The Separation of Anatomic Components Technique for the Reconstruction of Massive Midline Abdominal Wall Defects: Anatomy, Surgical Technique, Applications, and Limitations Revisited

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Learning Objectives: After studying this article, the participant should be able to: 1. Describe the anatomic muscle complex that is advanced toward the midline in the separation of components method of abdominal wall repair. 2. Understand the indications for components of separation reconstruction of the abdominal wall and the maximum transverse defect width that can be reconstructed at various levels. 3. Describe the course of the intercostal nerves lateral to the linea semilunaris line as they run posterior to anterior. 4. Understand the plane of dissection necessary to develop this muscle complex and be aware of the technical maneuver to increase the mobility of this complex at the costal margin, waist, and suprapubic area.

Reconstruction of massive abdominal wall defects has long been a vexing clinical problem. A landmark development for the autogenous tissue reconstruction of these difficult wounds was the introduction of “components of anatomic separation” technique by Ramirez et al. This method uses bilateral, innervated, bipedicled, rectus abdominis-transversus abdominis-internal oblique muscle flap complexes transposed medially to reconstruct the central abdominal wall. Enamored with this concept, this institution sought to define the limitations and complications and to quantify functional outcome with the use of this technique. During a 4-year period (July of 1991 to 1995), 22 patients underwent reconstruction of massive midline abdominal wounds. The defects varied in size from 6 to 14 cm in width and from 10 to 24 cm in height. Causes included removal of infected synthetic mesh material \( n = 7 \), recurrent hernia \( n = 4 \), removal of split-thickness skin graft and dense abdominal wall cicatrix \( n = 4 \), parastomal hernia \( n = 2 \), primary incisional hernia \( n = 2 \), trauma/enteric sepsis \( n = 2 \), and tumor resection (abdominal wall desmoid tumor involving the right rectus abdominis muscle) \( n = 1 \). Twenty patients were treated with mobilization of both rectus abdominis muscles, and in two patients one muscle complex was used. The plane of “separation” was the interface between the external and internal oblique muscles. A quantitative dynamic assessment of the abdominal wall was performed in two patients by using a Cybex TEF machine, with analysis of truncal flexion strength being undertaken preoperatively and at 6 months after surgery. Patients achieved wound healing in all cases with one operation. Minor complications included superficial infection in two patients and a wound seroma in one. One patient developed a recurrent incisional hernia 8 months postoperatively. There was one postoperative death caused by multisystem organ failure. One patient required the addition of synthetic mesh to achieve abdominal closure. This case involved a thin patient whose defect exceeded 16 cm in width. There has been no clinically apparent muscle weakness in the abdomen over that present preoperatively. Analysis of preoperative and postoperative truncal force generation revealed a 40 percent increase in strength in the two patients tested on a Cybex machine. Reoperation was possible through the reconstructed abdominal wall in two patients without untoward sequela. This operation is an effective method for autogenous reconstruction of massive midline abdominal wall defects. It can be used either as a primary mode of defect closure or to treat the complications of trauma, surgery, or various diseases. (Plast. Reconstr. Surg. 105: 731, 2000.)

The objectives of abdominal wall reconstruction include restoring structural support, providing stable soft-tissue coverage, and optimizing aesthetic appearance. Reconstruction of
small midline defects (less than 5 cm in width) is most often accomplished with medial advancement of adjacent abdominal wall structures, provided that these tissues are available, well vascularized, and mobile, i.e., not fixed by cicatrix or scar.

When full-thickness abdominal wall defects become larger than 6 cm in diameter, closure has most often required the application of synthetic mesh. Autogenous tissue options include the transposition of local or regional musculocutaneous or musculofascial flaps and, occasionally, the provision of a free flap transfer. These procedures involve donor-site morbidity in the form of significant scarring and contour deformity; often they do not provide adequate structural support, thus entailing the addition of synthetic mesh material. Transferred flaps are usually denervated, and subsequent atrophy of the muscle component with the predictable occurrence of tissue laxity will occur. Hence, a predisposition to recurrent abdominal wall protuberance is entailed if the surgeon does not reinforce the initial autogenous repair with synthetic mesh.

The complication rate accompanying the use of synthetic mesh is significant, however, with the most dreaded complications being infection, extrusion, and enterocutaneous fistula formation. Therefore, an autogenous tissue repair that reliably restores the structural integrity of the abdominal wall without the use of synthetic material would be a very important addition to the treatment of massive defects midline (herein defined as defects greater than 6 cm in transverse dimension) of the abdominal wall.

The causes of such substantial defects are diverse. They can be primary, i.e., occurring as the result of a traumatic injury or surgically created, most often resulting from tumor resection. However, they are most often secondary, the result of a previous problem such as an incisional or parastomal hernia, a failed hernia repair, and problems with a previous synthetic mesh repair, including infection or extrusion.

In 1990, Ramirez and colleagues published a report on the “components separation” method of abdominal wall repair in which they outlined the principles and technique of an operation that uses the medial advancement of an innervated composite of muscle and fascial tissues to reconstruct such massive midline defects and reviewed their experience with 19 patients treated for massive abdominal wounds. We were enamored with this approach and have used it in 22 patients with massive midline full-thickness defects of the abdominal wall. This report summarizes our observations regarding the utility and limitations of this procedure.

**Patients and Methods**

From 1991 to 1995, we treated 22 patients with complex, full-thickness midline abdominal wall wounds. The causes were diverse and included removal of infected synthetic mesh material \((n = 7)\), recurrent hernia \((n = 4)\), removal of split-thickness skin grafts and dense abdominal wall cicatrix \((n = 4)\), parastomal hernia \((n = 2)\), primary incisional hernia \((n = 2)\), trauma and enteric sepsis \((n = 2)\), and tumor resection (abdominal wall desmoid tumor involving the right rectus abdominis muscle) \((n = 1)\). There were 17 female and 5 male patients. One patient underwent primary repair after the resection of two desmoid tumors of the abdominal wall, involving the right rectus abdominis muscle. The remaining 21 patients were treated for defects arising as sequelae of complicated abdominal problems, such as trauma, intraabdominal sepsis, massive incisional hernia, recurrent incisional hernia, failed previous mesh repair, synthetic mesh infection or extrusion, and recurrent parastomal hernia.

All defects were greater than 6 cm in transverse dimension and were of variable superior to inferior dimensions. Defects ranged in size from \(84 \text{ cm}^2 (7 \times 12 \text{ cm})\) to \(375 \text{ cm}^2 (15 \times 25 \text{ cm})\) in dimension. Measurements of transverse defect dimension at the xiphoid area, waist region, and suprapubic region were recorded preoperatively in every case. All operative procedures were performed under general anesthesia. Suction drains were used routinely, and patients were maintained on nothing-by-mouth status postoperatively until the return of bowel function marked by the passage of flatus.

**Defect Analysis and Operative Technique**

The exact size and position of the defect relative to the anatomic midline and level of the umbilicus are noted. The surgeon must also carefully analyze the quality, position, vascularity, and mobility of the skin and muscle structures on both sides of the defect.

It is also extremely important to determine whether or not there is evidence of missing tissue, i.e., whether each rectus muscle is...
present in its entirety or whether portions of the rectus muscle are absent. In our experience, the abdominal wall structures are most often present but are frequently attenuated or displaced. In the event that only one rectus muscle is available, it is still possible to use this single muscle unit but the size of the defect that can be reconstructed is diminished. The maximum mobility of each rectus muscle unit is illustrated in Figure 1.

The procedure is begun by elevating the skin flaps off of the underlying abdominal musculature in a lateral direction toward the anterior axillary line (Fig. 2). Next, the linea semilunaris is noted, along with the insertion of the external oblique fascia. A vertically oriented incision parallel with the linea semilunaris is made 1 cm lateral to it to identify and develop the plane beneath the external oblique fascia but superficial to the internal oblique fascia (Fig. 2). One must be careful not to dissect deep to this layer to avoid injuring the internal oblique fascia or muscle. Deep dissection here may damage the segmental innervation of the rectus abdominis muscle or injure the Spigelian fascia, thus predisposing the patient to a Spigelian hernia. Generally, the planes are quite distinct (Fig. 3).

The dissection proceeds in this relatively avascular intermuscular plane and is continued in a lateral direction beyond the area of skin undermining to at least the level of the mid-axillary line (Fig. 3). At this point, the mobility of the innervated rectus abdominis-internal oblique-transversus abdominis muscle complex is determined. If additional mobility of these structures on either side of the midline is desired, then the dissection in the intermuscular plane can be continued to the posterior axillary line. In our experience, each ipsilateral complex can be advanced toward the midline 4 cm in the upper abdomen, 8 cm at the waist, and 3 cm in the lower abdomen as noted in Figure 1.

In the rare instance that additional advancement is needed, the rectus muscle can be elevated off of the posterior rectus sheath in its entirety. Two centimeters of additional advancement can be obtained at each level by using this maneuver (Fig. 2). However, the surgeon must leave the anterior rectus fascia intact to allow secure suture placement. The muscles are joined together in the midline with an interrupted closure by using strong nonabsorbable suture (0 Surgillon is our preference). The skin flaps are then also advanced to the midline and approximated in a layered closure. Four suction drains are used routinely, and these are positioned in the plane between the oblique muscles and beneath the skin flaps on each side of the midline and brought out through separate stab incisions in the pubic area, lateral abdomen, or both. They are maintained until the drainage decreases to less than 30 cc per 24 hours, which is usually at an average of 7 days. Patients are maintained on nothing-by-mouth status until the resumption of bowel function. Nasogastric tubes are used if extensive intraabdominal dissection is required as part of the procedure.

**Results**

There were 14 male and 8 female patients with a mean age of 47 years. Follow-up ranged between 84 and 44 months with a mean follow-up of 52 months.

Primary repair of the abdominal wall defect after mobilization of the innervated rectus abdominis-internal oblique-transversus abdomi-
nis muscle complex was possible in all but one patient. Closure of the overlying skin flaps raised as a separate layer was accomplished in 20 of the 22 patients, with two patients requiring the additional placement of a split-thickness skin graft. Patients were hospitalized for an average of 8 days after surgery, and the suction drains (10 mm Jackson-Pratt, Zimmer, Dover, Ohio) were used for an average of 7 days postoperatively. No reoperations were required in the acute phase of recovery after the initial procedure. Acute complications included wound infections in two patients, which were limited and were treated in the office by opening a small segment of the wound. There was one seroma, which was aspirated postoperatively in an outpatient setting.

The midline abdominal scars showed signs of spreading in virtually all patients, but no scar sensitivity or keloid formation was noted. There were two instances of localized wound separation, which healed by secondary intention.

In one very thin, extremely cachectic patient, closure of the defect resulted in difficulty with ventilation intraoperatively, which was immediately noted by the anesthesia service. This patient had a long-standing open wound, and we believed the ventilatory difficulty was caused by the “loss of domain” phenomenon. In this case, the problem was addressed at the primary operation by taking down the midline fascial repair and interposing Prolene mesh to increase the intraabdominal volume. This patient’s skin wound healed uneventfully, and there were no other complications. This was the only case in which supplemental synthetic mesh was needed.

There was one perioperative death. The patient who died had multiple medical problems and death was believed to be caused by a multiple organ system failure.

Long-term complications included one recurrence of an incisional hernia noted 8 months postoperatively in a morbidly obese (5 feet, 5 inches tall, 325 pounds) diabetic patient who underwent emergency laparotomy for an incarcerated incisional hernia with infarcted bowel. There were no other instances of compromise of the abdominal wall repair.
All patients reported a subjective increase in abdominal wall strength and significant improvement in the ease of performing activities of daily living. Two patients underwent quantitative assessment of truncal flexion strength preoperatively and 6 months postoperatively by using a Cybex TEF (truncal extension-flexion) machine. This apparatus was used to assess abdominal flexion force generation capability. Both patients demonstrated an approximately 40 percent gain in truncal flexion force generation capability after the operative repair of their abdominal wall region.

**DISCUSSION**

Reconstruction of massive full-thickness defects involving the abdominal wall has always represented a formidable challenge to the reconstructive surgeon. Not only are such defects frequently unsightly, but they also produce ab-
dominal wall weakness with marked contour abnormality and protuberance of abdominal viscera (Fig. 4). These sequelae from such massive defects often interfere with the patient’s customary activities of daily living.

As previously mentioned, many defects of the midline region can be reconstructed by the mobilization and medial advancement of abdominal tissues adjacent to the defect. This technique is most often used to repair small defects, namely those that are less than 5 cm in width. This is only possible if the abdominal wall tissues are not fixed by scar. Unfortunately, scar formation is frequently encountered, and this finding may result in the immobility of abdominal wall tissues.

A major advance in restoring structural integrity by using autogenous tissue was developed by Wangensteen, who reported the use of a tensor fasciae latae musculofascial flap to reconstruct defects of the lower abdomen. This procedure, which was used for large defects, was extensive in scope and required a turnover of abdominal fascia tissue. It produced significant scars on both the abdomen and thigh tissues. Ger and Duboys described muscle flap transposition to reconstruct full-thickness defects of the abdomen, but such a strategy often results in a muscle atrophy and eventual abdominal protuberance because of the laxity of the muscle tissue. This process is caused by the obligatory denervation that occurs at the time of muscle flap transfer.

Ramirez and coworkers introduced the concept of “components separation” for closure of abdominal wall defects in 1990. Their anatomic studies revealed that separating the external oblique fascia with an incision just lateral to the linea semilunaris allows the surgeon to develop and open the plane between the external oblique and internal oblique muscles all the way to the posterior axillary line if necessary (Fig. 3). This method produces immediate mobility of the ipsilateral rectus abdominis muscle–internal oblique–transversus abdominis muscle complex and allows significant freedom for medial transposition of this entire complex.

Surgical dissection and separation in this avascular plane totally preserves the innervation of the rectus abdominis muscles, because the intercostal nerves supplying this muscle run deep to the fascia of the internal oblique muscle lateral to the linea semilunaris. This innervated muscle complex can be advanced approximately 4 cm at the subxiphoid level, approximately 8 cm at the waist region, and 3 cm in the suprapubic region on each side, allowing the surgeon to reconstruct defects up to 16 cm in width at the waist level. An additional small amount of medial advancement (2 cm on each side) can be obtained by separating the deep surface of the rectus abdominis muscle from the underlying posterior rectus sheath above the arcuate line. This procedure can contribute an additional 2 cm of medial advancement for each muscle complex (Fig. 1).

Therefore, it is possible to close extremely large midline defects in a single operation with minimal morbidity. Two illustrative cases follow.

Fig. 6. Anterior view of 14 × 26 cm abdominal wall defect after treatment for abdominal sepsis. Patient has Marlex mesh placed over the abdominal viscera with an end colostomy having been placed through the left rectus muscle.

We were asked to evaluate a 19-year-old woman who sustained an accidental gunshot wound of the abdomen, necessitating a splenectomy, left nephrectomy, and repair of multiple enterotomies, including an injury to the colon at the splenic flexure. After five opera-
tions, she was left with a $12 \times 25$ cm defect of the midabdomen with a split-thickness skin graft on the abdominal viscera (Fig. 4). Both rectus abdominis muscles were present but laterally displaced. The patient was treated with skin graft removal and a bilateral separation of anatomic components, which provided complete closure of the defect with no untoward sequela at a 3-year follow-up (Fig. 5).

Additionally, we treated a 35-year-old woman with a $14 \times 26$ cm defect resulting from intra-abdominal sepsis secondary to a left colon perforation. She was eventually treated by the general surgical service with an end colostomy and the application of Marlex mesh (Fig. 6). Reconstruction of this defect included removal of the mesh, colostomy takedown, and colon re-anastomosis followed by bilateral separation of anatomic components for abdominal wall reconstruction. The patient recovered uneventfully and is asymptomatic with normal abdominal wall muscle function at 4 years postoperatively (Fig. 7).

Our clinical case experience confirms the safety and utility of this procedure as described in the previous study. All but one patient in our series achieved abdominal wall reconstruction without the use of synthetic material. The one case in which the addition of mesh as part of the repair was required was interesting in that this involved an extremely thin patient with a long-standing open wound. The innervated and dynamic rectus abdominis-internal oblique and transversus abdominis muscle complex could be approximated in the midline. However, because of the thin body composition, there was difficulty in ventilating the patient noted at the time of repair, owing to an abrupt decrease in intraabdominal volume at the time of defect closure. For this reason, we could not allow the muscle complexes to remain together in the midline, and out of necessity we interposed a piece of synthetic mesh with a width of 4 cm to allow sufficient intraabdominal volume to permit normal diaphragmatic excursion. It is important to note that this phenomenon was not a clinical problem in any of the other cases.

This operation is relatively straightforward. The surgeon must carefully identify the thin layer of the external oblique fascia and avoid dissecting beneath the internal oblique fascia just lateral to the linea semilunaris. If dissection is not limited to the external oblique-internal oblique interface, a weakness in the lateral aspect of the abdominal wall and the potential for a Spigelian hernia are present. This surgical dissection plane is usually quite
distinct and easily developed, even in the setting of previous surgery (Fig. 3).

Because of the extensive intermuscular tissue plane dissection and undermining of abdominal skin flaps, prolonged suction drainage is sometimes necessary. Our patients have tolerated this without difficulty. We believe that it is important to withhold oral alimentation until the resumption of normal bowel function to minimize problems with postoperative abdominal distention. Wound complications and other problems have been minimal and included superficial wound infection \(n = 2\), seroma \(n = 1\), and recurrent midline abdominal wall hernia \(n = 1\).

The one hernia recurrence was in a morbidly obese diabetic female patient (5 feet 5 inches tall, 325 pounds) who returned approximately 8 months after emergency laparotomy for an incarcerated hernia with infarcted bowel. Her midline repair remained well healed up to this time, and there was no specific event producing the recurrence. Perhaps the weight of her abdominal wall pannus was a predisposing factor for this recurrence.

Postoperative evaluation of our patients included a subjective assessment of each patient’s performance capability. There was uniform attestation of a marked subjective increase in ability to perform activities of daily living, most importantly in the ability to more comfortably fit and wear clothing.

In two patients, we attempted to quantify abdominal flexion force generation capability by using a Cybex machine. In both of these patients who were studied preoperatively and 6 months after surgery, there was a substantial increase in force generation capability of 40 percent when compared with the preoperative performance in both patients.

In summary, we think that the method of separation of anatomic components of the abdominal wall greatly simplifies and facilitates reconstruction of massive midline defects. This procedure provides a dynamic autogenous tissue repair and avoids additional donor-site morbidity. It can be used only if there is an intact and innervated rectus abdominis muscle(s). The rectus abdominis muscle function is completely preserved with the dissection as outlined. We strongly recommend this as the procedure of choice for the autogenous tissue reconstruction of massive midline defects of the abdominal wall.
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1. The motor innervation of the rectus abdominis muscle arises through intercostal nerves
   A) 7 through 12
   B) 6 through 11
   C) 6 through 12
   D) 7 through 11

2. The anatomic position of these nerves lateral to the linea semilunaris as they course from posterior to anterior is
   A) Within the external oblique muscle fibers
   B) In the interface between the external oblique and internal oblique muscles
   C) Deep to the internal oblique muscle fascia and within the substance of the internal oblique muscle
   D) Within the transversus abdominis muscle

3. Surgical dissection deep to the internal oblique fascia just lateral to the linea semilunaris may result in which of the following hernias
   A) Spigelian
   B) Bochdalek
   C) Obturator
   D) Richter's

4. The use of synthetic mesh in abdominal wall hernia repair is associated with an increase in which of the following complications?
   A) Recurrent hernia
   B) Enterocutaneous fistula
   C) Chronic sinus tract formation
   D) All of the above

5. When using the separation of anatomic components method for abdominal wall reconstruction, the amount of mobilization of the
   rectus abdominis muscle is the same at all of the levels of the abdominal wall.
   A) True
   B) False

To complete the examination for CME credit, turn to page 825 for instructions and the response form.