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# Posterior component separation/transversus abdominis release

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## Abstract

The Rives-Stoppa technique for ventral hernia repair is commonly utilized due to well-proven outcomes with low overall morbidity. However, this approach is limited by the amount of myofascial advancement and sublay space available for a wide mesh overlap. Thus, anterior component separation was developed to allow further myofascial advancement. Some limitations were noted, which led to the subsequent study, utilization, and refinement of the posterior component separation (PCS) technique. PCS continues to demonstrate low hernia recurrence, surgical site occurrences, and improvement in rectus muscle function. Continued adoption of this technique has expanded to minimally invasive approaches for hernia repair. This paper is a comprehensive review of the evolution of PCS, technique, and outcomes.

**Keywords:** Posterior component separation, transversus abdominis release, ventral hernia repair

## INTRODUCTION

The major tenants of herniorrhaphy and abdominal wall reconstruction are reduction of the hernia, defect closure, and strengthening the repair with mesh reinforcement. While small ventral defects lend themselves to various techniques of herniorrhaphy, larger, recurrent, and more complex hernias require more nuanced approaches. Stoppa *et al.*[1] published his original technique of preperitoneal repair of recurrent bilateral inguinal hernias with polyester mesh in 1973. This was shortly followed by a colleague, Rives *et al.*[2], who described incisional hernia repair with mesh placed behind the rectus muscle to protect the visceral sac from mesh contact. With minor modifications, the Rives-Stoppa repair became widely utilized due to well-proven outcomes with low overall morbidity[3,4]. However, despite the great success of this repair, the retrorectus repair does not easily facilitate myofascial advancement and the limited surface area in the retrorectus space prevents wide mesh overlap.

To overcome these limitations, Ramirez *et al.*[5] performed anatomic studies describing separation of the components of the abdominal wall to allow for medial mobility (myofascial advancement) to close large ventral hernias with restoration of the linea alba. This technique involved developing the avascular plane between the external and internal oblique muscle layers through relaxing incisions lateral to the rectus sheath, and became known as the anterior component separation (ACS). The authors were able to demonstrate up to 10-cm myofascial advancement at the umbilicus with this technique. With early adoption of this technique, subsequent study revealed some notable drawbacks including technical challenges in patients with enterostomies, difficulty repairing hernias lateral to the rectus muscles or near bony prominences, and recurrence rates as high as 32%. Most notably, raising large subcutaneous flaps in order to perform ACS puts patients at risk for skin necrosis or wound complication, with rates as high as 40%[6].

Considering the limitations associated with the Rives-Stoppa and ACS techniques, Novitsky *et al.*[7] developed the posterior component separation (PCS). Two years later, Carbonell *et al.*[8] described their technique of dividing the transversus abdominis aponeurosis lateral to the linea semilunaris and developing a plane between the TA and IO, which allowed medial advancement of the external oblique (EO) and IO with a large space for mesh placement in a sublay fashion. One major pitfall of this technique is the division of the neurovascular bundles supplying the rectus laterally, which can lead to muscle atrophy, abdominal wall bulges, recurrent hernia, and asymmetry[6].

To further the novel idea of separating the posterior components, but avoid division of the neurovascular bundles, Novitsky *et al.*[9] described the Transversus Abdominis Release (TAR) in 2012, whereby, after extending the Rives-Stoppa technique laterally, an incision is made in the posterior rectus sheath to expose the TA. The muscle of its associated aponeurosis is then divided along its medial edge, separating the TA from the underlying transversalis fascia and peritoneum.

This modification allows the surgeon to develop the retromuscular space laterally as far as the retroperitoneum and psoas muscle. Initial study of this technique demonstrated low hernia recurrence and SSI with improvement in rectus muscle function[9-11].

## PATIENT SELECTION

Patient selection for the appropriate herniorrhaphy is paramount as there is a vast array of techniques, abdominal wall planes, and patient characteristics. The authors generally reserve laparoscopic repairs for small to medium sized defects (2-7 cm) in patients without a history of multiple abdominal operations or previous underlay mesh. Patients with defects greater than 8 cm in diameter are approached with a robotic or open repair. In some cases, posterior sheath reapproximation at the midline is achievable with a Rives-Stoppa repair. However, TAR may be required if a classic Rives-Stoppa is unable to achieve midline closure, when there is insufficient mesh coverage behind the rectus muscle or in the following settings: large defects, multiply recurrent hernias, non-compliant abdominal walls necessitating myofascial release, and parastomal hernias. Although it is hard to definitively predict preoperatively which patients will require a TAR in addition to a Rives-Stoppa repair, Love *et al.*[12] hypothesized that Rives-Stoppa repair will achieve midline closure if the sum of the rectus widths is twice the width of the defect width when measured on CT scan. The authors recommend that previous subcutaneous or wound related complications should be approached with TAR rather than open ACS. In patients with tenuous vascularity (diabetics, smokers, and patients with vasculopathies), we avoid open ACS and recommend a TAR approach, although a minimally invasive component separation (compared to open ACS) may be an appropriate option as this approach has demonstrated superior outcomes to open ACS[13].

There are few relative contraindications to performing a TAR. TAR can be exceptionally challenging in patients with previously placed pre-peritoneal or retromuscular mesh. In patients who have undergone resection of the posterior abdominal wall components (such as occurs during radical cystectomy or procedures to excise peritoneal cancer implants), the loss of tissue planes may make the creation or continuation of a retromuscular plane impossible. Similarly, TAR should be used with caution in patients who have undergone previous ACS as this could lead to lateral hernia formation, although favorable results have been reported by Pauli *et al*.[14] in short-term follow up.

## PREOPERATIVE PREPARATION

The authors strongly recommend preoperative CT imaging of the abdomen and pelvis as it well elucidates the abdominal wall musculature, hernia defect, contents, and dimensions. CT scans can also show signs of active infection, previous mesh, and any evidence of underlying visceral abnormalities. Routine use of contrast is unnecessary, although IV contrast is recommended with concerns for intra-abdominal infection and oral contrast should be used to evaluate gastrointestinal pathologies such as obstructions or fistulas. Imaging is also advantageous in obese patients where physical exam is limited to evaluate the hernia.

Of upmost importance is preoperative patient optimization. There are increased complications after hernia repair in patients who are actively smoking, poorly controlled diabetics, obese, or with poor nutrition. Cigarette smoking adversely affects wound healing[15]. After 4 weeks of smoking cessation, the inflammatory aspect of wound healing normalizes[16]. Thus, a minimum of one month of smoking cessation is recommended before elective repair. Similar to smoking, poor glucose control (HbA1c > 7%) increases the rate of surgical site infections (SSI)[17]. Studies have shown a 30% increase in SSIs with every increase of 40 mg/dL of glucose over 110 mg/dL[18]. We recommend HbA1c < 7% before offering elective component separation hernia repair.

Obesity greatly effects the formation of hernias, hernia recurrence, and hernia repair morbidity. There is also an association between nosocomial infection, readmissions, and requirement for transfusions among obese patients. Wound morbidity increases sharply with body mass index (BMI), where a BMI > 40 incurs a 1.66 odds of surgical site occurrence (SSO)[19]. We routinely encourage overweight patients to pursue an active weight loss program with a goal of achieving a BMI < 40. Given the often-elective nature of hernia repair, we routinely follow patients for three months. Patients are supported by our institutional weight loss program; however, if reasonable weight loss is not achieved despite best efforts, we often refer patients to our bariatric surgery program.

Lastly, we ensure our patients are nutritionally optimized. A large, multi-center study of nearly 90,000 veterans demonstrated that the single most valuable predictor of surgical morbidity was a serum albumin < 3.0 g/dL, which emphasizes the need to evaluate and address the nutritional status of patients prior to operation[20]. Validated nutritional risk assessment tools are readily available[21]. There are many data in support of nutritional supplementation preoperatively. One common regimen is arginine/omega-3 supplementation (Impact Advanced Recovery; Nestle Healthcare Nutrition Inc., Florham Park, NJ) given 3 times a day for the 5 days prior to surgery[22].

## RELEVANT ANATOMY FOR TRANSVERSUS ABDOMINIS RELEASE

With the above-mentioned evolution from a Carbonell PCS technique to Novitsky's TAR, understanding of the TA anatomy is vital. The TA is the deepest of the lateral muscles, and fibers run in a horizontal direction, 90 degrees to the fibers of the rectus abdominis muscle. Inferiorly, it originates from the anterior aspect of the iliac crest and lateral third of the inguinal ligament. Below the arcuate line, the TA inserts into the pubic crest and pectineal line to form the conjoined tendon with contributions from the IO. In the upper third of the abdominal cavity, the TA muscle inserts onto the costal cartilages of the 7th-12th ribs as well as the xiphoid process. In this area, it extends medially beyond the semilunar line and lateral edge of rectus abdominis (RA). Cephalad, the TA fibers interdigitate with the diaphragm muscle as well. As the TA muscle moves caudally, its medial border moves obliquely and laterally. At the level of the arcuate line, TA muscle fibers may no longer be visible; rather, only the aponeurosis is noticed.

The TA and internal oblique muscles are key contributors to intra-abdominal tone throughout the thoracolumbar space. Mobilization of the TA off the underlying fascia removes its contribution to the lateral abdominal wall leaving the IO's contribution intact. This allows for expansion of the abdominal cavity and thus myofascial advancement to the midline of both the lateral and medial components of the abdominal wall, up to 8-12 cm per side in studies performed by Novitsky *et al*.[9]. Additionally, TAR allows for extensive lateral dissection for herniorrhaphy of large, recurrent, off-midline defects as well as those that approach bony landmarks.

## OPERATIVE TECHNIQUE

### Patient position

The patient should be placed supine on the operating table with arms extended. The field should be prepped from the nipple line superiorly to the mid-thigh inferiorly and to the table edge laterally. This wide prep allows for wide mesh fixation points, if needed. Some surgeons routinely place an iodine impregnated drape over the field to protect the mesh prosthesis from contact with any skin flora.

### Entering the abdominal cavity

The surgeon should take note of previous scars; we routinely mark all prior surgical incisions prior to placing the iodine-impregnated dressing. Poorly healed midline scars or ulcerated skin may be excised with an elliptical midline incision for cosmetic effect. A generous midline incision is made from above to below the hernia defect. We base the location for initial abdominal entry based on physical examination (ideally in a location not previously violated) and on CT scan review (ideally in an area where there is clear omental or pre-peritoneal fat present separating the fascia from the viscera). For hernias where the sac closely approaches the skin, care should be taken when entering the hernia sac, as viscera may be shallow to the incision. Once inside the abdominal cavity, we focus next on completing the midline laparotomy before addressing adhesions that may be found laterally. However, generous lysis of adhesions should be completed to free the undersurface of the posterior abdominal wall layers to allow medial advancement and free any attachments that could lead to internal hernias. Once completed, a countable, radiopaque towel is placed over the viscera to protect them during subsequent dissection.

### Entering the retrorectus space

The medial edge of the rectus muscle should be palpated as the hernia sac or a diastasis of the recti can cause lateralization of the muscle. Using a finger-pinch technique, the rectus can be palpated and a Kocher clamp placed on the fascia at the anterior medial edge of the muscle. The posterior rectus sheath is then incised 5-10 mm lateral to the medial edge. The muscle fibers must be visible to ensure that entry into the retrorectus space (rather than transection of the linea alba) [Figure 1]. With few exceptions (notably prior PCS), this plane should easily open and reveal loose alveolar tissue. Electrocautery is then used to extend the incision on the posterior sheath superiorly and inferiorly. It is important to keep this incision close to the medial edge of the muscle and not skive laterally, to preserve as much posterior sheath as possible for reapproximation. As the incision is extended, we place more clamps (Kocher or Lahey) on both the anterior sheath (linea alba) and the now liberated posterior sheath. The more clamps on the fascia, the more the

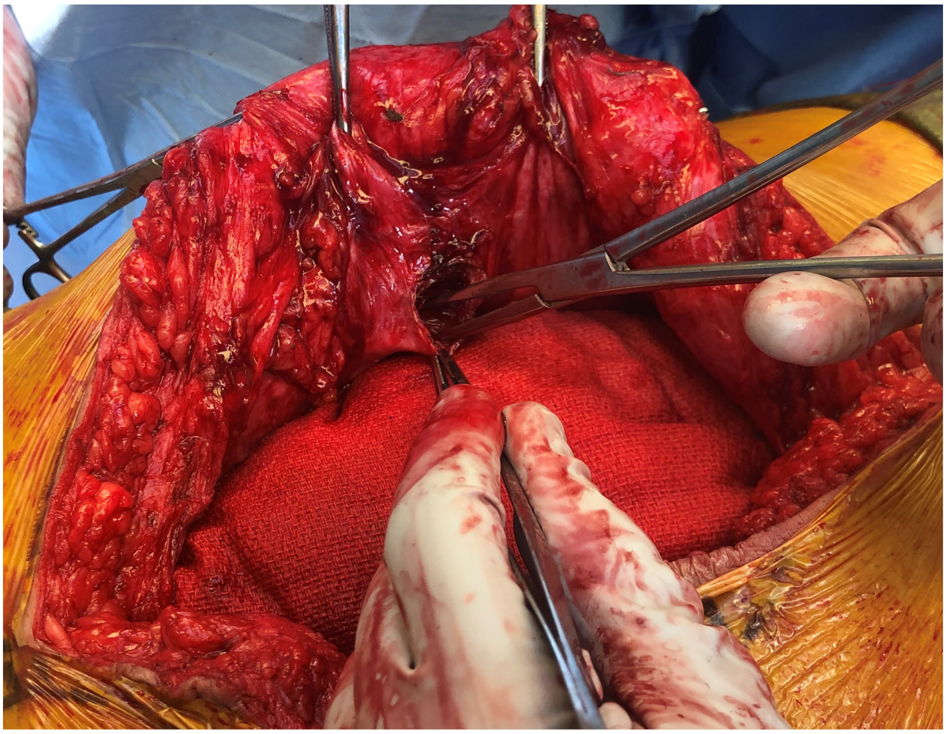

**Figure 1.** Entering the retrorectus space: After palpating the edge of the rectus muscle, the rectus sheath is incised 5-10 mm lateral to the medial edge revealing muscle fibers

retraction (tension) is evenly distributed and less likely to tear fascia. Blunt and electrocautery dissection is then used to extend the dissection to the lateral edge of the recuts muscle where the linea semilunaris is encountered. Working lateral, it is helpful to have the assistant use a Richardson retractor to lift the rectus up and away from the posterior sheath as the surgeon moves laterally. Kittner (peanut) dissectors are helpful tools to sweep the loose alveolar tissue off the posterior sheath as one works laterally.

The dissection is extended cephalad towards the costal margin. The extent depends on the size of the hernia, although it commonly extends to the epigastric or subxiphoid area. Inferiorly, the surgeon works towards the space of Retzius. Below the arcuate line, the posterior rectus sheath thins (being composed only of peritoneum and transversalis fascia). Crossing from the one retrorectus space to the other in the low midline requires division of the transversalis insertion points to the linea alba to create one confluent plane [Figure 2]. At this level, care must be taken to identify and preserve the deep inferior epigastric vessels as they run along the posterolateral surface of the rectus muscle in the pretransversalis plane. They are typically invested in fibro fatty tissue that can be swept off the posterior sheath/transversalis fascia towards the muscle in a dissection that mimics maneuvers performed during a laparoscopic inguinal hernia repair. Often, the caudal extent of dissection proceeds into the space of Retzius to expose the pubis symphysis and Cooper's ligaments. This completes the extent of a Rives-Stoppa exposure.

### Division of the transversus abdominis

At this point, if the linea alba cannot be reconstructed in the midline without undue tension or there is insufficient sublay space for wide mesh overlap, a TAR should be completed. The TAR can be started cephalad first ("top-down" approach) or from the caudal aspect ("bottom-up" approach), often chosen by surgeon preference or dictated by patient anatomy. The "top-down" approach starts in the upper aspect of dissection where the TA muscle is more medial to the linea semilunaris and is generally thicker. Beginning the dissection at this level offers a level of safety, as the muscle belly is a good anatomic landmark and

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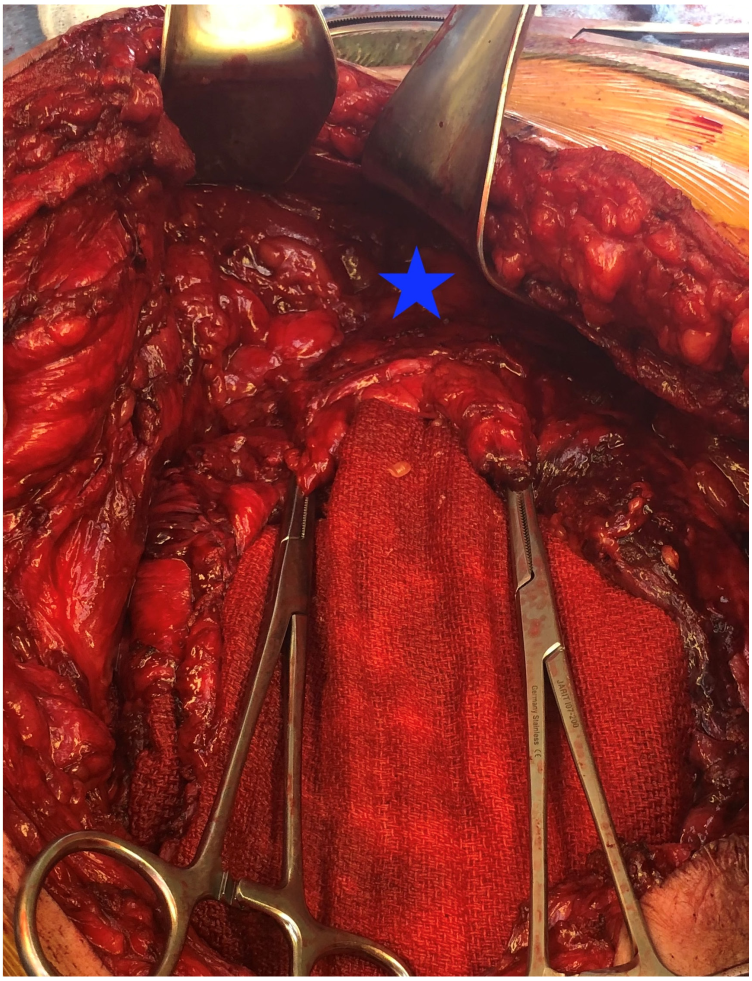

**Figure 2.** Connecting planes (inferior): crossing from the one retrorectus space to the other inferiorly to create one confluent plane. The blue star marks the pubic symphysis

is thick enough to prevent inadvertent holes from being created in the underlying transversalis fascia/peritoneum. It is important to remember that the lateral neurovascular supply to the rectus muscles penetrate the posterior lamina of the IO at the lateral rectus boarder; care must be taken to start the TAR medial to these bundles to prevent denervation of the rectus itself. To start the TAR, the posterior lamina of the IO aponeurosis is incised just medial to the perforating neurovascular bundles exposing the underlying TA muscle belly [Figure 3]. The TA fibers are separated from the underlying transversalis fascia/peritoneum [Figure 4]. The TA release should continue inferiorly. Once the edge of the TA is freed, it can be grasped with a clamp and carefully retracted anterior to further release it from the posterior elements.

There are 2 planes within which the dissection can proceed. Dissection between the TA and the transversalis fascia allows access to the pre-transversalis plane. Dissection in this layer is a bit more difficult as the fascia is generally quite stuck to the muscle belly. This can make the dissection more difficult, resulting in more bleeding/ooze. However, it also leaves both the transversalis fascia and the peritoneum as the posterior layers of the reconstruction, making it thicker and less prone to hole formation and tearing. Alternatively, dissection can proceed between the transversalis fascia and the peritoneum in the pre-peritoneal plane. Dissection in this layer is generally much easier as there is less connective tissue between the layers and no blood vessels. However, the peritoneum is exceptionally thin and is prone to tearing (and

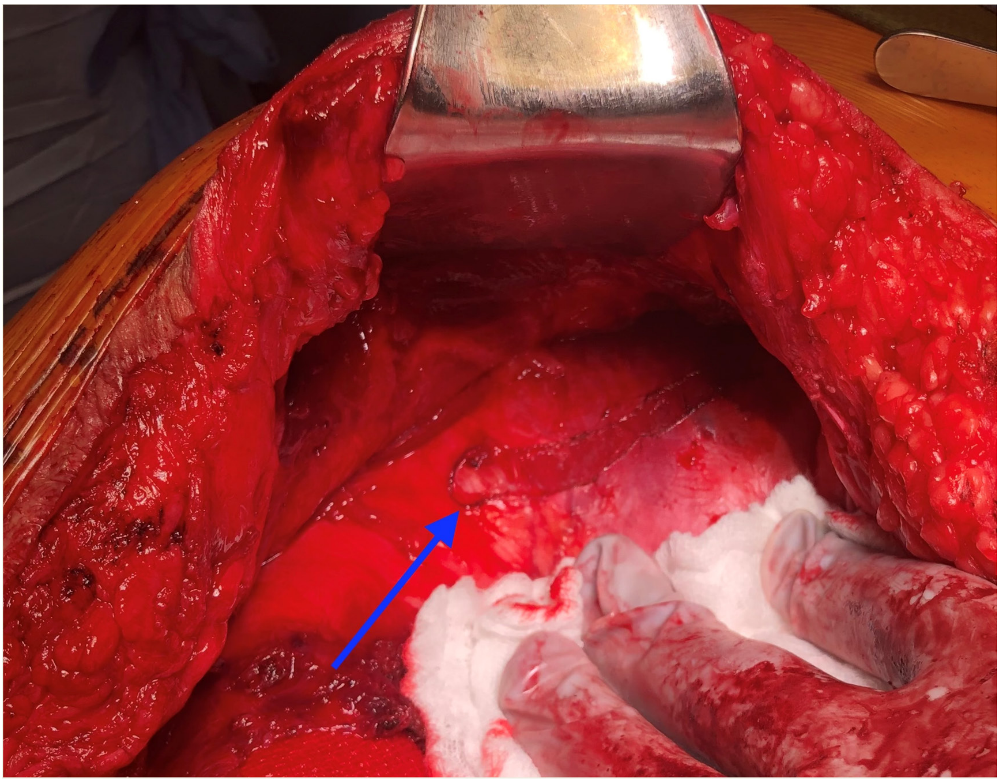

**Figure 3.** Accessing the transversus abdominis: the posterior lamella of the internal oblique is scored (blue arrow) to reveal the underlying transversus abdominis

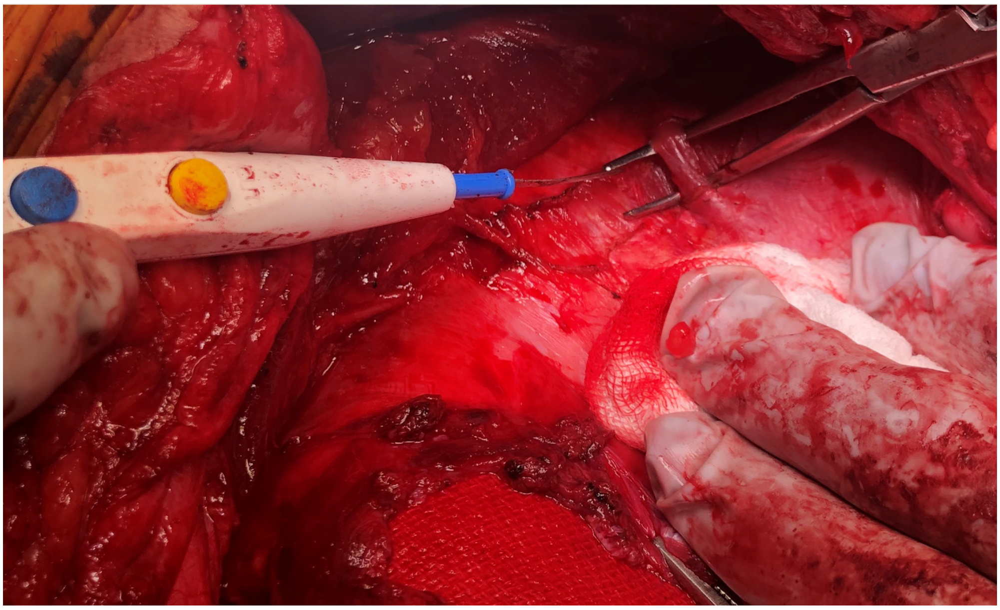

**Figure 4.** Releasing the transversus abdominis: a right angle clamp gentle reveals the muscle fibers that are then divided with electrocautery

propagating tears once they start can be challenging to fix). Either plane can be used, and surgeons should become comfortable learning how to "plane-hop" between these two as needed on a patient-by-patient basis and based on the need to address focal areas of difficulty in any individual patient.

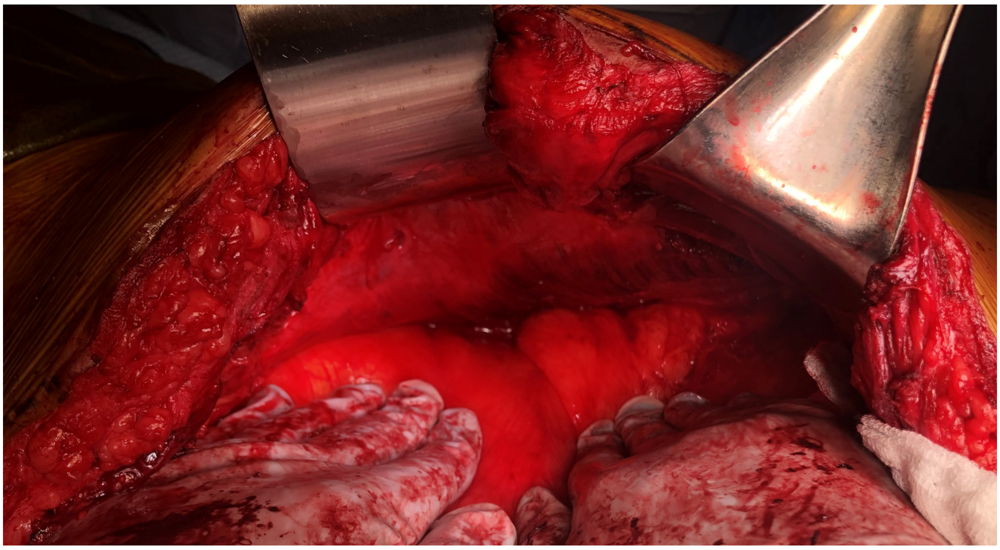

**Figure 5.** Lateral dissection: the lateral dissection can proceed as far back as the psoas muscle in the retroperitoneum

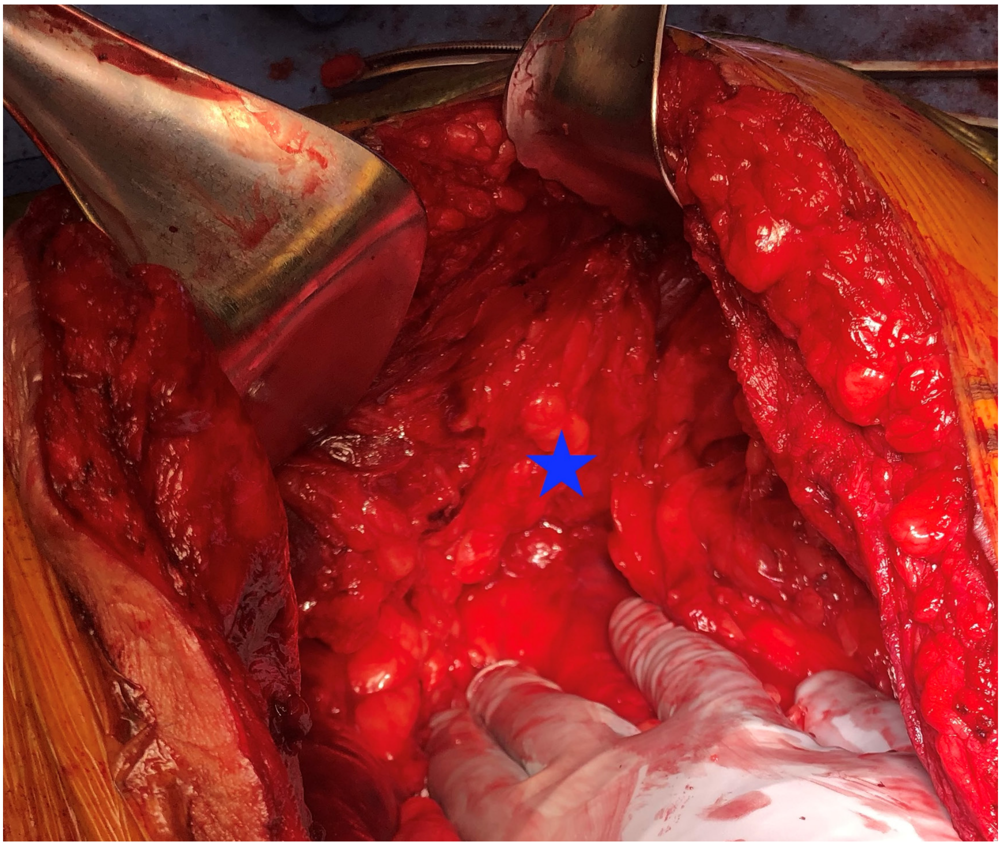

**Figure 6.** Inferior view: fat within the inferior pre-peritoneal plane should be cleared in this dissection to reveal the myopectineal orifice. The blue star marks the pubic symphysis

Dissection in the pre-peritoneal or pre-transversalis plane is continued moving laterally to extend the space towards the retroperitoneum and the psoas muscle [Figure 5]. Cranially, the dissection can proceed above the costal margin on the diaphragm. The plane stops at central tendon of the diaphragm in the midline. Care must be taken to perform limited finger dissection underneath the costal margin, dorsal to the ribs, and not to inadvertently divide diaphragm fibers that interdigitate with the TA in the cranial-medial aspect. Doing so may create an iatrogenic diaphragm hernia. At the superior/medial extent of the dissection, the TA release will join a subxiphoid pre-peritoneal dissection plane (discussed in next section).

Working caudally, it is important to remember that the TA muscle fibers do not reach as far medial as they do in the upper abdomen. By the level of the umbilicus, there is only a bilayered aponeurotic insertion of the TA to divide as part of the TAR. The plane between the TA aponeurosis (tendon) and the underlying peritoneum can be dissected bluntly in a relatively straightforward fashion. Further caudally, there will be substantial fat within the pre-peritoneal plane that further facilitates this dissection [Figure 6]. The ease of separation of the layers is the basis for a "bottom-up" TAR. By bluntly dissecting from the retrorectus space towards the myopectineal orifice, a pre-peritoneal/pretransversalis plane can be created. Further blunt dissection cranially separates the TA aponeurosis from the underlying layers, and the aponeurosis can then be divided. Some surgeons prefer the "bottom-up" approach to TAR because of the ease of starting the plane at this level.

### Midline crossover/transition

When the sublay plane is fully dissected to the superior and inferior extent, the right and left retromuscular planes need to be connected. This is sometimes referred to as "plane hopping" or "crossing over". Inferiorly, the space of Retzius should be exposed down to the pubis. Connecting the right and left sides at this level requires no more than ensuring the dissection planes (either pre-peritoneal or pre-transversalis) meet in the midline. If one side is performed pre-peritoneal and one side pre-transversalis, they will not meet properly in the midline without additional division of transversalis fibers off of the linea alba in the midline. For low (European Hernia Society Classification: M4 or M5 zone) hernias, Cooper's ligaments should be exposed and may be used as fixation points for mesh[23]. Any hernias of the myopectineal orifice should be identified and reduced (including lipomas of the cord). The round ligament in women can routinely be divided, while the spermatic cord in men must be carefully dissected around. With this exposure, the sublay planes will connect at the caudal aspect.

For the cranial dissection, if the hernia defect approaches xiphoid process in the M1 zone, the insertion of the posterior rectus sheath into the linea alba is divided to the level of the xiphoid. First, a plane superficial to the falciform ligament and deep to linea alba must be developed. Next, retroxiphoid space should be accessed. This is a fatty subxiphoid plane that extends to the sternum. This can be finger-swept posteriorly off the xiphoid. Additionally, this preperitoneal space can be worked along the diaphragm to the central tendon. The process of connecting the right and left retrorectus spaces with the pre-peritoneal plane of the falciform ligament in the midline is referred to by some as the "pant leg maneuver" because of the appearance of the undivided planes [Figure 7]. The insertion should be cut 0.5 cm lateral to the linea alba on each side, which will drop the edge of the posterior sheath to allow reapproximation. Dividing the posterior sheath insertion into the lineal alba, moving cranially along the xiphoid process, connects these spaces [Figure 8].

### Closure of the posterior sheath

Once the entirety of the retromuscular plane is developed, the posterior sheath is closed. Small defects in the posterior sheath should be closed with an absorbable suture, generally in a transverse direction (perpendicular to the midline) to prevent herniation of bowel into the retromuscular pocket. Larger defects or areas that are extremely thin may not be closable primarily. In such circumstances, a piece of autologous tissue (hernia sac and omentum) can be used to patch the graft. At times, difficulty with reconstruction of the posterior layer can be predicted before any myofascial release is performed. In such cases, we generally take the hernia sac off the subcutaneous tissues in the midline and leave it attached to the posterior rectus sheath to serve as a continuous layer for reconstruction later. Larger defects can also be closed

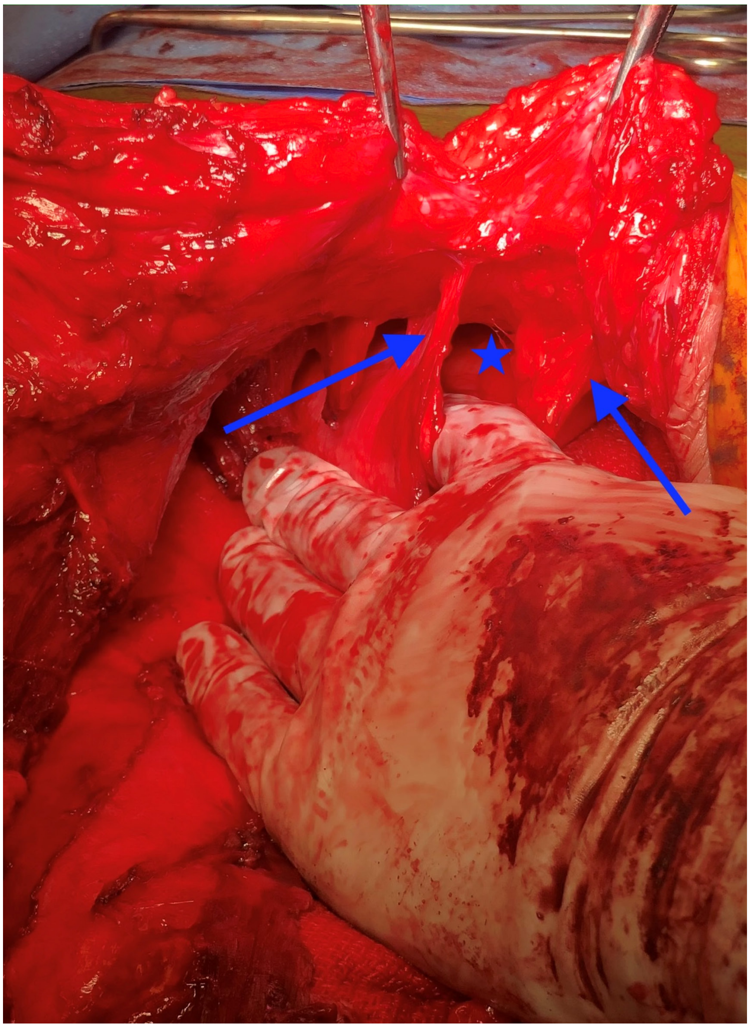

**Figure 7.** Pant leg maneuver: the subxiphoid plane is dissected. After the right and left retrorectus spaces are developed, the surgeon's fingers can straddle these planes demonstrating the two "pant legs". The blue arrows show the right and left "pant legs" (linea alba insertion) that straddle subxiphoid/preperitoneal space (blue star)

with polyglycolic acid, biologic or coated 4-hydroxybuterate mesh if autologous tissue is not available. Polyglycolic acid mesh is the most inexpensive of the three, and is proven to be safe for such reconstruction purposes[24].

Bilateral TAR should provide enough myofascial advancement to allow the posterior sheaths to meet in the midline [Figure 9]. If there is undue tension on the midline closure, additional lateral dissection can be performed bluntly to gain additional midline advancement. The right- and left-hand sides of the posterior layer are closed in the midline with an absorbable running suture from the superior and inferior ends. If the midline can be approximated, but is closing with some tension, a locking bite can be performed every few travels. Prior to closing the mid portion, the countable towel must be removed from the peritoneal cavity.

### Preparation of the sublay space

Any remaining hernia sac is dissected free from the subcutaneous fat. The sac and any unusable fascial bands are resected, revealing healthy EO fascia at the medial boarder of the RA. Some surgeons routinely irrigate the retromuscular space with antibiotic lavage solution. The purpose is to reduce the bioburden of

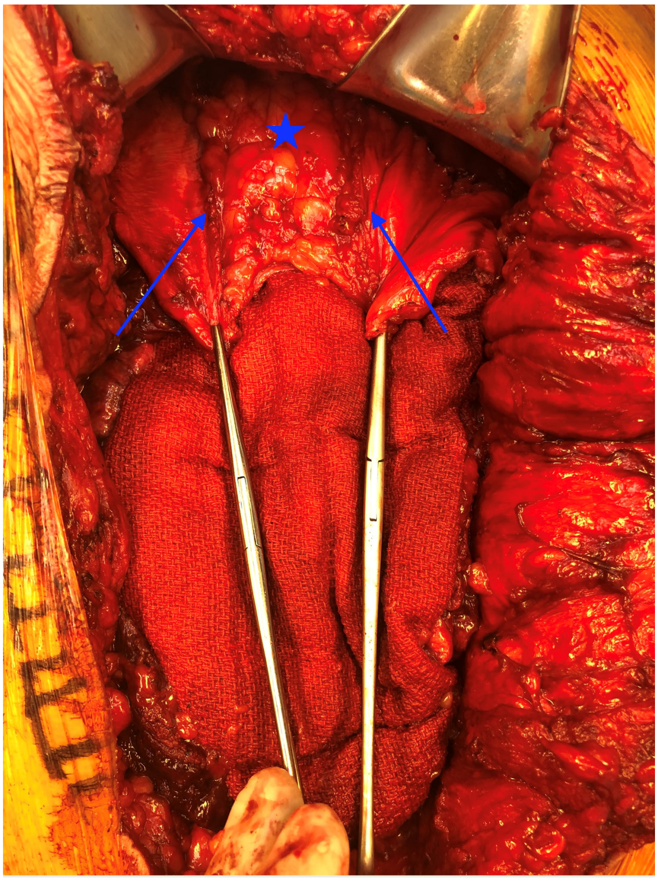

**Figure 8.** Connecting plans superiorly: cutting the "pant leg" insertion will drop the edge of the posterior sheath (blue arrows). This connects the bilateral retrorectus spaces with the subxiphoid/preperitoneal space (blue star)

the space prior to placement of mesh. Warren and colleagues showed that irrigation with a combination of gentamicin and clindamycin significantly lowers the rate of SSI/SSOs and reoperation for wound complications[25]. Similarly, Majumder *et al.*[26] showed that pressurized antibiotic pulse lavage was effective at reducing bioburden in the TAR plane in both clean and contaminated cases. While irrigation cannot eliminate SSI, we utilize lavage as part of our standard operative methods to reduce the risk of mesh contamination.

Next, we perform transversus abdominis plane blocks by injecting liposomal bupivacaine (266 mg/20 mL diluted in 180 mL of saline) into the intramuscular plane between the internal oblique and TA muscles with an 18-gauge needle under direct visualization. We have previously shown this method to provide superior analgesia (as proven by significantly less postoperative narcotic utilization) when compared to ultrasound-guided administration of the same agent in the same plane[27].

### Placement of mesh and fixation

The mesh should be large enough for large defect overlap (~8 cm), filling the entire retromuscular space. We generally favor a medium weight, large pore, polypropylene product to allow for robust tissue ingrowth and incorporation. Our typical mesh implant is 30 cm × 30 cm, which when oriented as a diamond has a 42 cm cranial-caudal dimension [Figure 10]. In this orientation, there is often insufficient overlap in the superior aspects (above the costal margin). In such cases, a second piece of 30 cm × 30 cm mesh is placed as a square, overlapping the top of the first mesh placed as a diamond. This configuration is commonly referred to as "home plate" mesh configuration due to the resemblance to home plate of a baseball field.

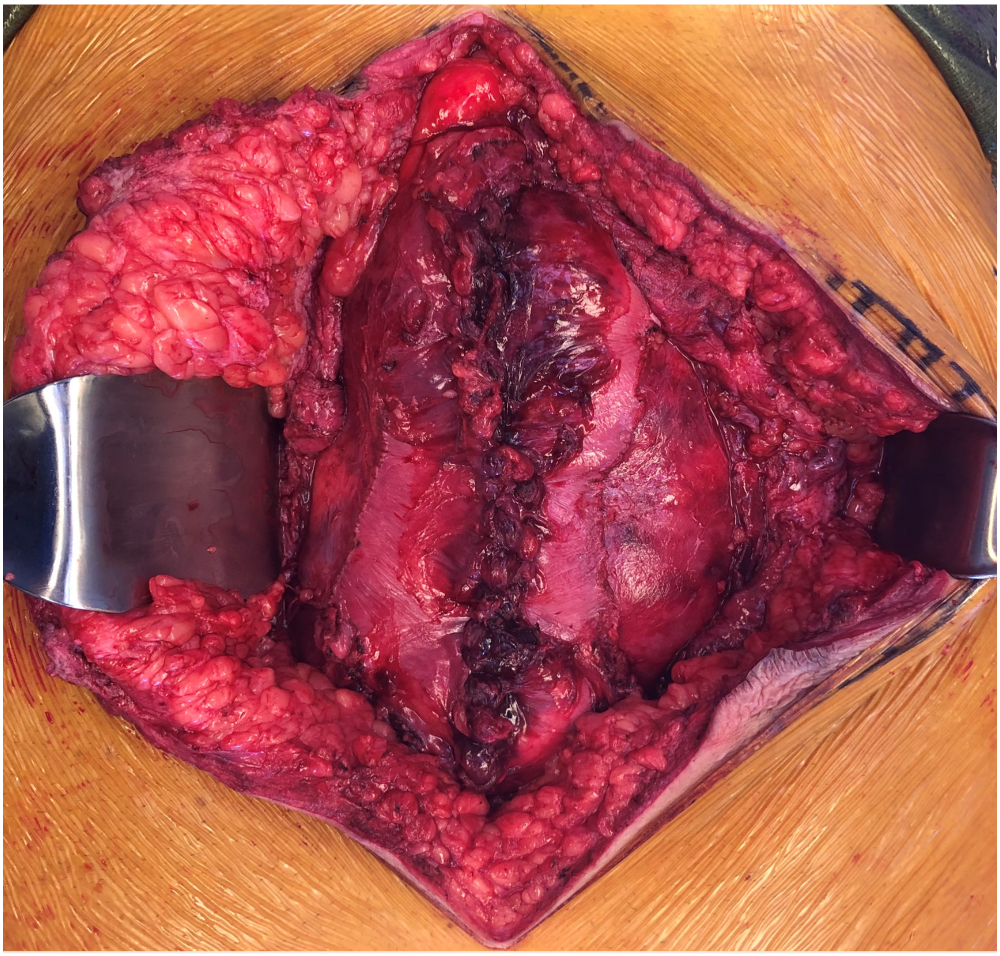

**Figure 9.** Reapproximation of posterior sheath: the visceral sac is reapproximated, and a large sublay space is created

The overlap of mesh in the midline appears to be inconsequential in our experience, although no study has evaluated this issue specifically.

Mesh fixation is an active topic of discussion among hernia surgeons. Most would agree that inferior fixation is important. For low hernia defects, the inferior aspect of the mesh can be sutured to Cooper's ligament bilaterally with 2 interrupted monofilament, slowly absorbable sutures. If the caudal extent is more than 5 cm above the pubis, transfascial fixation (described below) can be achieved without suturing to Cooper's ligament. Advocates of "minimal" or "no" fixation support the idea that wide placement mesh along with radial intra-abdominal pressure will keep the mesh in place. One "minimal fixation" technique is the use of fibrin sealant fixation to the underlying posterior sheath [Figure 11]. Others simply place the mesh in the retromuscular space with no fixation. When sutures are felt to be necessary, we place 6-8 #1 slowly absorbable, monofilament, slowly-absorbable sutures radially around the mesh utilizing a suture passer delivered through percutaneous stab incisions[28]. This technique uses the transfascial sutures to "off load" the tension off the midline closure and onto the mesh and prevents buckling of the mesh during closure[29].

### Closure of anterior fascia and skin

For open TAR operations, we routinely place a single 19Fr drain into the retromuscular pocket to reduce the volume of seroma that can accumulate in the immediate postoperative period. The lineal alba is then

**Figure 10.** Mesh placement: after antibiotic irrigation of the sublay space, mesh is placed. In this case, a square piece of mesh oriented in diamond fashion with apices running vertically and horizontally

reapproximated with either a running (low tension closure) or interrupted Figure 8 pattern (high tension closure) #1 slowly absorbable, monofilament suture [Figure 12]. Any additional dermal scar, ischemic skin, and typically the umbilicus are resected back to healthy bleeding skin. The subcutaneous tissue is closed in layers. If large subcutaneous spaces remain, a 19Fr drain is placed on the patients left side (left = lipocutaneous). The peripheral stab incisions can be closed with skin adhesive. If there is significant radial tension on the skin closure, if there was GI tract contamination during the case, or there is an ostomy present, we choose to place a closed incisional vacuum dressing to further protect the wound. This practice may not be beneficial in routine TAR cases[30].

## POSTOPERATIVE MANAGEMENT

One of the biggest immediate perioperative concerns is in patients with loss of domain defects that put them at risk for postoperative abdominal compartment syndrome and respiratory complication. If pulmonary plateau pressures increase more than 6 mmHg after closure, patients remain intubated in the intensive care unit overnight. In those with more than 11 mmHg increase in plateau pressures, consideration to 24 h of paralysis should be made[31]. Generally, abdominal compliance improves within the first day. An abdominal binder is placed on all patients before exiting the operating room and the bladder catheter is kept in place.

Much attention is given to Enhanced Recovery After Surgery (ERAS) pathways and early outcomes in abdominal wall reconstruction are encouraging[32]. Barring extensive lysis of adhesions or a bowel

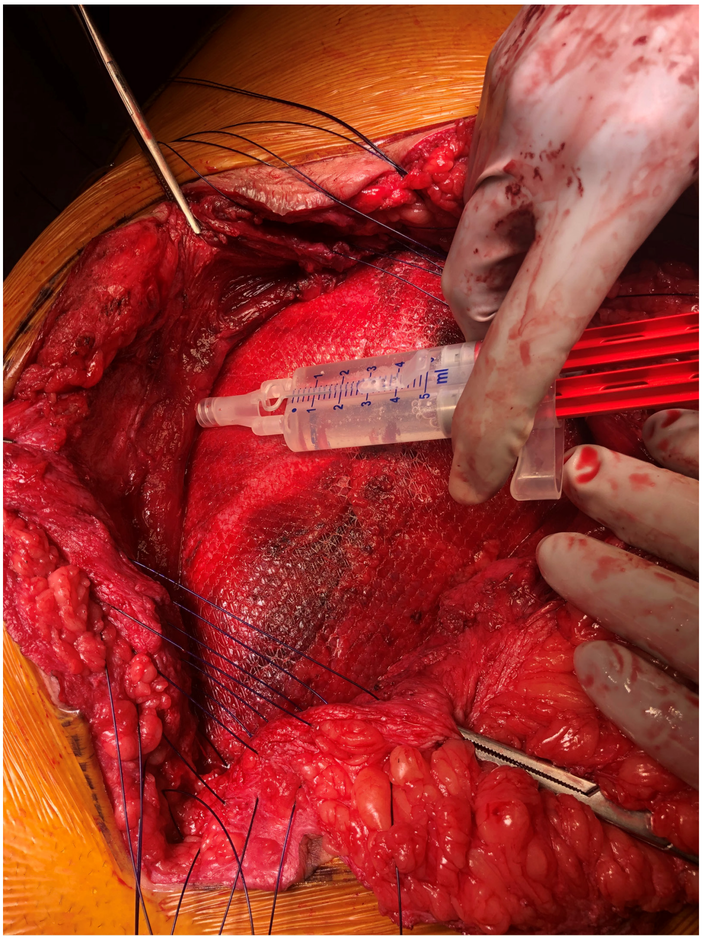

**Figure 11.** Fixation: fibrin glue is used to fixate the mesh in the sublay space

resection, a clear liquid diet is started on postoperative Day 1, and advanced as tolerated the following day. Alvimopan can be used to accelerate intestinal recovery, but first dose must be given in the preoperative holding area. Deep vein thrombosis prophylaxis is started the evening of surgery or the next morning and continues throughout their hospitalization. Intravenous fluids are weaned and held on postoperative Day 2 if the patient is self-hydrating. The bladder catheter is generally removed on postoperative Day 1.

Analgesia may be offered in many forms. For those who received intraoperative TAP blocks, minimal narcotics are used postoperatively. Otherwise, scheduled acetaminophen and gabapentin are used. If narcotics are required, we often use as needed oxycodone orally and a patient-controlled analgesia administration of intravenous hydromorphone. Patients are encouraged to ambulate as soon as they are able, and as frequently as possible. Pulmonary hygiene is equally emphasized. Drain output should be recorded daily. Our practice is to remove the retromuscular drain prior to discharge, unless the output is exceptionally high in the 24 h before discharge (> 150-200 mL). Subcutaneous drains (if utilized) are left until the output is < 30 mL per day for two consecutive days.

We typically have postoperative clinic follow up at 4-6 weeks and 1 year postoperatively. It is our practice to routinely perform CT imaging postoperatively to assess for occult issues (including fluid collections and recurrent hernias).

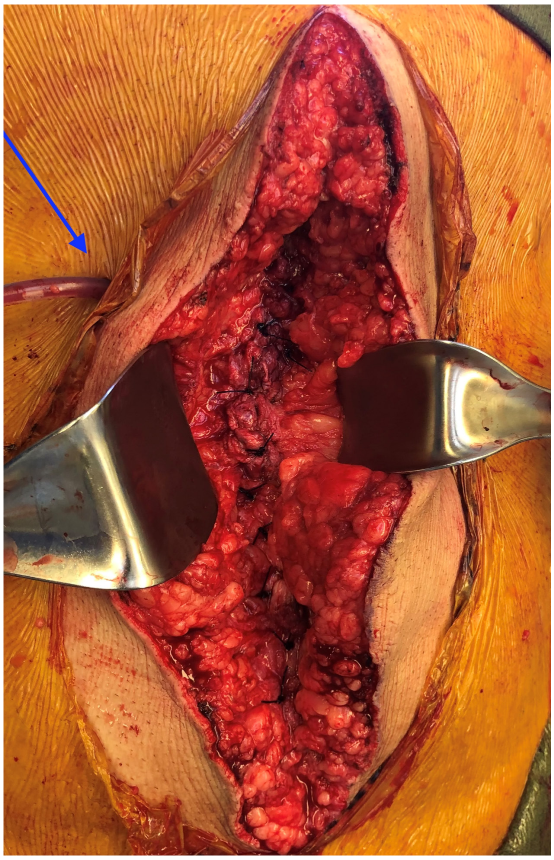

**Figure 12.** Anterior fascia reapproximation: the anterior fascia is closed. In this case, it was closed with interrupted suture to offload midline tension. A retromuscular drain is placed on the patient's right side (blue arrow)

## SPECIAL SITUATIONS

The transversus abdominis release technique can be utilized in unique hernias as well. We have found TAR to be successful for the management of parastomal hernia (or for large midline hernias occurring in patient with an ostomy adjacent to the defect)[33,34]. If the stoma does not warrant relocation, a TAR is carefully performed around the stoma as described above. Next, the posterior sheath defect for the stoma is intentionally extended laterally. The bowel proximal to the stoma is delivered into the retroperitoneal plane and posterior sheath defect is closed lateralizing the bowel within the retromuscular space. Mesh is positioned around the bowel in a Sugarbaker fashion, which permits wide overlap of hernia defects without the need to cut the mesh or relocate the stoma[33].

Another special situation is a hernia recurrence after ACS, reported in 7%-32% of cases[35]. As stated previously, the concern in performing a TAR after ACS centers on the potential for lateral hernia formation. Previous evaluation of TAR after EO release resulted in hernia recurrence in only 3% of patients after 11-month follow-up, suggesting the method may be utilized successfully in experienced hands[12].

## MINIMALLY INVASIVE APPROACHES TO TAR

In the era of new surgical technologies, much attention is paid to developing minimally invasive approaches to TAR. The following subsections briefly describe some of the novel techniques.

### Mini or less-open sublay operation

The mini or less-open sublay operation (MILOS) technique was developed by Dr. Reinpold *et al.*[36] out of a desire to minimize complications and pain related to open repair, but allow a large sublay mesh to be placed through a small incision through the hernia. Briefly, this procedure starts with an incision centered over the hernia defect and exposure of the hernia sac. Transhernia laparoscopy is set up and adhesiolysis is performed to expose the hernia defect ring. The peritoneum is detached from the abdominal wall and the posterior sheath is entered. An assistant elevates the abdominal wall and the retrorectus space is developed laparoscopically or with direct visualization with a 10-mm light tube (Endo-torch, Wolf TM, Knittlingen, Germany). After 8 cm of extraperitoneal space is achieved circumferentially, the peritoneum is closed and the operation is converted to a laparoscopic extraperitoneal repair [extended total extraperitoneal repair (eTEP)]. The posterior sheath is closed under low gas insufflation and the mesh is rolled, inserted into the field, and then unfolded.

In 2019, this group reported their results after 615 MILOS repairs[36]. There was a statistically significant reduction in postoperative complications, recurrences, and chronic pain compared to laparoscopic intraperitoneal onlay mesh (IPOM) technique.

### Extended total extraperitoneal repair TAR

eTEP of ventral hernias was created as an extension of total extraperitoneal (TEP) repair of inguinal hernias. The major advantage of this approach is a lack of entry into the abdominal cavity, obviating bowel manipulation, peritoneal defect closure, and intra-abdominal adhesion formation. Classic TEP repairs are limited by their minimal dissection space, thus space for mesh overlap as well as restricted port placement. Daes[37] popularized the "extended view" of TEP inguinal hernia repair to allow for easy creation of the extraperitoneal space in a large surgical field to facilitate mastery of the repair and utility in complex cases. Subsequently, Belyanksy *et al*.[38] and an international group of hernia specialists reported on expanding this technique to laparoscopic ventral hernia repairs (eTEP). Their technique is described briefly.

The patient is placed supine on the operating table in a flexed position to widen the space between the costal margin and anterior superior iliac spine. Port location depends on the location of the defect, but the guiding principles of eTEP rely on initiating the dissection in the retrorectus space of one side and "crossing over" to the contralateral retrorectus space in the fat pads of the falciform ligament of the space or Retzius. The dissection is carried out along the length of the RA muscles and the bilateral posterior sheaths are released to connect the contralateral spaces in the midline by mobilizing the hernia sac out of the defect, keeping it in continuity with the posterior rectus sheath. For larger defects, TAR can be added on either side (or both) to permit further posterior and anterior sheath mobilization. Posterior sheath defects are closed with absorbable suture, and the anterior fascial defect is closed with a running barbed suture under low-pressure pneumoperitoneum. Mesh is then placed to fill the retromuscular pocket and fixated as desired. Early results eTEP posterior component releases have shown promising results. Of the 79 patients reported by this group, there was a 3% wound complication rate, no 30-day readmissions, and only one hernia recurrence with 11 months of follow-up[39].

## ROBOTIC TAR

Further advancement in surgical technology leads to the development of robotics, which have the added benefit of finer instrument movements, greater range of freedom, and elimination of tremor. An essential first consideration is paid to trocar placement and robot docking. Patients are placed in the supine position. The arms are extended at 90 degrees to allow lateral robot arm placement for more working space and a full range of motion. An 8-mm robotic trocar is placed in the lower lateral abdomen as well as the upper abdomen on the ipsilateral side, while a 12-mm trocar is placed half way between the two as far lateral as possible. Future mesh placement can be through the camera's 12-mm port, or a fourth accessory port (12 mm) can be utilized and placed in a subxiphoid or suprapubic location. In general, a grasping instrument with bipolar energy and scissors with monopolar energy are used.

Initial steps in robotic TAR parallel those in open surgery. With the camera in a 30-degree-up configuration, extensive adhesiolysis is performed to free bowel from the abdominal wall. The contralateral edge of the rectus muscle is identified and grasped and the retrorectus space is entered with the scissors. This space is developed both inferiorly and superiorly staying parallel to the fibers of the rectus muscle. Once the retrorectus space is developed, the camera is changed to 30 degrees down to begin the TAR dissection, either in a top-down or bottom-up fashion (as discussed above). Below the arcuate line, the space of Bogros is developed. Staying medial to the linea semilunaris and the neurovascular bundles, the posterior lamina of the IO aponeurosis is incised exposing the TA muscle. The fibers are separated from the underlying transversalis fascia/peritoneum, extending laterally towards the psoas muscle. The dissection can be extended as laterally, inferiorly, and superiorly as previously described.

Once enough sublay space is developed for adequate mesh overlap and holes in the posterior sheath are closed, the posterior sheath is reapproximated with a running 2-0 absorbable barbed suture. Next, the hernia defect and linea alba are closed with a running #1 permanent barbed suture. Pneumoperitoneum can be lowered to reduce the tension on the closure. Mesh is introduced and unrolled to fill the sublay space. Fixation of the mesh is a debated topic, though many experts use fibrin sealant spray to achieve fixation and hemostasis. A surgical drain may then be introduced.

Outcome data of robotic repairs are promising. In a two-institution study, Martin-Del-Campo *et al*.[39] reported reduced blood loss and systemic complications. The patients undergoing robotic repair also benefited from shorter length of stay and reduced readmissions compared to a matched group of open TAR patients. There is ongoing study of this new approach, and long-term data are approaching.

## OUTCOMES

Hernia repair utilizing TAR is safe and effective in published series. Novitsky *et al*.[11] described their experience in 428 consecutive cases in 2016. With a minimum of one-year follow-up, they demonstrated a 3% recurrence rate and a SSI rate of only 9%. No mesh prosthetics required explantation, although 3 patients required debridement. The most common reason for recurrence was central mesh failure followed by lateral, suprapubic, and subxiphoid recurrence.

Studies compared PCS with ACS to determine which release yields better outcomes. With regard to myofascial advancement, anatomic study in 13 human cadavers evaluated PCS, ACS, and the Rives-Stoppa repair[40]. The authors found that ACS provided marginally more medialization of the anterior sheath compared to PCS. On the contrary, PCS advanced the posterior sheath more. A subsequent study of 10 cadavers revealed that each subsequent step of TAR (rectus sheath release, IO lamella release, TA muscle division, and lateral retromuscular dissection) permits increasing myofascial advancement up to approximately 10 cm per side[41].

Clinical outcomes between these methods have similarly been evaluated. A retrospective comparison of 56 ACS cases to 55 PCS cases found significantly more wound complications in the ACS group (48.2% *vs*. 25.5%, $P$ = 0.01) and a higher hernia recurrence rate (14.3% *vs*. 3.6%, $P$ = 0.09)[42]. To reduce wound healing complications associated with ACS, several minimally invasive techniques (MI-ACS) have been developed[43]. However, even though a 2017 study comparing MIS-ACS to TAR found equivalent rates of SSI/SSO, there was a non-significant, albeit double, recurrence rate in the MIS-ACS group. A recent meta-analysis compared mesh location in the abdominal wall and reported reduced recurrence and SSIs with preperitoneal mesh (as performed in TAR) compared to intraperitoneal and onlay (in most ACS approaches)[44].

Most comparative data are retrospective and heterogeneous. No randomized controlled, prospective trial comparing ACS to PCS has been completed at this time. However, data do support improvement in quality of life scores and abdominal wall function after abdominal wall reconstruction with transversus abdominis release[10,45,46].

## CONCLUSION

The transversus abdominis release technique to repair large ventral defects is durable and reliable. It obviates the creation and morbidity of large lipocutaneous flap performed in ACSs. The TAR approach is beneficial in cases of previous anterior hernia repairs and provides the mesh with a well-vascularized space for tissue ingrowth and incorporation. This technique can be utilized in special scenarios and in novel techniques focusing on minimally invasive approaches.

## DECLARATIONS

### Authors' contributions

Made substantial contributions to the entirety of this review: Siegal SR, Pauli EM

### Availability of data and materials

Not applicable.

### Financial support and sponsorship

None.

### Conflicts of interest

All authors declared that there are no conflicts of interest

### Ethical approval and consent to participate

Not applicable.

### Consent for publication

Not applicable.



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