Chapter

Refinements and Advancements in Anterior Component Separation

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Abstract

This chapter will explore the newest innovations for performing anterior component separation (CS). It will include open CS, perforator sparing CS and minimally invasive component separation (MICS). It will also address the use of various meshes and their plane of inset. It will cover soft tissue management including panniculectomy, quilting sutures and drains. Fascial closure techniques will also be included. The highlight of this chapter will be the description of tips and tricks of performing MICS. We will also touch upon preoperative preparation such as body mass index (BMI) optimization and smoking cessation as well as management of postoperative complications including surgical site infections, skin necrosis and seroma.

Keywords: hernia, mesh, component separation, abdominal wall

1. Introduction

Abdominal wall domain and function is maintained by balancing the centripetal forces exerted on the abdominal wall by the internal organs with the centrifugal forces exerted by the combined action of the musculofascial abdominal wall. This musculoaponeurotic girdle consisting of a layered muscle arrangement coalescing into a static ligamentous supports can be broadly subdivided into the ventral abdominal wall and the lateral abdominal wall. The ventral abdominal wall comprises of longitudinally oriented rectus abdominis muscles encased in the anterior and posterior rectus sheath bounded centrally by the linea alba. It extends from the xiphoid process to the pubic symphysis. The lateral abdominal wall consists of a layered arrangement the external oblique, internal oblique, transversus abdominis and transversalis fascia. It extends from the costal margins superiorly to the iliac crest inferiorly and the linea semilunaris anteriorly to the thoracolumbar fascia posteriorly. The linea alba, linea semilunaris, and thoracolumbar fascia serve as a static attachment points for these muscles and translate their circumferentially and longitudinally oriented force vectors to generate centrifugal forces necessary to contain the internal organs and maintain abdominal wall domain.

The incidence of ventral or incisional hernia following laparotomy ranges from 1 to 20% [1–3], while the recurrence rates can range from 20 to 48% [4]. Once the linea alba has been incised via midline laparotomy, the healed scar tissue that results is much weaker than the uninjured fascia and can attenuate over time leading to bulge or hernia formation. The main objective of treating ventral hernias is to achieve primary fascial closure, reduce tension acting along the midline scar and add support or reinforcement to the areas of attenuated tissue. This chapter will describe the main force reduction and tissue reinforcement techniques that are the current standard of care for ventral abdominal wall reconstruction.

2. Primary fascial closure

One of the main determinants of abdominal wall reconstruction outcomes as it pertains to wound complication and hernia recurrence is whether the fascia can be reapproximated in the midline. While there has been some initial discussion in the literature that bridged repair may achieve similar outcomes to primary fascial closure, recent evidence clearly shows the superiority of primary fascial closure such that that every maneuver should be considered to achieve primary closure. In 2013 The MD Anderson group, published their outcomes with 222 patients who underwent either primary closure with mesh reinforcement or bridged repair. The patients undergoing bridged repairs had a significantly higher risk of hernia recurrence (56 vs. 8%), and a higher overall complication rate (74 vs. 32%). The interval to recurrence was 9-fold shorter in the bridged group [5]. A more recent study from the same group which included 535 consecutive patients with a mean follow up of 30 months reinforced the fact that primary repair had a lower hernia recurrence rate (6.2 vs. 33.3%, $p < 0.001$) and lower overall complication rate (30 vs. 59%, $p = 0.001$) than bridged repair. Propensity score analysis was used to make the comparisons less heterogeneous such that predictive factors (defect width, contamination grade and postoperative chemotherapy) that were significantly higher in the bridged hernia population and could be adjusted for to make for a stronger support of a reinforced repair rather than bridging [6]. Given the clearly demonstrated advantages of primary fascial closure, appropriate use of tension reduction techniques, which increase the likelihood of primary closure, are essential for improved outcomes in hernia reconstruction.

These tension reduction techniques take advantage of the layered anatomy of the lateral abdominal wall and can be categorized as anterior or posterior component separation, based on which layers are released.

3. Anterior component separation

The laterally oriented forces of the oblique muscles are translated via the rectus sheaths to the linea alba and apply tension along the midline laparotomy closure. This tension increases the risk of hernia formation and can be attenuated by disconnecting some of these components of the lateral abdominal wall. Anterior component separation was described in the 1950s but was formalized and popularized by Ramirez [7]. Ramirez and colleagues noted that the medial advancement of the external oblique muscle was restricted due to its attachments at the costal margin superiorly and the groin inferiorly. It could only be advanced by 2-cm at the epigastrium, 4-cm at the midline and 2-cm at the groin on each side. In order to be able to further medialize the rectus complex, they found it necessary to divide the external oblique fascia 2-cm lateral to the linea semilunaris from the costal margin to the inguinal ligament and then elevate the external oblique muscle off the internal oblique. Additionally, they released posterior rectus sheath. The technique avoids injury to the thoracoabdominal neurovascular bundles, which lie in the plane between the internal oblique and the transversus abdominis muscles. With this release, the rectus complex could be advanced 3-cm at the epigastrium, 5-cm in the middle and 2-cm inferiorly on each side, thereby allowing for bilateral medial migration of up to 10-cm in the midline. This technique gave surgeons the ability to achieve primary fascial closure in situations where bridged repair had been the only option. Furthermore, the repair is generally reinforced by the placement of mesh, often in the retrorectus plane [7].

The main drawback of the traditional open component release technique is the need to elevate wide soft tissue flaps that extend from the midline to 2-cm lateral to the linea semilunaris. This requires ligation of the periumbilical perforators that provide the major source of vascularity to the medial skin of the abdominal wall. Since the midline closure is subject to the highest tension, loss the periumbilical perforators can cause relative ischemia and increases the risk of soft tissue complications. Moreover, the large deadspace created by extensive undermining of the skin flaps increases the risk of seroma and abscess formation. Consequently, high rates of wound complications ranging from 24 to 50% have been reported [8, 9].

Perforator preserving techniques have, therefore, gained importance. These can be categorized into four subtypes: endoscopic component separation, open release with preservation of periumbilical perforators and surrounding soft tissue, open release with additional costal margin incisions and the MICS (Minimally Invasive Component Separation) technique. The endoscopic technique is a hybrid approach to hernia repair. The component separation portion of the procedure is performed with an endoscope but the remaining portion of the procedure is performed via an open approach. An incision is made along the anterior axillary line superiorly at the level of the costal margin or inferiorly at the level of the ASIS. Blunt dissection is then carried out to the external oblique fascia which is incised. A balloon dissector is then placed between the external oblique and internal oblique muscles and inflated to create a space. Additional ports are then placed for instrumentation and the remaining length of the external oblique fascia is divided. The endoscope is then removed and abdominal wall reconstruction with mesh placement using an open technique is performed [10].

Non-endoscopic techniques include an open technique with preservation of periumbilical perforators. In this technique, as described by Dumanian and colleagues, supraumbilical skin and fat are dissected off the anterior rectus sheath for a width of about 8 cm in order to identify the semilunar line. A second infraumbilical access to the linea semilunaris is then created by suprafascial dissection and the two spaces are connected to better visualize the linea semilunaris. Care is taken to preserve the periumbilical perforators. While this technique spares many of the periumbilical perforators, a significant amount of soft tissue undermining and elevation is performed, which increases dead space and thus the risk of wound complications [11] (**Figure 1**). Another technique by the same group uses supplemental subcostal transverse incisions through which the external oblique aponeurosis is longitudinally incised from the level of the costal margin to the inguinal ligament. This technique requires less soft tissue undermining than the previously described technique but requires transverse subcostal incisions [12].

The Minimally Invasive Component Separation (MICS) technique described by Butler et al. avoids the need for endoscopic instruments, additional access incisions and involves much less undermining and soft tissue elevation than the above described techniques. The MICS technique can be performed with either bioprosthetic as originally described [minimally invasive component separation with inlay bioprosthetic mesh (MICSIB)] or synthetic mesh placed in the retrorectus, preperitoneal or intraperitoneal plane. After the hernia has been reduced and lysis of adhesions has been completed, two horizontal subcutaneous tunnels (3-cm wide and 2-cm inferior to the costal margin) are dissected superficial to the anterior

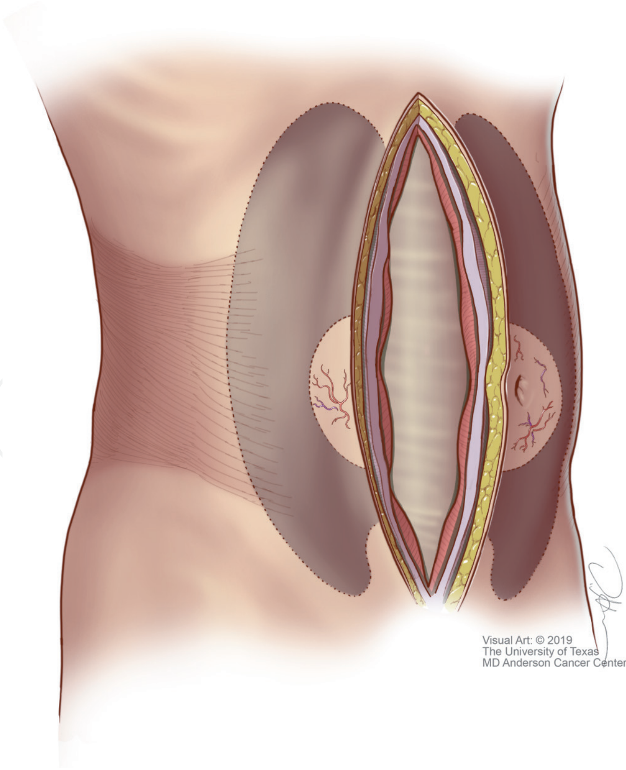

Figure 1.
Area of subcutaneous dissection in periumbilical perforator sparing anterior component separation technique. Even though periumbilical perforators are spared, there is significant undermining of the subcutaneous tissue and increased risk of wound complications (Visual Art: © 2019 The University of Texas M.D. Anderson Cancer Center).

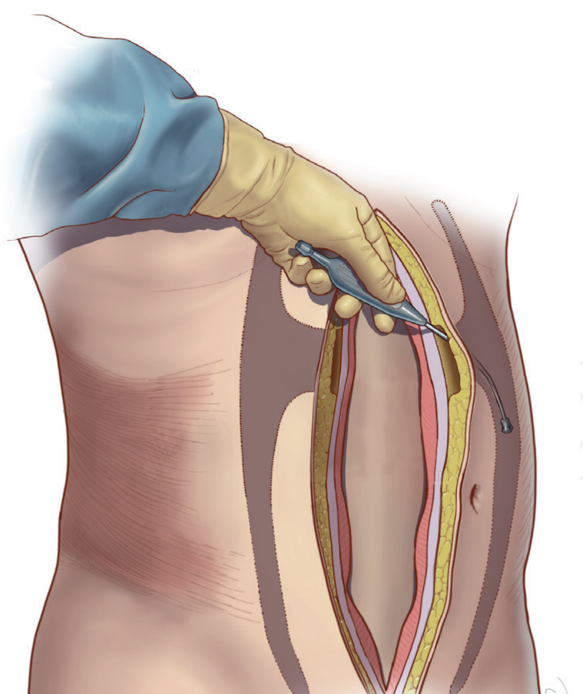

Figure 2.
Area of subcutaneous dissection in the minimally invasive anterior component separation technique (MICS). Width of the horizontal and vertical tunnels is 4 and 2 cm respectively implying much less soft tissue undermining. (Visual Art: © 2019 The University of Texas M.D. Anderson Cancer Center).

rectus sheath that extend laterally to just lateral to the linea semilunaris (**Figure 2**) Through a 2-cm long incision through the external oblique aponeurosis located 1.5 cm lateral to the linea semilunar, the Yankauer sucker is inserted and used to dissect between the internal and external oblique muscles in the loose areolar plane using sweeping motions inferiorly and superiorly. With the use of a lighted retractor, narrow vertical subcutaneous tunnels measuring 2-cm in width are dissected superficial to the external oblique aponeurosis along the path of intended aponeurotic release. With the use of Yankauer suction tip placed below the external oblique aponeurosis and pushed against the rectus complex as a guide, the external oblique fascia is incised 1.5–2-cm lateral to the linea semilunaris. Through these subcutaneous tunnels the exterior oblique aponeurosis is released from 12-cm superior to the costal margin and inferiorly to the inguinal ligament [13] (**Figure 3**).

The midline soft tissues are then elevated off the anterior sheath laterally to just medial to the medial row of rectus abdominis muscle perforators. The preperitoneal layer is dissected off the posterior rectus sheath and a bioprosthetic or synthetic mesh is placed as an underlay in the preperitoneal plane deep to the posterior rectus sheath. The mesh can also be placed in the retrorectus plane (between the rectus muscle and the posterior rectus sheath). Polypropylene sutures are used to place U-stitches between the mesh and the linea semilunaris or rectus muscle complex at least 5-cm lateral to the true fascial edge. The rectus muscle complex is primarily approximated in the midline over the mesh using interrupted or running

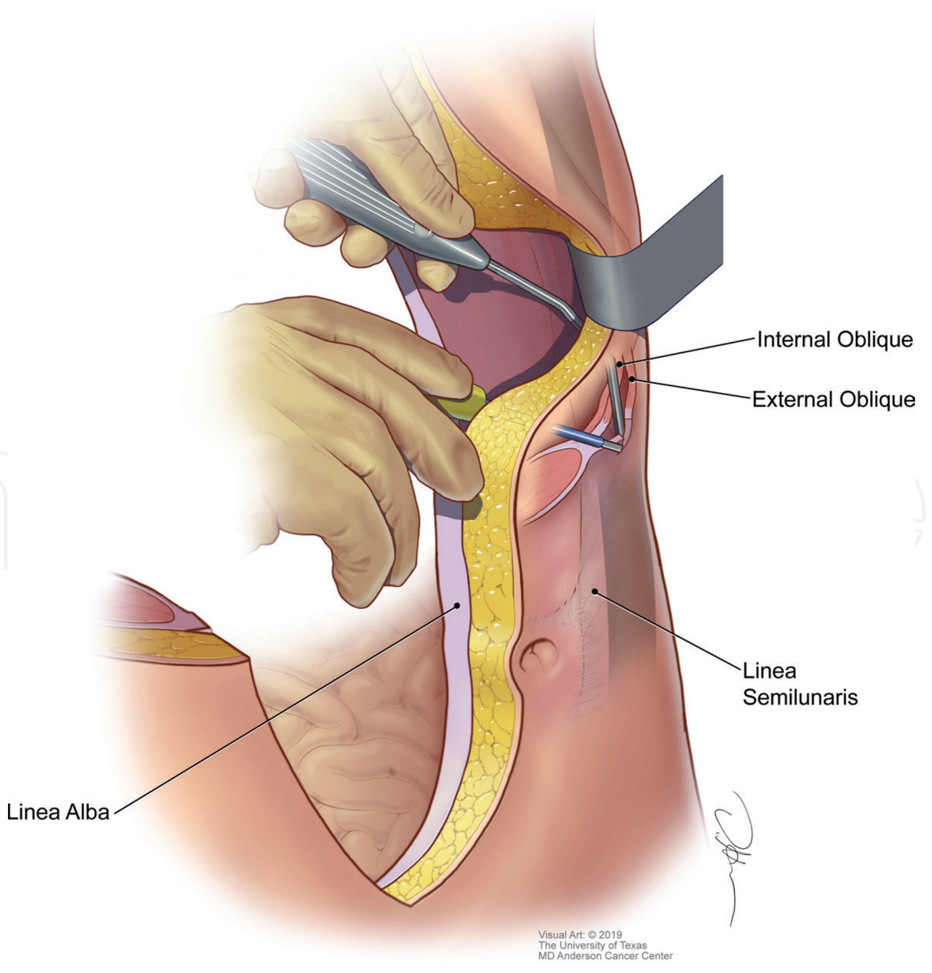

Figure 3.
MICS technique demonstrating access to the external oblique fascia through a subcutaneous tunnel. The Yankauer suction tip is then used to create the plane between the external oblique and internal oblique. The external oblique fascia is then incised 1.5 cm lateral to the linea semilunaris (Visual Art: © 2019 The University of Texas M.D. Anderson Cancer Center).

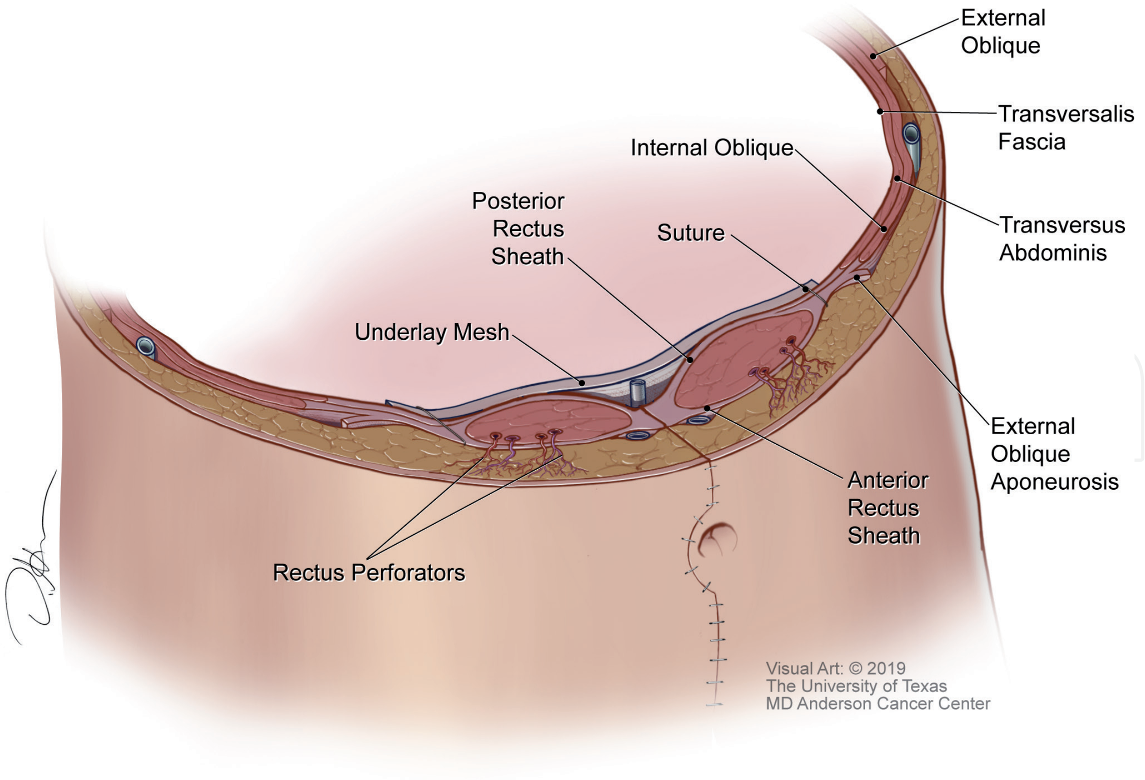

Figure 4.
Cross-sectional image demonstrating release of the external oblique after anterior component separation. A mesh has been placed in the underlay plane. Rectus perforators to the overlying skin flap have been spared (Visual Art: © 2019 The University of Texas M.D. Anderson Cancer Center).

#1 polypropylene sutures. Deadspace reduction is achieved by placing resorbable quilting sutures between the posterior sheath and the mesh as well as between the anterior rectus sheath and the overlying elevated soft tissue. Drains are placed between the underlay mesh and the fascial closure, the component separation donor sites and in the subcutaneous plane along the midline closure (**Figure 4**).

As expected, these modifications to the traditional open technique improve vascularity to the overlying soft tissue, reduce deadspace and significantly decrease wound complications. A review of 107 patients who underwent abdominal wall reconstruction using either an open technique or the MICS technique showed that, despite a larger mean hernia defect size, patients undergoing the MICS technique had a significantly lower rate of skin dehiscence (11 vs. 28%; $p < 0.011$), and wound healing complications (14 vs. 32%; $p < 0.026$) [14].

While anterior component separation has multiple advantages, some surgeons raised concerns about using this technique in the setting of rectus muscle violation. The main concern was that prior injury to the rectus muscle complex due to direct incision or excision of the muscle or due to placement of an ostomy or tube through it would increase the risk of scarring and prevent safe component release and adequate medial migration [15]. In order to further study this issue, the MD Anderson group performed a retrospective review of patients with or without prior rectus muscle violation, who underwent subsequent abdominal wall reconstruction using anterior component separation, was conducted. A total of 68% of patients in the study had rectus violation while 32% of patients did not. Patients in the rectus violation group had elevated BMI, larger hernia defects, increased incidence of chemotherapy and two or more prior operations. Yet, the overall wound healing, hernia recurrence and complication rates were similar in the 2 groups. The study also noted that the type of rectus violation (prior incision/excision of muscle or ostomy/tube placement) did not influence complication rates [16]. Anterior component separation remains a safe and effective technique even in the setting of prior or concurrent rectus violation.

4. Posterior component separation

In addition to anterior component separation, posterior releases of the abdominal musculofascial components have been described. Posterior component separation (PCS) such as the transverse abdominis muscle release (TAR), have evolved as extensions of the Rives-Stoppa repair. The Rives-Stoppa repair, described in the 1970s, involves elevation of the posterior rectus sheath in the retrorectus plane laterally to the linea semilunaris [17]. While the traditional repair stops here, the TAR technique involves division of the transversus abdominis muscle followed by dissection laterally between the transversus abdominis muscle and the transversalis fascia followed by wide mesh reinforcement [18]. Once the thoracolumbar intercostal nerves are visualized along the lateral edge of the rectus muscle complex, the posterior lamella of the internal oblique muscle is incised medial to these nerves which exposes the transversus abdominis muscle. The transversus muscle is then incised to reach the plane between the transversus abdominis muscle and transversalis fascia (**Figure 5**). This plane of dissection can be extended laterally to the psoas muscles thereby allowing for placement of a very large mesh (**Figures 6** and 7). Proponents of this technique claim that it can provide up to 10-cm of medialization of the rectus muscle complex and have demonstrated promising outcomes [19]. A retrospective review of 428 patients who

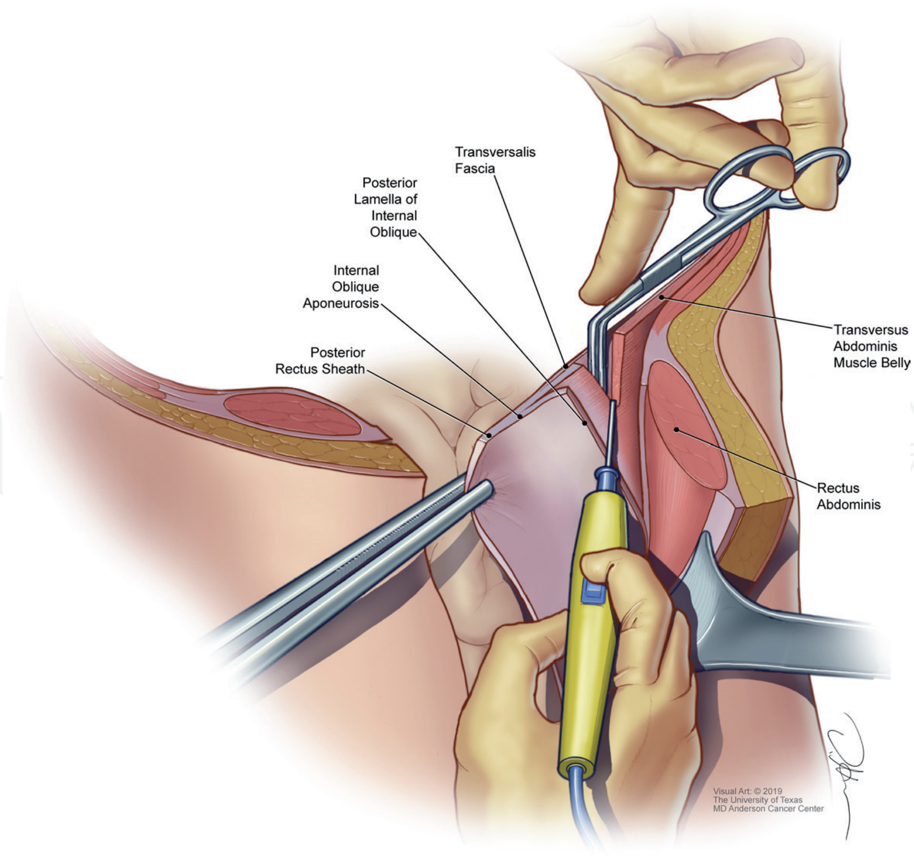

Figure 5.
Transversus abdominis release technique demonstrating that the posterior lamella of the internal oblique aponeurosis has been incised to provide access to the transversus abdominis muscle. The transversus abdominis muscle is then incised. The plane between the internal oblique and transversus abdominis muscle is not opened or disturbed (Visual Art: © 2019 The University of Texas M.D. Anderson Cancer Center).

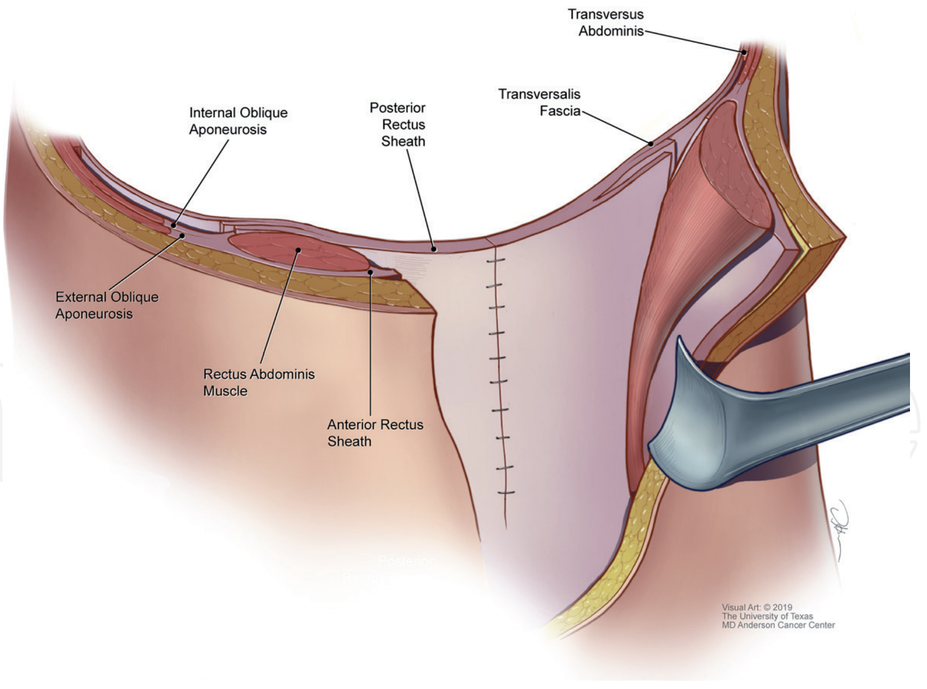

Figure 6.
Posterior sheath is approximated following transversus abdominis muscle release.

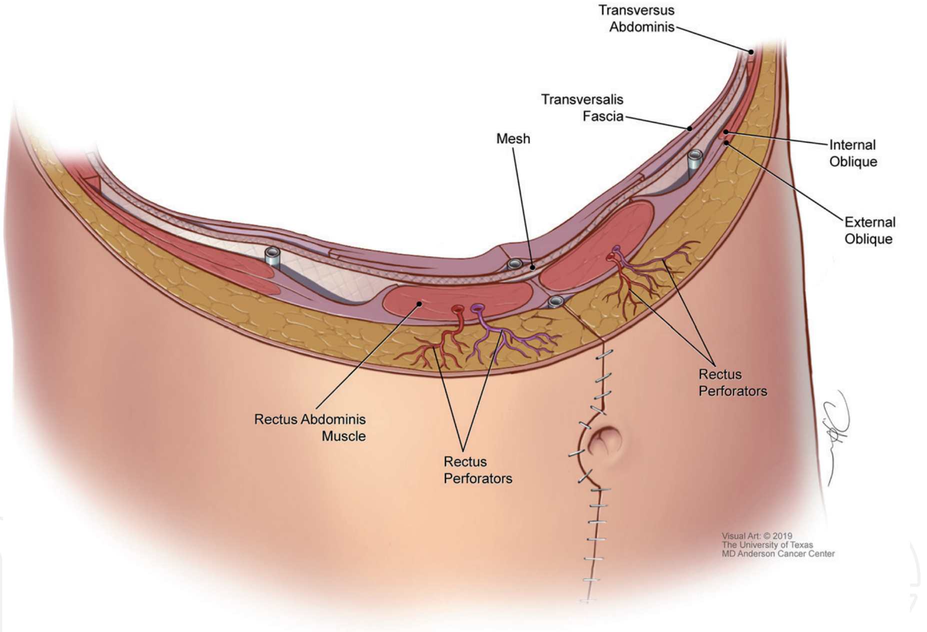

Figure 7.
Cross-sectional image demonstrating Transversus abdominis release (posterior component separation) with retrorectus placement of mesh (Visual Art: © 2019 The University of Texas M.D. Anderson Cancer Center).

underwent abdominal wall reconstruction using the TAR technique were noted to have a surgical site occurrence rate of 18% and a 30 day SSI of 9.1%. Hernia recurrence rate was 3.7% at a mean follow-up time of 31.5 months, which is lower than average recurrence rates reported in the literature [20]. Since the TAR release is always accompanied by a very wide mesh, it is unclear if the benefits of lower hernia recurrence are related to the reduction in tension by the TAR release or the extra wide placement of mesh. One benefit of the TAR includes being able to place a large mesh in the pretransversalis fascial plane so there is essentially no risk of bowel exposure to mesh. Another major benefit is that skin flaps do not have to be elevated thus reducing the risk of medical skin ischemia. The TAR release is considered the dominant posterior component release technique and is sometimes referred to as posterior component separation in the literature (PCS).

While both anterior and posterior component separation techniques are commonly used for abdominal wall reconstruction there have been few head to head comparisons between the techniques. Useful comparative analysis is difficult given the heterogeneity of hernia defects and the biases related to surgeon preferences and patient selection. In 2012 Krpata and colleagues published a retrospective review comparing outcomes following anterior component separation (ACS) and transversus abdominis muscle release (TAR) in their patient population. They found that the overall complication rate was significantly lower for TAR (25.5%) compared to ACS (48.2%) and also noted a higher hernia recurrence rate for ACS (14.3%) vs. TAR (3.6%), but this was not statistically significant [21]. The ACS repairs in this study were performed using traditional open techniques, which as described earlier, are known to have a higher rate of wound healing complications than the more recent perforator sparing techniques. Furthermore, 38% of patients undergoing ACS underwent simultaneous panniculectomy compared to 4% of TAR patients which could bias the complication profile in favor of TAR. It is not unreasonable to believe that higher wound complication rates would translate to increased risk of hernia recurrence. A more recent study published in 2017 that compared MICS to posterior component separation noted a much lower rate of complications for the ACS repairs and no significant difference in complication profile or recurrence rates between TAR and anterior MICS [22]. They did note that a slightly higher hernia recurrence risk with the MICS technique but this was not statistically different. Based on their description they did not release superior to the costal margin. The full benefit of the MICS release is attained when the release is extended 12-cm superior to the costal margin, especially when treating epigastric hernias. Large prospective studies are needed to better compare these techniques, however both anterior and posterior components are widely practiced by surgeons. Choice between the techniques generally depends on surgeon preference and training [23].

5. Mesh types and plane of mesh placement

In addition to tension reduction techniques, the use of mesh reinforcement has significantly improved hernia recurrence rates. Previous landmark studies demonstrated that when mesh was used for the repair hernia recurrence rate was reduced my almost 50% compared to fascial closure alone at three and 10 year follow up [24, 25]. Synthetic and bioprosthetic mesh are the two major categories of mesh in use today. Polypropylene, polyester and polytetrafluoroethylene (PTFE) are common polymers used to create synthetic mesh material. Multiple studies over the past two decades have been performed in order to identify the clinically relevant features of different mesh architectures [26]. In general, these mesh materials can vary with respect to their pore-size and weight. Studies have shown that lighter weight mesh materials with large pore sizes induce increased type 1 collagen deposition and demonstrate an increase in tensile strength over time. They demonstrate better incorporation and improved abdominal wall compliance compared to mesh with smaller pore sizes [27]. Light weight mesh materials, however, have an increased risk of mesh fracture. Small pore sizes increase the risk of bridging fibrosis and rigid scar formation which reduces the compliance of the reinforced abdominal wall [28]. PTFE has the smallest pores size which reduces adhesion formation, however, since the pore size is too small for macrophages to enter, the clearance of bacteria and/or biofilm is very difficult and the mesh usually needs to be explanted in the setting of persistent infection [29]. Ideally synthetic meshes need to be created using strong, yet complaint materials that do not induce visceral adhesion formation.

A newer subtype of synthetic meshes consisting of resorbable materials, such as polyglycolic acid (PGA), polylactic acid (PLA), trimethyl carbonate (TMC) and poly-4-hydroxybuturate (P4HB), has been recently introduced. Each of these materials varies in the absorption rates and mechanisms and can be combined to develop mesh with different profiles. The main proposed advantage is that these materials can resorb and therefore have less associated long-term foreign body reaction, lower risk of infection and preserved compliance [30]. There have been few outcomes-based studies with these mesh materials with regard to long-term recurrence rates. The Complex Open Bioresorbable Reconstruction of the Abdominal Wall (COBRA) Study analyzed outcomes related to PGA/TMC absorbable mesh and reported 28% SSO and 18% SSI rates. Recurrence rate was 17% at 2 years. More in depth studies and comparative analysis are necessary before these materials can be universally adopted [31]. The indications for these materials are not yet clear.

Synthetic meshes, although very reasonably priced, are associated with an increased risk of adhesion or fistula formation if placed in contact with abdominal viscera and an increased risk of infection when placed in contaminated wounds. Bioprosthetic meshes were introduced to mitigate some of these drawbacks related to infection and adhesion formation. Bioprosthetic meshes are generally derived from human, porcine or bovine sources and mainly consist of dermis, pericardium or intestinal submucosa. Acellular dermal matrix (ADM) is the most common substrate used in abdominal wall reinforcement [32]. Radiation and chemical or enzymatic treatment are used to decellularize, sterilize and treat the matrix to reduce the likelihood of a host rejection response. These processes are not benign and may alter the characteristics of the mesh and reduce its potential to integrate with the surrounding tissues. Increased cross-linking, caused by some of these treatments, inhibits tissue and vascular ingrowth and integration, which lead to scarring or encapsulation as seen with synthetic meshes [33]. This phenomenon was witnessed when a highly cross-linked porcine acellular dermal matrix (Permacol; Medtronic, Minneapolis, MN) was compared to a non-cross linked matrix (Strattice; LifeCell Corp. Branchburg, NJ). The study showed that while the two meshes did not differ with respect to the hernia or bulge recurrence, there was a significantly higher risk SSI associated with the cross linked mesh [34].

The mesh types can also be affected by the source from which the tissue was harvested. For instance, compared to xenogeneic mesh, human dermal matrix has a higher proportion of elastin and a faster remodeling rate [35]. Therefore, bioprosthetic meshes harvested from human skin have higher hernia and bulge occurrence. While this feature might be useful in other indications for soft tissue support, such as breast reconstruction, it is disadvantageous in abdominal wall reconstructions and has been mostly abandoned by hernia surgeons [36]. Comparison between bovine and porcine derived meshes however have not yielded significant long-term differences with respect to hernia recurrence or SSOs [37, 38].

While large long-term, head to head comparisons between synthetic and bioprosthetic mesh products have been lacking, there have been multiple studies with each of these products. Carbonell and colleagues conducted a retrospective review of 100 patients who underwent ventral hernia repair with macroporous light-weight synthetic mesh in clean-contaminated (42 patients) and a contaminated (58 patients) setting and were followed only for a mean of 10.8 months. They reported a 7% SSI rate, 31% SSO rate and a 7% recurrence rate. They also had a 4%

mesh explantation rate [39]. The experience with bioprosthetic meshes has been variable [40]. The MD Anderson group compared outcomes using bioprosthetic mesh in clean (CDC Class 1) vs. combined contaminated [clean-contaminated (Class 2) + Contaminated (Class 3) + Dirty/Infected (Class 4)] cases in a review of 359 patients followed for a much longer mean follow-up of 28 months. The analysis demonstrated no significant difference in overall 30 day SSI, hernia recurrence rates or mesh removal rates in the clean vs. combined contaminated groups. Factors independently predictive of hernia recurrence included bridged repair, use of human ADM, reoperation and mesh removal. The study demonstrated increasing wound related SSOs with increasing CDC classification however the wounds did not progress to higher overall SSI or recurrent hernia rates [41]. A more recent study using propensity score matched groups on a similar group of patients from the same institution demonstrated even more compelling results. In this study of 519 patients, 420 patients underwent abdominal wall reconstruction with bioprosthetic mesh placement in ventral hernia working group (VHWG) Class 1 or 2 wounds and 99 patients underwent mesh placement in Class 3 and 4 wounds. No differences were seen in wound related outcomes, infections, dehiscences, reoperation and hernia recurrence [42]. Consequently the VHWG promotes the use of bioprosthetic meshes in grade 3 or 4 cases [43].

The plane of mesh placement is another important factor that may affect outcomes. An ideal plane for mesh placement should be deep enough to reduce susceptibility to superficial skin and soft tissue infection or cutaneous exposure in the event of skin separation. Contact with bowel or intraperitoneal contents should be avoided in order to reduce the risk of bowel adhesion and possible enterocutaneous fistula formation. Antiadhesive, barrier-coated meshes have been used to reduce intestinal adhesions associated with intraperitoneal macroporous synthetic mesh placement [44]. Recent analyses have also shown that SSI and hernia recurrence is much higher in mesh placed as onlay (superficial to the fascial closure), or interposition configurations (bridged repair without fascial closure), than when mesh has been placed in sublay fashion (retrorectus, intraperitoneal or preperitoneal plane). These findings have been noted in laparoscopic as well as open repairs [45].

6. Soft tissue coverage options

Successful reconstruction of the abdominal wall relies on robust well vascularized overlying soft tissue. The main drawback of the traditional anterior component technique was related to poor vascularization of the overlying skin flaps caused by the disruption of the rectus abdominis perforators. In many scenarios the overlying soft tissues may be compromised due to massive ventral hernia, prior trauma, surgical incisions or tumor resection. In addition to restoring the myofascial integrity using tension reducing component separation techniques and mesh reinforcement of the abdominal wall, it may be necessary to take additional steps to restore the overlying soft tissue [46].

Options for soft tissue coverage in the case of skin deficiency depend upon surface area and location of the defect and may involve the use of local tissue rearrangement, pedicled flaps or free flaps. From the standpoint of soft tissue reconstruction, defects can be characterized as epigastric, periumbilical, hypogastric or suprapubic defects. Small defects in all locations can be reconstructed with local advancement or rotational advancement of tissue based upon available soft tissue laxity.

However, intermediate to large size defects may require more extensive techniques for soft tissue transfer. Superior skin defects located laterally may be reconstructed using pedicled flaps based on the thoracodorsal or circumflex scapular vascular pedicles. These include latissimus dorsi flaps, serratus or parascapular flaps. These reconstructions require an intraoperative position change, which may increase operative time. In certain cases, when the defect lies beyond the reach of a pedicled flap, a free tissue transfer often with the use of interposition vein grafts is necessary [47, 48].

For midline skin defect between the xiphoid and umbilicus, there are no reliable pedicled flap options. These defects usually need to be reconstructed with a free flap from the thigh or back, often with vein grafts. Inferior, medial and lateral skin defects can usually be reconstructed using pedicled thigh-based flaps. These include pedicled anterolateral thigh flaps, rectus femoris or subtotal thigh flaps. It is best to use mesh to reconstruct the musculofascial component of a composite (soft tissue and musculofascial) defect rather than the fascia from a fasciocutaneous flap. The flap fascia is unreliable and associated with increased risk of hernia and bulge [47, 49]. For defects that are too large or out of reach of pedicled flaps, free flaps need to be used. In addition to the complexity associated with free tissue transfer, the lack of useful local recipient vessels is a significant hurdle. It is generally important to avoid the use of intraperitoneal recipient vessels. An iatrogenic hernia must be created to allow the pedicle to traverse the mesh-musculofascial reconstruction which can result in a pedicle kink leading to flap vascular compromise and/or symptomatic hernia formation. In addition, the management of flap vascular compromise requires a reoperative laparotomy to access the anastomosis. The main recipient vessels include the internal mammary, inferior epigastric, axillary and femoral vessels. If the free flap pedicle is too short, cephalic or saphenous vein grafts are used as interposition graft between the flap pedicle and the recipient vessels. In many cases an arteriovenous vein loop is created by anastomosing the saphenous vein to the superficial femoral artery and then transferred to the abdomen to serve as a useful recipient. Healthy soft tissue coverage reduces risk of infection, helps reduce the effect of radiation, increases likelihood of mesh integration and therefore contributes to lower incidence of soft tissue complications and hernia recurrence [47, 50].

Excess subcutaneous tissue, on the other hand, can cause increased physical strain on wound closures and heighten the risk of dehiscence. In these situations, the redundant tissue should be addressed using a panniculectomy. Use of a panniculectomy in the setting of ventral hernia repair has been associated with higher wound morbidity, increased rates of fat necrosis and abscess formation but similar overall complication and hernia recurrence rates to abdominal reconstruction without panniculectomy [51]. Vertical excess can be removed via an elliptical or tear drop incision. Simultaneous horizontal and vertical excess can be removed using a combined longitudinal and transverse panniculectomy in a fleur-de-lis pattern. Due to an increase in wound breakdown at the central trifurcation point of this incision, Butler and Reis described a modified "mercedes" incision pattern. The shorter triangle flaps with a more obtuse angle at the trifurcation or T-junction and the more cephalad location of this trifurcation point reduces the risk of breakdown by improving blood flow and relocating the trifurcation point further away from the groin and appearing like a "Mercedes" symbol [52].

The use of closed incision negative pressure wound therapy has also improved wound related outcomes in high risk patients. Negative pressure wound therapy has yielded statistically lower wound complications and surgical site occurrences [53]. Further modifications of this technique such as partial closure of the incision and management of both open and closed areas with negative pressure therapy, described as the "French Fry or String of pearls" technique are also gaining interest [54].

7. Preoperative optimization

There are multiple intraoperative techniques that have improved outcomes in ventral hernia reconstruction, however when possible, every attempt should be made to optimize the patient prior to surgery. This can be achieved my managing or alleviating certain modifiable risk factors that have been shown to increase the risk of complications and include smoking, diabetes control, and obesity [55].

Smoking has been shown to increase risk of hypoperfusion, especially to the undermined flap, and lead to tissue necrosis and abscess formation. In a systematic review of 6 randomized trials and 15 observational studies, the authors found that each week of smoking cessation increases the magnitude of effect by 19%. Trials of 4 weeks of smoking cessation had a significantly larger effect than shorter trials [56]. Nicotine replacement therapy, however, has not been shown to have a detrimental impact to wound healing and complications in gastrointestinal surgery [57].

Diabetes control in the perioperative setting is another important factor in reducing risk of infection and complications. Postoperative hyperglycemia >200 and a Hemoglobin A1c greater than 6.5 have been associated with a 3-fold higher rate of wound dehiscence in certain studies. Perioperative blood glucose should be maintained below 120–160 mg/dl. Even a single instance of postoperative hyperglycemia greater than 200 mg/dl has been shown to significantly increase dehiscence risk [58–60].

Obesity is well known factor that has been shown to increase the risk of SSO following ventral hernia repair. A study published in 2016 reviewed 313 patients who underwent complex hernia repair analyzed the effect of obesity over a 15.6 month follow-up. They divided the population based on BMI according the World Health Organization (WHO) classification and found a significantly higher risk of hernia recurrence and reoperation in patients with increasing BMI [61]. Contrary to this, a more recent larger study from the MD Anderson group including 511 patients with a longer mean follow-up of 32 months demonstrated that class 1 or higher obesity does not affect hernia recurrence rates. Increasing class of obesity, however, does increase the risk of SSOs such as infection, fat necrosis, skin dehiscence [62]. An inflection point above which SSO became a considerable problem was noted to be a BMI of 31.9. It is important to understand that most patients in this study had a BMI less than 40. Hernia recurrence has been shown to increase as the BMI increases over 40. (2-year recurrence rate 8% of BMI between 30 and 39 which then increases to 25% for BMI between 40 and 49 and 45% in patients with BMI > 50) [55].

8. Conclusion

Abdominal wall reconstruction has multiple complex nuances which need to be understood and adjusted based on the clinical scenario. In order to improve outcomes, the patient needs to be optimized from the standpoint of modifiable risk factors such as diabetes, obesity and tobacco use. Next, procedures to reduce tension and achieve primary closure such as anterior and posterior component separation need to be performed. Anterior component separation has been associated with wound related complications which can be prevented by minimally invasive techniques designed to spare perforators as described in this chapter.

The repair then needs to be reinforced with synthetic or biologic mesh. Bioprosthetic mesh has been shown to have a low rate of surgical site complications in contaminated cases. Finally, techniques of maintaining well perfused soft tissue coverage is important and can be achieved by local rearrangement of tissue, pedicled flaps or free flaps. All of these factors, including clinical features of the case, and surgeon familiarity with the technique help facilitate a successful outcome.

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