16 Open Anterior Component Separation with Perforator Preservation

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Introduction

As surgeons, we can all agree that blood flow to tissues is associated with healing, while ischemia is associated with tissue loss and complications. In regard to hernia repair, a technique called "perforator preservation" serves to maintain pulsatile skin blood flow while still performing a components separation hernia repair by avoiding the undermining of skin flaps. This style of ventral hernia repair is more than simply avoiding the division of blood vessels to the skin; it also requires an understanding of abdominal skin blood flow, an appreciation of the forces at the suture/tissue interface (STI), a means to achieve primary fascial closure with mesh using concepts of force distribution, and excision of redundant midline skin. In the following chapter, a brief introduction of laminar versus pulsatile blood flow and the angiosome theory of perfusion will be presented. The history of perforator preservation as an adjunct to the components separation technique will be recounted. The value of components separation as a means to reduce suture pull-through will then be introduced. The technique of perforator preservation at the time of components separation and use of a narrow mesh will be presented in a video demonstrating this repair in a 76 year old gentleman with heart disease, a one pack per day current smoker, four previous attempts at repair including prior mesh, and with a 16 cm in transverse dimension hernia by CT.

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Laminar Versus Pulsatile Blood Flow/Blood Flow of the Abdominal Wall

Vascular surgeons have extensive studies correlating the quality of tissue perfusion with the healing of surgical incisions. In the early 1970s, lower extremity blood flow was analyzed using a combination of pulse-volume recordings and blood pressures [1]. A tiny blood pressure cuff placed on a toe or across the instep of the foot would have a small incremental change in pressure due to the stroke volume of blood introduced into the aorta by the heart during systole. Normal blood flow is pulsatile, correlating to each heartbeat. Laminar flow, in contradistinction, does not experience the repeated episodic increases in pressure. Laminar flow is associated with numerous conditions familiar to surgeons including prior scar, radiation, proximal vascular obstruction, and division of native vascularity. It has been shown experimentally and clinically that primary healing

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occurs more predictably when tissue is vascularized with pulsatile blood flow [2–4].

An angiosome is defined as a three-dimensional block of tissue supplied by a single named blood vessel. The size of a particular angiosome varies depending on the flow in the vessel and has patterns based on locations in the body. At the borders of the angiosome exist choke vessels that are normally without flow, but that can open and provide flow when a border area becomes ischemic. Over time, choke vessels can reestablish pulsatile blood flow in an area that has lost its original vascularity. The opening of choke vessels occurs more slowly with advancing age, when the adjacent angiosome is itself not well perfused, when the tissues have been radiated, and in smokers. In a typical patient, choke vessels between skin angiosomes do not open robustly for 2–3 weeks.

The blood flow of the abdominal wall comes from numerous sources. The central tissue is predominantly supplied from *periumbilical perforators* traveling through the rectus abdominis muscle from the deep inferior and the superior epigastric arteries. The tendinous inscription of the rectus muscles that exists typically 1 cm above the umbilicus is the inexact boundary between these two arterial territories. Inferolaterally, perfusion is from the superficial inferior epigastrics, commonly coagulated during inguinal hernia repair. The superficial and deep inferior epigastrics have overlapping territories for the abdominal skin, with one vessel being able to supply the other's territory when necessary. Congenitally large deep systems usually coexist with small superficial systems, and vice versa. Superiorly and laterally, the segmental intercostal vessels and lumbar arteries give off perforators through the external oblique muscle at the level of the mid-axillary line. Connections exist between the periumbilical perforators and these lateral segmental vessels in imaginary dermatomal lines traveling between the umbilicus and the tip of the scapula.

Plastic surgery and flaps require a basic understanding of the limits of tissue undermining. In general, tissue elevation during the creation of skin flaps requires that an adjacent angiosome supply the newly elevated skin. Rather than having pulsatile blood flow, the newly elevated skin is maintained with laminar blood flow, and healing may be somewhat compromised. Common skin flap elevations where history and experience teaches that the quality of laminar blood flow is sufficient for healing include the standard abdominoplasty skin elevation from the symphysis pubis to the xiphoid, and the oblique rectus abdominis myocutaneous flap (ORAM) [5]. As these flaps require the immediate opening of choke vessels to allow perfusion, these flaps are not performed when perpendicular scars are present, or in smokers. Judgment is involved in what can be elevated safely and what would be considered unreliable. The importance of what lies underneath the skin is also critical. In an abdominoplasty, there is intact well-vascularized abdominal wall, while in a spanning mesh hernia repair; there would be exposed prosthetic mesh if the skin were to become nonviable. While in the former, one may rely on skin with a large laminar component, a spanning prosthetic mesh would almost demand skin with pulsatile flow to increase the odds for healing.

History of Perforator Preservation

The concept of perforator preservation [6] can be traced to a morbidity and mortality conference at the University of Pittsburgh in 1994. Advances in treatment of the abdominal wall came from this institution, both due to the huge demands placed on the abdominal wall for liver transplantation, and due to the fact that Dr. Oscar Ramirez had been a plastic surgery resident at the University of Pittsburgh soon after performing his cadaveric abdominal wall muscle dissections in Baltimore, MD. The morbidity and mortality conference presented a patient who had undergone a components release hernia repair for a massive hernia that developed after placement of a tube graft for an abdominal aortic aneurysm. Large skin flaps were elevated as was the standard, dividing the periumbilical perforators in order to access the semilunar lines for division of the external oblique muscle and fascia. The skin lost its primary blood flow with division of the periumbilical perforators, and the adjacent angiosomes fed by the lumbar perforators were unable to compensate due to a prior division of segmental vessels off of the aorta at the time of the tube graft. This patient, therefore, had a near total loss of blood flow to the skin, and therefore lost all of the skin of the abdominal wall that had been elevated. Dr. Kenneth Shestak, during the discussion, questioned if it would be possible to go around the periumbilical perforators and still perform a components release. Dr. Jaime Garza was the chief resident sitting next to me during this conference and later he took a position at the University of Texas in Austen. There, he helped to perform seven components separation hernia repairs where a laparoscope was used to access the semilunar lines. These patients were presented at a regional meeting in 1997, and Dr. Garza published the account in 2000 [7]. Across the Atlantic nearly simultaneously, Maas in 1999 used a lateral incision to perform an external oblique release in four patients to avoid an enterostomy [8]. At Northwestern several years later, I was having an unacceptable wound complication rate after components separation hernia repairs with standard skin undermining. Remembering Dr. Shestak's comments, I started to go around the periumbilical perforators either through subcutaneous tunnels or later through lateral incisions. Our report in 2002 was the first to directly compare wound complication rates in components procedures with and without perforator preservation [9]. An addtitional publication directly comparing the hernia repairs complications of standard open components with perforator preservation was written by Butler in 2011 [10].

Decrease Forces at the STI with Components Releases

A central question is why are releases of the abdominal wall musculature beneficial during the performance of ventral hernia repairs. It is well established that suture repairs of abdominal wall hernias fail at alarming rates. Even the laparoscopy incision closure in some patient groups will develop hernias over 30% of the time [11]. The central question remains as to why divided tissues approximated by sutures go on to fail and not demonstrate a lasting union. There are three types of suture failures. Acute failure, as in catastrophic evisceration after a laparotomy, results from tearing of sutures through intact tissue [12–14]. Subacute failures of laparotomy suture lines were demonstrated by Pollock [15, 16] and later confirmed by Burger [17]. Early separation of metal clips placed on either side of a laparotomy closure can be seen radiographically within the first month after surgery in patients who will later develop an incisional hernia. The gapping of newly opposed tissues sewn under tension has recently been shown in laboratory animals [18]. Chronic failures are represented by hernia formation late after laparotomy [19] and occur when scar contained within the suture loop remodels and thins over time [20]. Surgeons refer to this chronic remodeling of scar tissue as "cheesewiring", and it is the result of chronic suture migration through tissue. A problem central to sutures is that the forces required to achieve tissue apposition can cause local damage at the STI from pressure-induced ischemia and overtightening [21]. The greater the force, such as in laparotomy closure, the greater the potential for tissue damage. After laparotomy closure, episodic waves of force directed at the new suture line from coughs, movement, lifting, and stairs further stress the STI. A stiff abdominal wall will transmit those energy waves more than would compliant musculature. While many surgeons view components releases as moving the rectus muscles to the midline, I view components releases as a means to improve lateral abdominal wall compliance and to protect the new suture line from tearing. A second means to ensure lower forces at the STI is to better distribute the forces with mesh, as will be discussed. The trick is to have a means to fixate the mesh while at the same time performing a components release and to maintain skin pulsatile blood flow. This surgical problem is addressed by using a narrow mesh to minimize the necessary skin elevation, and lateral incisions to avoid devascularization of the skin for the components release.

Patient Preoperative Evaluation

The evaluation of a patient with a midline ventral hernia is rather straightforward, as many old operative reports are collected as possible. A CT scan both delineates the transverse separation of the rectus muscles and rules out unexpected intra-abdominal pathology. An assessment needs to be made as to abdominal wall compliance. The patient should be placed flat for examination, and pressure is applied onto the abdominal wall to assess compliance. Weight loss, a history of large pregnancies, and a history of treated ascites all favorably influence compliance. Being at one's maximum weight, prior lateral incisions, a history of intra-abdominal sepsis, COPD, and multiple prior abdominal wall procedures negatively influence compliance. The amount of bowel found within the hernia sac is important in terms of concepts of loss of domain, but this only rises in importance in a patient with low muscle compliance.

The wider the separation of the rectus muscles in a transverse plane, and the less compliant the abdominal wall, the more a components release will be necessary to prevent tearing at the midline suture line. For patients with normal compliance, rectus separations of 6 cm or less rarely need a components release. Over 10 cm, separations are almost always required. Patients in the middle ground have an intra-operative decision as to the need for a release or not.

Weight loss for patients prior to surgery is beneficial and is encouraged but is not a requirement for the majority of patients with body mass indices under 35. Cessation of tobacco is clearly supported in the medical and hernia literature, but has not been overly problematic for the procedure to be described. Immunosuppression (in the absence of steroids) for transplantation has not been an issue with healing, and likewise for a diabetic in reasonable control. The patient is cleared for surgery for major cardiopulmonary issues, and a bowel prep of clear liquids, a half bottle of magnesium citrate, and two dulcolax tablets suffice to clear the majority of particulate matter within the bowel. The bowel preparation is performed to minimize the controllable intra-abdominal volume to minimize the forces at the STI.

Surgery Technique

This procedure as well as mesh choice has remained essentially unchanged for the last decade. The goals of the procedure are to approximate the rectus complexes in the midline, to fix a narrow mesh flat and tight with numerous sutures coursing through the rectus muscles to distribute the forces across the repair, and to maintain pulsatile blood flow for closure.

1. The patient is prepped and draped widely under general anesthesia. The room should be kept warm during induction to maintain patient normothermia.
2. The midline incision is widely opened. In general, the length of the incision will be *far longer* than the length of the hernia because above and below the actual hernia rectus diastasis exists that will also need to be repaired. Repair of the rectus diastasis will actually take tension off of the repair at its widest point by "working out the dog ear" [22].
3. The posterior aspect of the hernia sac and the posterior aspect of the abdominal wall are cleared of any attachments to the viscera so that eventual medial movement of the rectus muscles will not pull bowel with it. The procedure is kept as two-dimensional as possible, and so individual bowel loops are not separated. The preoperative CT scan suffices to rule out bowel pathology. If facile, the omentum is mobilized for eventual coverage of the bowel in the midline.
4. The anterior rectus fascia is cleared of soft tissue for 4 cm along its width for the length of the muscle to be repaired. *Perforator preservation, therefore, is of the perforators more than 4 cm from the medial edge of the rectus*.
5. Tension is applied to the rectus muscles to see if their medial aspects can be brought together to the midline. In general, if this can be achieved with finger tension only, a components release does not need to be performed.

6. A decision at this point is made if the mesh will be placed intra-abdominally or in the retro-rectus position. Both are acceptable with advantages and disadvantages. As mesh incorporation will occur from both sides when in the retro-rectus position, this is preferred. The widest hernia defects are repaired with the mesh intra-abdominally placed.
7. In the video supplement, the retro-rectus space is created with care taken to maintain the patency of the inferior epigastric arteries.
8. Through a 6-cm transverse incision at the inferior aspect of the rib cage (Fig. 16.1), dissection is performed through Scarpa's fascia to reach the abdominal wall. With spreading, the semilunar line is reached, and the anterior-most fibers of the external oblique are visualized. A small perforator often requires coagulation. Spreading with a Mayo scissor or equivalent vertically along the semilunar line begins the visualization of the semilunar line, and the exposure is completed using a 1 in. Deaver retractor bluntly aimed superiorly and a bit medially. The external oblique muscle is held and elevated with forceps to confirm it is not the anterior rectus fascia, and then it is incised under direct vision with a cautery. Yellow fat is typically seen immediately deep to the external oblique fascia. A dissecting finger sweeps laterally to confirm the space between the external and internal oblique muscles, and this dissecting finger continues to sweep the space now on top of the ribs. With the external oblique extension into the anterior rectus fascia completely visualized on top of the rib cage, cautery divides the external muscle and fascia. A fascia layer deep to the external oblique but still above the internal oblique needs to be identified and divided for best movement. The Deaver retractor is now replaced to aim toward the anterior superior iliac spine, and again blunt force opens the tissues without bleeding or excessive force. The same dissecting finger between the external and internal obliques now develops the plane inferiorly to be divided by cautery.

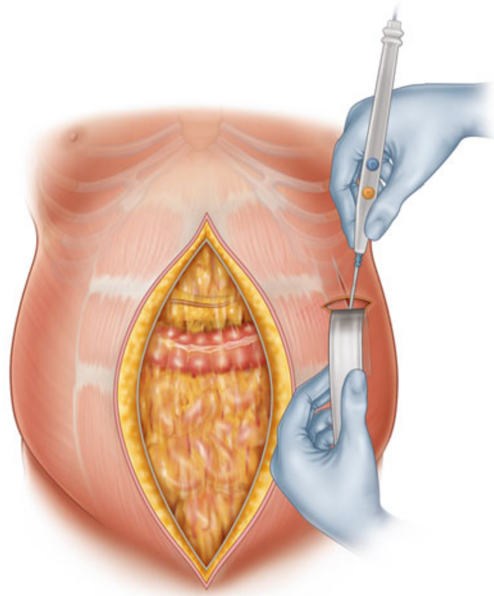

Fig. 16.1 Semilunar lines exposed through 6 cm transverse incisions located at the inferior aspect of the rib cage

One trick is required to complete the division of the external oblique toward the symphysis pubis. From the midline incision and low on the abdominal wall, a tunnel is created from the midline to the lateral semilunar line dissection (Fig. 16.2). The end of the divided external oblique muscle is captured by feeling for the cut end of the fascia, and it feels like the inner vertex of the letter "V". This fascia is pulled into the midline wound where cautery serves to complete the release. Alternatively, especially for very obese patients where the lower midline tissue is not incised, the completion of the external oblique release can be performed through a second transverse skin incision located near the ASIS.

Finally, the space between the external and internal oblique muscles is widely undermined with digital pressure from the upper transverse incision. The entire external oblique release can be performed while still maintaining pulsatile blood flow to the skin and takes 4–5 min to perform without special lighting or equipment.

9. A 7.5 cm wide mesh is cut that will extend the length of the hernia and any associated

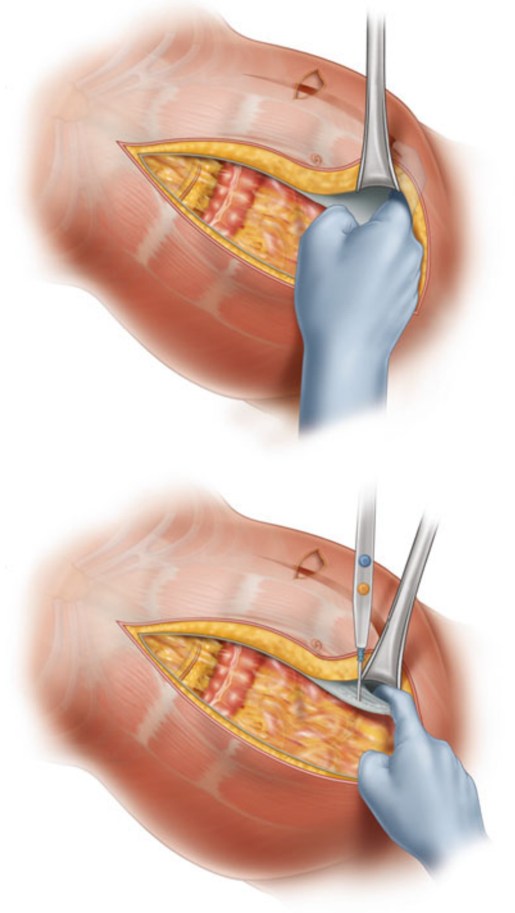

Fig. 16.2 The inferior aspect of the divided external oblique is captured by the index finger through a suprapubic tunnel to effect the completion of the release

rectus diastasis. The mesh is quilted to the undersurface of the rectus muscles with through-and-through full-thickness bites of 0-polypropylene suture introduced through the anterior rectus fascia, through the muscle, grabbing a small bite of mesh, and back through muscle and fascia. When two rows of sutures are placed 4 cm from the medial aspect of the rectus muscles and with a 7.5 cm wide mesh, the medial aspect of the rectus muscles will be brought together in the midline when the sutures are tied. By geometry, the mesh will be flat and tight, and the tension on the mesh will fight wrinkles. Chronic pain has not been an issue for these patients, as the segmental nerves of the rectus muscles are relatively small so close to the midline. The medial aspect of the rectus muscles is approximated over the mesh to achieve a direct supported repair (Fig. 16.3). Sutures are located 2–3 cm from each other to distribute the forces, and approximately 40 sutures are used for the three vertical lines for a full midline repair. Done in this manner, while the total tension on the midline may initially seem too tight, the tension experienced by each suture is below the point for suture pull-through. The added compliance achieved with the lateral releases will also be protective of the repair.

10. Medialization of the rectus muscles and the attached overlying skin produces redundant skin in the midline. Excess skin is excised in the midline as a vertical panniculectomy—an important issue both to remove the most undermined skin and to leave a smaller potential space where fluid collections can exist. Two or three subcutaneous drains are used for the time in the hospital. On occasion, "pumpkin-teeth" skin flaps are fashioned to create a neo-umbilicus. Not only cosmetically important, these skin flaps can be tacked down to the abdominal wall for improved soft tissue healing. Figures 16.4, 16.5, and 16.6 demonstrate an older gentleman who smokes with a large 16 cm hernia treated with this technique.

Outcomes

Components separation hernia repairs are associated with increased numbers of wound complications, and perforator preservation is one technical modification to decrease the rate of these problems. In Dumanian's 2002 series of 66 patients, wound complications dropped from 20% down to 2% when skin vascularity was maintained. Performing this procedure with lateral incisions for 12 years, there has been uniform acceptance of the transverse scars, and they heal quite well being located along the natural crease lines of the abdominal wall. Butler's 2012 series of 107

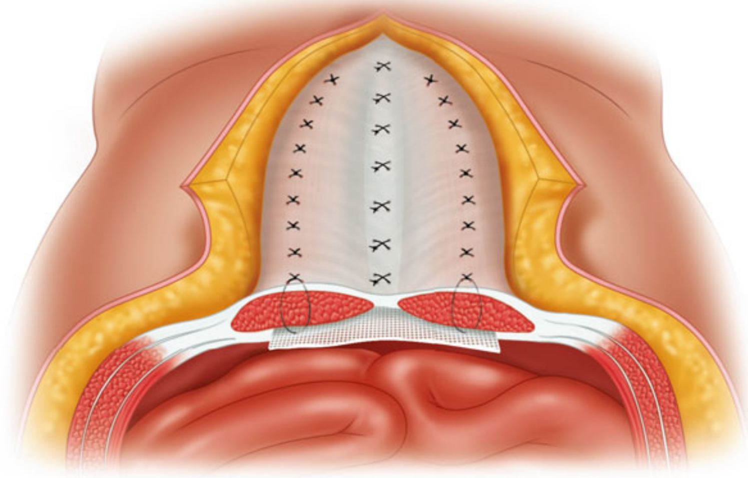

Fig. 16.3 Geometry of narrow mesh placement with three rows of sutures in this direct supported repair

Fig. 16.4 Preoperative and postoperative anterior views of an older gentleman with a large midline hernia

patients mirrored these results when comparing open vs perforator preserving techniques during components separation. Despite a more challenging patient population in the perforator-sparing group, all wound-healing complications dropped from 32% down to 14%. In both series, the incidence of long-term hernia recurrences was the same or lower with perforator preservation. The soft tissue complication rates with these perforator sparing procedures are similar to that reported in a recent meta-analysis of laparoscopic releases of the external oblique [23].

Discussion

Hernia repairs are a balancing act, and the goal of the procedure is to approximate the abdominal wall under tension without the sutures tearing the tissue. It is clear that neither sutures alone [24] nor sutures with components alone [25] suffice to completely avoid the development of hernias. Therefore, a midweight macroporous uncoated polypropylene mesh is added to the procedure to distribute forces, but then fixation of the mesh becomes an issue. What may be unique to the

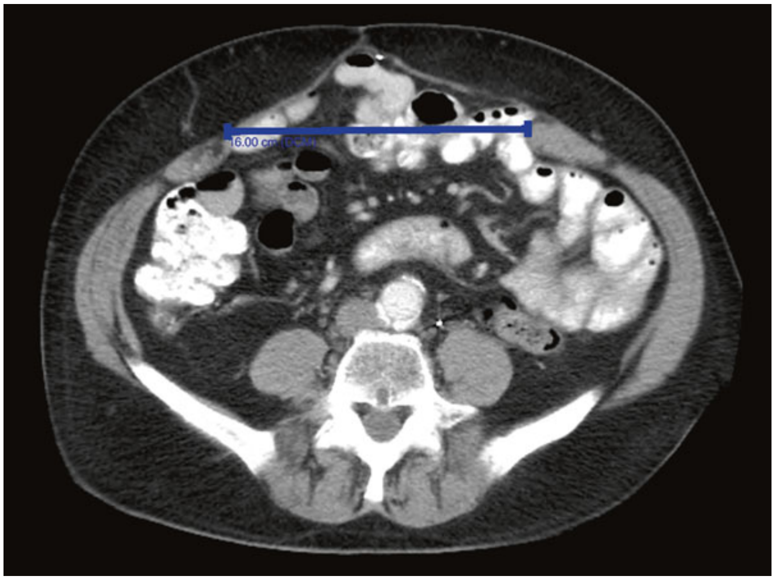

Fig. 16.5 Separation of the rectus muscles is 16 cm by CT scan

Fig. 16.6 Preoperative and postoperative oblique views. Final closure achieved after placement of a narrow well fixed retrorectus mesh, vertical panniculectomy, and umbilicus recreation

hernia repair described in this chapter is the use of a narrow mesh firmly fixed to the rectus complex. It is a plastic surgery principle that a well-fixed implant does not become infected. A recent series of mesh placed in this fashion documented no mesh infections, a surgical site infection incidence rate of 3%, and a surgical site occurrence rate of 10% in 100 consecutive cases [26]. The few complications were sporadic and were not predicted by the Ventral Hernia Working Group classification scheme. Chronic pain is not an issue with this procedure as the nerves are smaller closer to the midline. The narrow mesh requires less skin elevation from the anterior rectus sheath for placement of the sutures. Mesh placed in this fashion can be loaded with a fair degree of tension to avoid bridging. I believe it is the combination of a narrow mesh, achievement of a direct supported repair, and lateral incisions/perforator preservation to perform the external oblique releases, that is the optimal balance between a secure closure and minimizing abdominal wall dissection. These procedures are routinely now performed in under 2½ hours.

In comparison, larger meshes require greater elevation of tissue planes, more foreign material, and greater difficulty with fixation. Surgeons who advocate no suture fixation with giant meshes open large tissue planes permitting fluid to collect, and large meshes may have wrinkling at the outer edges when trying to fit a flat mesh to a curved surface. The large mesh and soft tissue dissection probably can cause uncomfortable stiffening in the lateral abdominal wall compliance over time that the patient may notice. A middle ground with large (not giant) meshes and transcutaneous fixation risks the capturing of larger segmental nerves. It may not be surprising that Rives-Stoppa hernia repairs with large meshes have a 27% chronic pain rate [27].

Perforator preservation alone is not a magic bullet to avoid all complications in components separation hernia repairs. In combination with a focus of the forces at the STI, force distribution with a narrow mesh, long repairs that address rectus diastasis, and excess vertical skin excision, wide hernia repairs in these components patients can be performed safely and with low morbidity.

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