suture of fine monofilament polyamide thread.

**Postoperative outpatient follow up:** All discharged patients were monitored frequently (approximately once weekly) until full healing occurred. Additional visits every two months.

Patients were followed up by clinical examination in both supine and erect positions for the previous lesion or any new lesions.

Radiographic examination by computed tomography was requested only when recurrence was in question.

**Statistical analysis**

The collected data were tabulated and analyzed by SPSS (statistical package for the social science software) statistical package version 13 on IBM compatible computer.

Quantitative data were expressed as means and standard deviation (X ± SD) and analyzed by applying Mann Whitney U test for the not normally distrusted variables.

Qualitative data were expressed as number and percentage (% and %) and analyzed by applying chi-square (X²) test and ANOVA (f) test.

Same letter means no significance difference. Different letters mean significant difference. All these tests were used as tests of significance at P < 0.05.

**Results**

Our patients were 28 (53.8%) males and 24 (46.2%) females with age ranging from 19 to 67 with mean ±SD = 36.1 ± 12.85 in cases with complete defects and 37.9 ± 13.3 in those with partial defects. Also, males dominated in the first group with complete fascial defect (58.8%) while females were dominant the second group with partial defect (55.6%), with no statistically significant difference between the two groups regarding either gender or age of patients (Table 1).
**Table 1: Sex and Age in relation to the type of fascial defect**

Abdominal trauma with resultant abdominal wall tissue loss was the most common etiology of complete abdominal wall defect, in twelve out of thirty four patients (35.3%), followed by wound dehiscence following abdominal operations (29.4%), infection of recent laparotomies (26.5%) and after abdominal wall desmoid tumor excision in one case (2.9%), while other cases were presented during the course of preparation for a second exploration in emergency situations (5.9%), there is a statistically significant difference, as shown in (Table 2).

In thirty four of our cases, it was impossible to primarily close the abdomen, thus a temporal closure was indicated. In 26% of cases, burst of the abdomen was the indication of temporal closure, while in 20% of cases; abdominal compartmental syndrome (ACS) was the indication. Also in emergency situations, damage control with relaparotomy was responsible for 15% of cases of temporal closure. Other indications of temporal closure were severe intra abdominal sepsis (11.8%), debridement of necrosis (8.8%), necrotizing fasciitis (5.9%) and lastly, excision of an abdominal wall tumor in (2.9%), with statistically significant difference as shown in (Table 3).

The time period consumed for temporal closure ranged from one day in emergency cases up to fifty seven days in cases with severe sepsis, intestinal fistula or necrotizing fasciitis and this had resulted in long hospital stay in such cases, with mean equals 19.15 and standard deviation of 11.33 as in Table (4).

In those presented with open fascial defect, out of twenty eight patients subjected to temporal vacuum assisted closure (VAC) as a bridge therapy for definitive closure, early primary closure was possible in only five patients (17.9%), in addition to two died cases, delayed primary closure could be done in another ten cases (35.7%), in addition to four died cases, while in the remaining thirteen cases (46.4%), creation of ventral hernia with secondary repair was done without any mortality and this is clear in (Figure 16).

The time allowed for wounds to granulate ranged from fourteen to forty nine days with mean 19.90 and standard deviation 8.93, after granulation tissue formation we could do skin graft or flap to cover the defect and create an incisional ventral hernia, the time spent while creating ventral hernia ranged from one hundred sixty six days to three hundred fifty six days with mean 239.93 and standard deviation 11.33.

Length as well as width of the defect was a major determinant factor in the choice of the techniques used for closure of the defect in cases with open abdomen, this is shown in (Table 6) as the defect length ranged from 15 -24, 12 -21 and 11 -23 cm in those underwent component separation technique, shoelace darn repair and propylene mesh repair respectively. While the width ranged from 10 -20, 8 -20 and 8 -18 cm respectively in the same order with no statistically significant difference between the three techniques.

Table (7) shows that the mean operative Time of final closure techniques was 161.06 ranging from 98 to 255 days and standard deviation of 48.17, it is also clear that the mean of the volume of blood loss was 232.23 ranging from 100 to 500 cc with standard deviation of 107.43.

Some complications had followed the final defect closure techniques such as wound infection in the three techniques with different percentages; 12.5% in component separation technique, 10% with shoelace darn repair and 7.7% with propylene mesh repair. Other complications included: hematoma in10% of shoelace darn repair and in 7.7% of propylene mesh repair cases while mesh infection was seen in 7.7% of propylene mesh repair cases (Table 8).

Length of hospital stay was nearly equal in the three modalities: in component separation it ranged from thirty seven to sixty seven days with mean 48.25 and standard deviation 11.07, in shoelace darn repair and propylene mesh repair respectively.
repair hospital stay ranged from thirty three to sixty six days with mean 45.20 and standard deviation 10.87, while in propylene mesh repair hospital stay ranged from twenty one to sixty seven days with mean 41.23 and standard deviation 12.91 (Table 9).

Recurrence rate was found to be low in those who underwent component separation technique (12.5%), Highest in shoelace darn repair (30.0%) with an intermediate incidence in patients with propylene mesh repair (23.1%) but with no significant statistical difference, and the time of recurrence is included in (Table 10).

All mortalities had occurred within cases presented to us with an open defect with no single case died among cases with covered defects or ventral hernias; this indicates that the cause of death was due to the associated original pathology rather than the defect itself or its repair; the mortality rate was (11.5%) with two cases died due to trauma, two cases died due to infection of recent laparotomy, one case died due to acute dehiscence and one case died during planning for relaparotomy as shown in (Table 11).

**Discussion**

The present work focuses on midline abdominal wall defects that cannot be closed primarily, often resulting from intra-abdominal catastrophes, or recurrent incisional hernias. In these patients, a
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A large fascial gap results from retraction of the rectus abdominis muscle prohibiting tension free primary closure of the fascia. In a considerable part of patients, these defects are accompanied by contamination or infection.

The open abdomen is becoming an increasingly common challenging problem for the general surgeon to manage. The OA is a planned surgical technique for managing damage control (DC) trauma patients, severe abdominal sepsis, intra abdominal hypertension (IAH), necrotizing infections of the abdominal wall and acute mesenteric ischemia [13], we agree with this statement as these were the etiologies in our patients in addition to abdominal wall tumours as desmoids tumour. It is a temporizing measure that allows a planned escape from the operating theater to control medical bleeding, correct metabolic derangements and hypothermia or facilitate repeated abdominal debridement or bowel resections.

Prolonged laparotomy in critically ill trauma victims has a high mortality, principally by worsening the synergistic effects of the vicious triad of trauma; hypothermia, acidosis and coagulopathy [14].

In an effort to reduce this mortality, Rotondo et al. [15] introduced the concept of damage control surgery (DCS); an abbreviated laparotomy to control hemorrhage and limit contamination and placement of the patient on the intensive care unit for aggressive restoration of normal physiology before a second laparotomy 24-48 hours later. In this situation temporary abdominal closure is quick to apply and remove, limits heat and fluid losses and simplifies nursing care, we successfully used this technique in our study in open abdomen cases.

<table>
<thead>
<tr>
<th>Technique of late closure</th>
<th>Component Separation technique (No=8)</th>
<th>Shoelace Darn Repair (No=10)</th>
<th>Propylene mesh Repair (No=13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital Stay (days)</td>
<td>Mean 48.25</td>
<td>45.20</td>
<td>41.23</td>
</tr>
<tr>
<td></td>
<td>Std Deviation 11.07</td>
<td>10.87</td>
<td>12.91</td>
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<td></td>
<td>Range 37 -67</td>
<td>33 -66</td>
<td>21 -67</td>
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ANOVA, P=0.413. No statistically significant difference.

**Table 9:** Hospital Stay in ventral hernia and in late closure of open Abdomen

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<td>Recurrence (12.5%)</td>
<td>3 (30.0%)</td>
<td>3 (23.1%)</td>
</tr>
<tr>
<td>Recurrence Time (months)</td>
<td>10</td>
<td>6.7. 11</td>
</tr>
</tbody>
</table>

Kruskal-Wallis Test. P = 0.676. No statistically significant difference

**Table 10:** Recurrence in 31 patients after ventral hernia repair and after late closure of open Abdomen

<table>
<thead>
<tr>
<th>Clinical Data of mortality</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cause of complete facial defect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdominal trauma</td>
<td>2</td>
<td>33.3%</td>
</tr>
<tr>
<td>Acute dehiscence</td>
<td>1</td>
<td>16.7%</td>
</tr>
<tr>
<td>Planned re-exploration</td>
<td>1</td>
<td>16.7%</td>
</tr>
<tr>
<td>Infection of recent laparotomy</td>
<td>2</td>
<td>33.3%</td>
</tr>
<tr>
<td>Indications of temporal ACS CS</td>
<td>2</td>
<td>33.3%</td>
</tr>
<tr>
<td>Intra abdominal sepsis due to contamination</td>
<td>1</td>
<td>16.7%</td>
</tr>
<tr>
<td>Underlying primary operation in complete defect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair of Traumatic perforation of colon</td>
<td>1</td>
<td>16.7%</td>
</tr>
<tr>
<td>Resection-anastomosis for gangrenous loop</td>
<td>2</td>
<td>33.3%</td>
</tr>
<tr>
<td>Necrotizing pancreatitis</td>
<td>1</td>
<td>16.7%</td>
</tr>
<tr>
<td>penetrating trauma with Intraperitoneal hemorrhage</td>
<td>1</td>
<td>16.7%</td>
</tr>
<tr>
<td>Blunt trauma with liver injury</td>
<td>1</td>
<td>16.7%</td>
</tr>
</tbody>
</table>

**Table 11:** Clinical Data of mortality cases

Figure 16: Types of closure after temporal VAC in “Open Abdomen”

Figure 17: Summary of work up

In an effort to reduce this mortality, Rotondo et al. [15] introduced the concept of damage control surgery (DCS); an abbreviated laparotomy to control hemorrhage and limit contamination and placement of the patient on the intensive care unit for aggressive restoration of normal physiology before a second laparotomy 24-48 hours later. In this situation temporary abdominal closure is quick to apply and remove, limits heat and fluid losses and simplifies nursing care, we successfully used this technique in our study in open abdomen cases.
Preoperative predictors for DCS include penetrating torso trauma with hypotension, the need for resuscitative thoracotomy, blunt abdominal trauma with intra peritoneal hemorrhage and hypotension, severe pelvic fracture with hypotension, or severe multicavitary trauma [16].

Laboratory values including; a base deficit < -6 in patients < 55 years of age or < -15 in patients > 55 years of age, lactate > 5 mmol/L, prothrombin time > 16, or partial thromboplastin time > 50 have been associated with the need for DCS and decreased survival [16].

Any of these factors in a trauma patient undergoing open laparotomy should prompt the surgeon to perform an abbreviated first procedure and use TAC.

In the present study, damage control techniques have been utilized in 12 trauma patients, 7 due to ACS, 5 patients requiring rapid abbreviated and planned resuscitation due to liver laceration with pack to control bleeding, lacerated cecum and transected duodenum with coagulopathy, hypothermia and metabolic acidosis.

Damage control techniques and use of the OA may also be utilized in other populations; patients with abdominal compartment syndrome, defined as sustained intra abdominal pressure > 25 mmHg without acute organ dysfunction should also be considered for prophylactic decompressive laparotomy. Lastly, patients at high risk for postoperative ACS should be left open prophylactically following completion of surgery. These patients include those requiring > 15 L of crystalloid, or 10 units of PRBC intra operatively or patients with increased peak inspiratory pressures > 40 mmHg upon fascial closure [17].

Patients with acutely increased intra abdominal pressures > 25 mmHg without acute organ dysfunction should also be considered for prophylactic decompressive laparotomy. Lastly, patients at high risk for postoperative ACS should be left open prophylactically following completion of surgery. These patients include those requiring > 15 L of crystalloid, or 10 units of PRBC intra operatively or patients with increased peak inspiratory pressures > 40 mmHg upon fascial closure [17].

The OA is also used in the management of "second-look" or staged laparotomy, which may occur after an embolic phenomenon or mesenteric venous occlusive disease. It is also employed in patients with severe abdominal sepsis necessitating repeated debridement, most specifically severe pancreatic necrosis. In our thesis, large contaminated abdominal wall defects occurred after infection of recent laparotomy wounds in 9 patients.

There appear to be two groups of patients with OA; the first group is relatively uncomplicated and can be closed within 4-7 days, these patients generally have a high rate of primary fascial closure and likely do well regardless of the choice of TAC [19]. In our study, five out of the thirty four open defect cases are present in this group. The second group, for many reasons, has more complicated and prolonged resuscitative efforts and hospital courses, the timing of abdominal closure in this group tends to extend beyond 7 days, generally to 20-40 days [20]. In our study, ten cases belong to that group.

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The rates of primary closure are much lower in these patients, and the type of TAC chosen may have a significant impact on their ability to achieve primary facial closure. Several risk factors have been found that predict a more prolonged or complicated course—and subsequently a diminished rate of primary closure; prolonged duration of OA, multisystem injuries, particularly colonic or duodenal and active infection [21].

Teixeira et al. [21] have also indicated that patients with conservative fluid resuscitation (< 20 L) and fewer transfusions, or a net negative fluid balance, have improved rates of primary closure.

In our patients, regardless of the initial cause, the acute recovery period were managed by temporary abdominal wall closure. Unfortunately none of the techniques described so far controls the release of the often large volumes of exudate that are liberated from the partially exposed edematous bowel. In order to address this worry, wall suction was utilized to extract the fluid from beneath a temporary abdominal closure; so called ‘Vacuum pack’ therapy. The application of negative pressure was also postulated to increase closure rates. Barker et al reported a series of 112 patients treated in this manner over a 7 year period with a 55% primary fascial closure rate, although if the patients who died before abdominal closure was attempted are excluded this would rise to 69% [22].

In our study, we agree with this as the rate of primary closure (either early or late) is 44% but if we exclude the mortalities from calculation, the rate will rise to 53%. Delays beyond 6 days from injury were however associated with a much lower chance of success of primary closure because of fascial retraction and adherence of the viscera to the abdominal wall.

Quyn et al. [23] suggested that VAC induces some degree of tissue stretching, a stimulus to increased proliferation, angiogenesis and promotion of matrix synthesis. Vacuum-assisted closure is an evolution of the ‘do-it-yourself’ vacuum dressings that utilizes sub-atmospheric pressure to manage a variety of acute and chronic wounds including the open abdomen.

A purpose made fenestrated non adherent sheet is placed over the abdominal cavity to retain the contents and prevent their adhesion to the abdominal wall. The defect between the two fascial edges of the abdominal wall is then filled with a foam sponge cut by the surgeon to fit precisely. The whole abdomen is then covered by an adhesive drape for at least 5cm beyond the wound edges and the end of a length of suction tubing is embedded in the sponge through a small cut in the top drape.

Intermittent suction increases the amount of granulation tissue in a healing wound by 13% compared to continuous suction. The majority of the evidence for VAC therapy comes from small non-

![Figure 20: Stages of delayed primary closure after 15 days of vacuum pack dressing](image)

![Figure 21: Severe wound gapping and skin changes in a patient after two laparotomies with intestinal resections for mesenteric ischaemia following remote splenectomy](image)
randomized trials, animal studies or experimental data relating to VAC for chronic wound management, although some of the advantages may also be applicable to open abdominal wounds.

The overwhelming aim of VAC therapy however is to improve management of the open abdomen to decrease the rate of planned ventral hernia, requiring subsequent reconstructive surgery, by maximizing the rate of delayed primary fascial closure.

In the present series, out of 34 patients treated with VAC, 15 had primary closure (44%); 5 within 3 days and 10 within 17 days, with a mortality of 17%. Quyn et al. [23] reported similar results. The highest delayed primary closure rates were seen with the Wittmann patch and VAC.

This three-layered vacuum pack was able to maintain visceral containment, prevent desiccation and allow continuous evacuation of peritoneal fluids. The authors achieved primary fascial closure in 68% of patients with a 5% incidence of fistula formation [19].

Boele van Hensbroek et al. [24] have reported success using similar systems with primary fascial closure rates ranging from 35% to 92% (usually > 50%). Fistula rates ranged from 0% to 15% with an average of 5.7%.

In our series, the rate of fistula was two cases (15.3%) which is much more lest than these, this difference may be explained by a difference in the nature of cases and the method and place of case collection.

The principle worry when using VAC over exposed bowel is one of entero-cutaneous fistula, especially if there are exposed intestinal anastomoses, given that fistula in these circumstances rarely heal with conservative management compared to 80% healing rates seen when the abdominal wall is intact [23,25].

This complication has been reported in most series reporting treatment of the open abdomen. The bowel is vulnerable during dressing changes and further surgery, edema, adhesions, ischemia and malnutrition increase the risk of injury [26].

Miller et al. [20] reported only a single fistula in 53 successive patients (1.89%) treated with the commercial VAC system. Where as in present work, the fistulation occurred in 2 out of 34 patients (5.9%) with VAC.

Teiseira et al. [21] suggested that the risk of fistula is increased with intra abdominal sepsis and anastomoses directly underneath the vacuum pack, particularly colonic or duodenal ones. Fistula rates were also increased by an increased duration of OA and in patients in whom primary closure was not possible.

In vacuum pack “sandwich” technique, the visceral sac is first wrapped by a polyethylene sheet which is tucked between the bowel and the abdominal wall to be a physical barrier that prevents adhesion formation between the bowel and the abdominal wall. In other words, it preserves the peritoneal space and greatly delays the onset of “frozen abdomen”.

Many patients were treated with the VAC device up to 14 days, and at that time, skin grafts were placed on granulated mesh or bowel. As the authors have gained experience, VAC times longer than 14 days have allowed primary closure of abdominal wounds previously thought un closable during the same hospital stay. Time to definitive closure of all layers of the abdomen without a hernia was, therefore, dramatically reduced and a second delayed closure procedure was avoided.

Towel clips and sutures can tear soft tissue or fascia and damage the tissue needed for final abdominal wall closure. When used in combination or in sequence with traditional reconstructive procedures, therapy with VAC has provided early quality closures of the abdominal wall. Large defects associated with a great deal of inflammation or contamination can be shrunk with the use of VAC [27].

Following stabilization of the patient and resolution of the inflammatory process, 13 of 34 patients with open abdomen, in present work, failed to be closed primarily due to several causes; entero cutaneous fistula in two patients, persistent abdominal sepsis in one patient, need of debridement in one patient and large fascial defect in nine patients.

In the presence of sepsis or multiple organ dys function, the patient typically continues to accumulate fluid and interstitial edema, a process that may take weeks to resolve. Lateral retraction of the wound edges results in a progressively larger gap in the fascia [9].

From the perspective of abdominal closure, the granulation process obliterates the peritoneal space between the abdominal wall and the abdominal visceral mass, so that the abdominal contents get adherent to the undersurface of the anterior abdominal wall. If the abdomen cannot be closed by the end of the first week, granulation tissue starts to develop, and a “frozen abdomen” is evident by the end of the second week, this creates a hostile environment for early fascial closure and thus necessitates secondary staged fascial closure methods [28].

This “frozen abdomen” precludes definitive abdominal closure because it is impossible to mobilize the abdominal wall off the adherent bowel loops [29].

The granulating wound is thus covered with a skin graft and allowed to undergo gradual contraction and maturation over several months, the so-called “planned ventral hernia”, a concept first introduced by Fabian et al as a safe strategy for managing the open abdomen [9].

Our policy for the management of these patients, based on recent advances in literature, had been to continue with vacuum pack which is to be changed every 48 hours, allowing granulation tissue to cover intestine followed by Split-thickness skin graft applied when granulation tissue was adequate. Skin graft can be removed later from the wound bed and definitive closure of the abdominal wall can be achieved.

Initial skin graft closure of open abdominal wounds in patients with a frozen abdomen is advantageous for several reasons; it allows wound control and a return to normal homeostasis and in patients with fistula, skin grafting improves comfort allowing application of an ostomy appliance, in addition, skin grafts have a low morbidity. Once control of the abdominal cavity and wound is accomplished, attention can be directed towards a delayed definitive closure of the defect. Time to definitive closure of the abdominal wall has varied from as little as 6 months to well over 2 years from the time of initial injury [28].

The time allowed for wounds to granulate in 13 of our patients with open abdomen ranged from fourteen to forty nine days with a mean of 19.90 +893 days and the time for creating ventral hernia ranged from 166 - 356 days with a mean of 233.93 ± 60.27 days.

As with many surgical techniques, it is not the particular operation that has failed or has been met with success, but instead it is the choice of procedures that is of utmost importance. No one procedure is ideal for all situations and it is therefore incumbent upon the surgeon to select the proper procedure to fit the particular needs of the situation. In addressing complicated defects of the abdominal wall, the components separation technique can be viewed as simply a part, albeit a very important one, of the armamentarium necessary to address these deficits based upon their location, depth of the defect, timing of presentation, background milieu of the wound bed and the patient himself or herself. Rohrich and colleagues, in 2000 and Mathes and colleagues, also in 2000, had addressed this issue, each with their own approach and algorithms. Several techniques have been described to repair created ventral hernias [30].

In our work, three methods had been utilized for final reconstruction of complex midline anterior abdominal wall defects;

- repair with autologous tissue to bridge the fascial gap, using components separation technique (CST).
- prosthetic repair to bridge fascial defects.
- Shoelace repair.

The CST is a useful technique for large midline abdominal hernias.
Proposed benefits of this procedure focus on its use of innervated vascularized autologous tissues for reconstructing anterior abdominal wall defects. Additionally, beyond providing a tensionless closure, the use of these innervated myofascial flaps helps to recreate the dynamic nature of the native abdominal wall.

Ger and Duboys [31] recognized the benefits of innervated contractile muscle over denerve fascia or synthetic mesh, citing its ability to better resist strain and to better redistribute tension over the broad expanse of the abdominal wall.

Components separation is ideal for large midline myofascial defects. Bilateral relaxing incisions and release allow for approximately 12 cm, 22 cm and 10 cm of advancement in the upper, middle and lower thirds of the abdomen respectively [32].

In present work, component separation technique corrected defects 10-20 cm in width. Although the component separation technique is an attractive method for the reconstruction of abdominal wall defects, this method has five major disadvantages: First, the reherniation rate is relatively high, this might be related to the rather complex hernias which were included in the study and the 35% of reconstructions that were done under contaminated conditions but because no reasonable alternative for reconstruction under these circumstances is available, the component separation technique seems to be valuable. Second, the skin and subcutaneous tissue must be mobilized over a large distance to reach the aponeurosis of the external oblique muscle, which is retracted far laterally into the flank, this creates a large wound surface that covers the whole ventral abdominal wall from the costal margin to the pubic bone and predisposes to hematoma or seroma formation and infection. Also, mobilization of the skin and subcutaneous tissue endangers its blood supply, which can lead to skin necrosis in the midline. If the musculocutaneous perforators of the epigastric artery are transected, the blood supply of the skin depends solely on the intercostal arteries.

Interference with the blood supply from the intercostal arteries by scars, enterostomies, or even drains can result in skin necrosis, as was found in 20% of the patients in the study by Lowe and colleagues in 2000, here in our study the skin necrosis had occurred in 12.5% of those undergoing CST. Third, the technique de-stabilizes the outer layer of the abdominal wall, allowing shifting of the skin in relation to the underlying myopneurotic tissue, this makes application in patients with enterostomies difficult. Under these circumstances, we now use a modified technique in which separate incisions are made just lateral to the rectus sheath for transection of the aponeurosis of the external oblique muscle, in this way, the wound surface is markedly reduced and the blood supply to the skin via the dominant musculocutaneous perforators of the epigastric artery is preserved. A well vascularized compound flap is created that can be advanced to the midline. Existing enterostomies can be left in place and new enterostomies are facilitated because shifting of the skin in relation to the rectus muscle has been prevented [33].

Wound complications are reported in about a quarter of patients, this is explained by the very large wound surface, averaging 700 cm², which is created by mobilizing the skin and the subcutaneous fascia from the ventral abdominal wall muscles, in combination with transection of the peri umbilical epigastric perforating arteries, thus compromising the blood supply of the skin. Transection of the external oblique muscle and mobilization from the underlying internal oblique muscle further enlarges the wound surface and these very large wounds are predisposed to seroma and hematoma formation, also skin necrosis may occur because the blood supply to the ventral abdominal skin is insufficient especially when the blood supply via the intercostal, superficial circumflex iliac and external pudendal arteries is compromised owing to previous transverse or subcostal incisions [34].

Seroma and hematoma formation and the compromised blood supply of the skin in concert with long operations, sometimes performed in a contaminated field, predispose to the development of wound infections and these were found in about 20% of patients [35].

Because all but one of the series are retrospective and the method of wound surveillance and follow up are mentioned in only three studies, the overall complication rate is probably underestimated [35]. It is remarkable that after CST, which is frequently complicated by wound healing disturbances, reherniation rates of less than 10% have been reported.

In the study by de Vries Reilingh et al. [36], which exhibited the highest rate of recurrence (32%), midline fascial closure was achieved using an absorbable running suture of polydioxanone (PDS-loop).

Prosthetics require reliable skin and subcutaneous coverage and an adequate wound bed. The main problem with mesh material is that it provides no dynamic support to the abdominal wall. Problems occur at the interface between the dynamic native abdominal tissues and the static prosthetic mesh material. Fistula formation and infection are potential complications, but in most series are below 3%. Attempts should be made to interpose omentum between bowel and mesh to avoid adhesions.

The ideal prosthetic material for abdominal wall repair is not available. In very large hernias, where the peritoneum and/or the greater omentum are often lacking, dense adhesions to the bowels or damage to the intra abdominal viscera may occur when polypropylene is used [37].

**Figure 22**: Intraoperative steps of an elective incisional hernia repair with on lay prosthetic placement
The ideal prosthesis combines two conflicting properties: incorporation of the mesh into the fibrocollagenous tissue for adequate anchorage to the adjacent fascia and no adhesions to the mesh. Moreover, prosthetic repair increases the risk of infection, which is a major risk in patients with large hernias since wound complications are frequent.

De Vries Reilingh et al. [35] carried out a RCT comparing CST and prosthetic repair in patients with giant midline abdominal wall hernias. Both procedures produced a similar high wound complication rate; hematoma in 5%, seroma in 28%, skin necrosis 13% and wound infection in 5%. This coincides with our findings. These complications had major consequences for patients who underwent prosthetic repair, as the prosthesis had to be removed owing to infection in 38%.

Reherniation, including that in patients with explanted the prostheses, occurred in 60% after prosthetic repair and 53% after CST, at a follow-up of 24 months.

The shoelace darn repair is superior to re-suture or synthetic nonabsorbable mesh repair for the following reasons [38]:

1. Quick, easy, extra-peritoneal method that simply returns the unopened hernial sac and its contents to the abdominal cavity and thus avoids the tedious and perhaps risky dissection of the adherent loops of the bowel on the inner surface of the sac required in the re-suture and in the mesh repair.
2. The repair restores the functional anatomy of the abdominal wall as it reconstructs a strong new linea alba and allows the rectus muscles to straighten and lie along side each other at the midline, it also reconstructs the anterior rectus sheaths and fixes them to the new linea alba.
3. Tension free repair.
The shoelace darn repair, in present series, had comparable results as CST and prothetic repair as regards incidence of the postoperative complications, hospital stay and recurrence rate.

Abrahamson and Elder [38] wrote that he has no deaths and 2% recurrence; he concluded that since the operation is entirely extra peritoneal and technically relatively simple and quick, it is eminently suitable for elderly patients with other general medical problems.

Conclusion

• The management of patients with open abdomens is an evolving concept.

• Certain techniques for managing the open abdomen patients can be effective in treating ACS.

• A Temporal Abdominal Closure should not only protect the intra-abdominal contents, but facilitate primary closure of the fascia and minimize the need for secondary repairs of ventral hernias and subsequent repair.

• Serial bladder pressure monitoring should be a part of postoperative management protocols in high-risk patients and decompression of the abdomen with a pressure of > 25-30 mmHg should be considered even without clear clinical evidence of ACS.

• While many closure techniques are reported in the literature, a dynamic closure technique, such as Vacuum pack appears to have an advantage in meeting most requirements for managing an open abdomen.

• IAH and ACS remain the most significant considerations for the management of the open abdomen.

• Complications found in patients with open abdomens may be minimized with Vacuum pack Therapy resulting in early closure of the abdomen.

• Consideration for the type of closure is based on the patient's clinical status with the optimal result of primary fascial closure.

• When the fascia cannot be closed, skin over granulation tissue is preferred to skin grafting over granulation tissue to create ventral hernia.

• Several techniques have been described to repair created ventral hernias.

References


