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Incisional Hernia Repair: Laparoscopic Techniques

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Abstract. Repair of incisional hernias using the laparoscopic technique has continued to evolve since its inception in 1991. An analysis of the current literature has revealed that hernias as large as 1600 cm^2 have been successfully repaired with this method. The average size appears to be about 105 cm^2. Several choices of a biomaterial are available today, differing in the type of synthetic product or products that are used to manufacture them. Others incorporate an absorbable component. The goal of all of them is to prevent adhesion formation. The fixation devices that can be used are also varied. The results of laparoscopic incisional hernia repair are described. The conversion rate of these procedures is an impressive 2.4% with an enterotomy rate of 1.8%. These results affirm the low risk of this operation. The recurrence rate of 4.2% confirms the permanence of the repair. This procedure may become the standard of care in the near future.

The permanence of the repair of incisional hernias has been difficult because of the high frequency of failure with traditional open repair methods. Failure has been reported to be as high as 52% for the primary sutured repair and 25% when using a prosthetic biomaterial [1–4[k1]]. With introduction of the laparoscopic technique for this hernioplasty, it was hoped that an improvement in the recurrence and complication rates would be realized [5]. The increasing growth of this methodology across the world indicate that these goals might indeed be achieved. Many publications in the literature appear to prove that the complication and recurrence rates are markedly lower with the laparoscopic methodology.

Technique

Like most surgical procedures, there are numerous variations of the exact methodology used by any one surgeon, although several common steps are followed by all. The list would include entry into the abdominal cavity by any of a variety of methods based on the surgeon's preference and any prior abdominal procedures the patient may have undergone. This may include use of a Veress needle, an open entry, or use of an optical trocar that allows one to view the layers of the abdominal wall as they are penetrated.

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Once the appropriate number of trocars has been introduced into the abdomen, the next and most tedious portion of the operation commences. The adhesions in the abdomen are lysed with or without the use of an energy source, such as electrocautery or an ultrasonic scalpel. This choice is dictated by the proximity of the bowel. No energy should be applied adjacent to any structure that might incur an injury. Perforation of the intestine remains the most lethal risk associated with laparoscopic hernioplasty.

Once the hernia defect or defects are revealed, the surgeon must assess their dimensions. There are many alternatives by which to determine accurately the size of the fascial defects. For some, it is marked by the passage of spinal needles into the abdomen, whereas for others simple marks on the exterior surface of the skin denote the location of the craniocaudal and lateral extent of the hernia orifices (Figure 1.). The actual measurement of these marks is grossly inaccurate if the abdomen is fully insufflated when the measurement is taken. This is due to the extreme increase in the size of the abdominal wall because of the insufflation pressure. Therefore the carbon dioxide must be released prior to the measurement, revealing the true size of the fascial defect. The difference in the appearance of the abdomen is sometimes surprising (Figure 2). The craniocaudal and lateral measurements are then made. To these measurements, one adds 6 cm in both direction, which provide a minimum 3 cm overlap of the fascial edges of the hernia by the prosthetic biomaterial. This minimum overlap is the consensus of opinion of most laparoscopic surgeons, although some prefer a 4 to 5-cm overlap [6]. I tend to use the larger dimensions if the hernia is large, the patient is morbidly obese, or the hernia is multiply recurrent. The biomaterial that most closely approaches this measurement is selected for implantation. Generally, it is the next larger measurement. For instance, if the defect measures 10×15 cm, the additional 3 cm makes the measurement become 13×18 cm. The available patch size closest to that dimension is the 15×19 cm product, which should be chosen. On only a few occasions does any portion of the biomaterial require trimming. Additionally, most surgeons prefer to place a prosthesis of sufficient size so the entire incision is covered by the biomaterial even if the hernia is smaller than the length of the incision. This practice prevents future development of a hernia in the uncovered portion of the original incision.

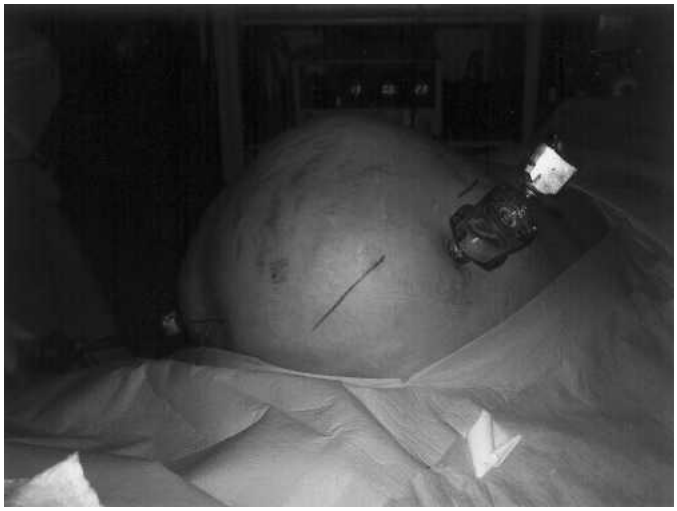

Fig. 1. Insufflated abdomen with appropriate skin marks that delineate the extent of the fascial margins of the hernia to be repaired.

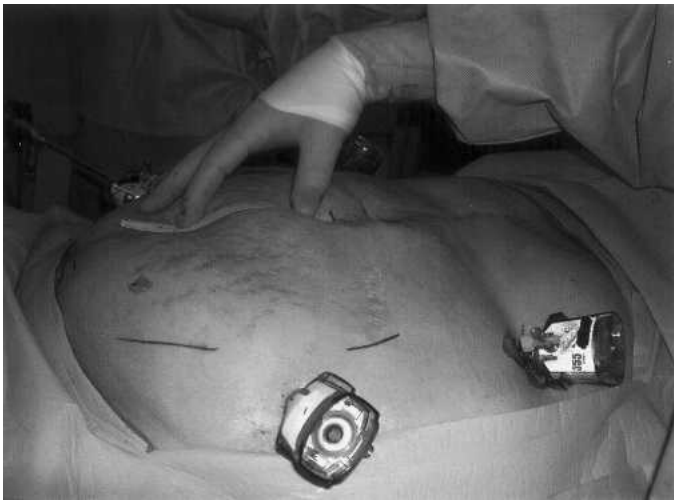

Fig. 2. Same patient as in Figure 1 with the abdomen desufflated of the carbon dioxide. Note the ruler in the midline of the surface of the skin.

Table 1. Prosthetic biomaterial available for laparoscopic incisional hernia repair.

Type of biomaterial	Product name	Manufacturer
ePTFE	DualMesh	WL Gore & Associates, Flagstaff, AZ, USA
ePTFE	DualMesh Plus	WL Gore & Associates, Flagstaff, AZ, USA
ePTFE	DualMesh with holes	WL Gore & Associates, Flagstaff, AZ, USA
ePTFE	DualMesh Plus with holes	WL Gore & Associates, Flagstaff, AZ, USA
ePTFE	Dulex	CR Bard, Cranston, NJ, USA
PPM(2) + ePTFE	Composix	CR Bard, Cranston, NJ, USA
PPM + ePTFE	Composix EX	CR Bard, Cranston, NJ, USA
PPM + ePTFE + POL ring	Composix Kugel	CE Bard, Cranston, NJ, USA
PPM + collagen	Parietene	Sofradim, Villefranche-sur-Saône, France
POL + collagen	Parietex	Sofradim, Villefranche-sur-Saône, France
PPM + HA + CMC	Sepramesh	Genyzme, Cambridge, MA, USA
PPM + PDS(2) + ORC	Proceed	Ethicon, Somerville, NJ, USA

ePTFE: expanded polytetrafluoroethylene; PPM: polypropylene; POL: polyester; HA: hyaluronic acid; CMC: carboxymethyl cellulose; PDS: polydioxanone; ORC: oxidized regenerated cellulose.

The choice of biomaterial varies greatly in even a single institution. A variety of products are commercially available that attempt to prevent contact of the intestinal contents with the synthetic biomaterial; hence the development of adhesions is diminished or prevented. The proven risk of fistula formation when there is direct contact of the bowel with polypropylene or polyester has caused most surgeons to avoid these biomaterials [7].

Finally, the prosthesis is introduced and fixed to the abdominal wall by any one of several metal fixation devices, transfascial sutures or both. The latter point is one that has been associated with a large degree of disagreement as to the true need to add these sutures. Those who use them argue that the recurrence rate is too high without them. Those who do not use them disagree and further state that the postoperative pain in these patients is lessened by the omission of their use.

Biomaterials

The biomaterials available to repair these hernias laparoscopically have undergone many changes over the last several years. In fact, there are new products that have either been recently introduced or are in the developmental stages. All seek to achieve two goals: rapid and permanent ingrowth into the prosthesis and diminution of the risk of intestinal adhesions. There are two types of such biomaterials: synthetic and collagen-based (Tables 1, 2). The synthetic products can be further subdivided into those composed of a single material or those composed of two or more composite materials. The composite types may or may not include an absorbable component. Most of these can be used either for the laparoscopic repair or the open method based on the preference of the surgeon.

The expanded polytetrafluoroethylene (ePTFE) biomaterials have the longest history of use for this hernia repair. The original description of the procedure used an early DualMesh product [5]. The current product is 1 mm thick and has different surfaces on either side of the sheet. One side has a smooth surface in which the interstices of the ePTFE measure 3 μm, and the other side has interstices of approximately 22 μm. Additionally, the surface on this side has ridges that resemble corduroy. This is meant to facilitate ingrowth of collagen to ensure firm fixation, which has been confirmed in the laboratory [8].The DualMesh with holes is 1.5 mm thick and has evenly spaced holes throughout the product. The antimicrobial agents silver and chlorhexidine have been

Table 2. Collagen-based prosthetic biomaterials for laparoscopic incisional hernia repair.

Source of collagen	Product name	Manufacturer
Porcine small intestinal submucosa	Surgisis Gold	Cook Surgical, Bloomington, IL, USA
Porcine small intestinal submucosa	FortaPerm	Organogenesis, Canton MA, USA
Porcine small intestinal submucosa	FortaGen	Organogenesis, Canton MA, USA
Porcine dermis	Permacol	Tissue Science Laboratories, Covington, GA, USA
Porcine dermis	Xenmatrix	Brennan Medical, St Paul, MN, USA
Cadaveric dermis	Alloderm	Lifecell, Branchburg, NJ, USA

incorporated into these biomaterials to become the "Plus" product line. Dulex has a sandpaper appearance on one surface and a smooth surface on the other. This ePTFE differs from that of the DualMesh in that it has a laminated structure rather than the pores that go transversely within the product.

All of the Composix prostheses have ePTFE and PPM but differ in their number and attachments. The original Composix has two layers, of Bard mesh that are heat-sealed together with a thin layer of ePTFE, and the Composix has a single layer of Bard mesh and a slightly thicker ePTFE layer sewn to it. The Composix Kugel is similar but adds a ring of polyester to stiffen the prosthesis in an effort to ease its manipulation within the abdominal cavity.

Parietene and Parietex both incorporate hydrophilic collagen into the weave of the biomaterial; the collagen is absorbed by the 14th postoperative day. It is meant to inhibit contact of the intestine to the polypropylene (PPM) or polyester (POL), respectively, thereby minimizing the risk of adhesions. Sepramesh attempts to accomplish this by placing hyaluronic acid and carboxymethyl cellulose as attached foam to the PPM. This must be handled carefully to avoid displacing the foam from the PPM. Proceed is the newest addition to these composite biomaterials. As noted in Table 1, there are four components. The PPM is the Prolene Soft mesh that is commercially available from Ethicon. On either side of it, a thin film of PDS has been laminated onto the PPM to stiffen the mesh. On one surface, oxidized regenerated cellulose (ORC) is attached to create a "tissue-separating" mesh in that the ORC separates the PPM from the underlying intestine to minimize tissue attachment. The PDS and ORC are absorbed to leave only the PPM.

The clinical experience with all of these products varies from country to country. DualMesh has gained the largest global experience, but use of the Composix products is increasing. Surgeons should base the choice of any of these products on the available clinical and research data.

The collagen-based biomaterials listed in Table 2 represent relatively new additions for the laparoscopic surgeon. All have been treated to eliminate all cells and proteins other than collagen that might evoke adverse reactions. Some have arisen from other applications, such as thinner materials in the treatment of chronic wounds (e.g., Surgisis). The original Surgisis was a one-layered product, but Surgisis Gold is an eight-layered product of submucosa. Fortagen and Fortaperm are similar except that the layers of the submucosa are crosslinked to prevent delamination. Permacol, Xenamatrix, and Alloderm are dermal collagen and are single-layer prostheses. All of them have had limited use in laparoscopic repair of incisional hernias but may be of benefit when used in an infected field [9]. It appears that the fascia must be closed to allow adequate vascularization of these collagen biomaterials, however.

Fixation Methods

Fixation of all of these biomaterials is required until sufficient ingrowth has made collagen impregnation sufficiently strong to ensure repair of the fascial defect. Whereas there is controversy about the need for suture fixation, there is agreement that the use of a metal fixation device is vital. Five devices are currently available, each of which is different in some way.

The original methods were those that much titanium staples. There have been many variations of the shape, size, and articulations of the devices themselves. Currently, the most commonly available staplers are the Ethicon EMS and the AutoSuture Universal stapler (Figures 3, 4). These staplers are not used extensively because each requires use of a trocar larger than 5 mm. An additional unique fixation device that differs from all of the others is the Sofradim Pariefix. This is the only fixation device that utilizes an absorbable product to fixate the mesh. It has a distinctive T shape appliance that is delivered via a 10 mm instrument.

The more commonly used fixation methods are 5 mm products (Figures 5–7). The Protack delivers a helical titanium coil that is screwed into the mesh and the fascia (Figure 8). There is a large experience with this product, and a few adverse reactions have been reported, such as fistulization or herniation as a direct result of the product [10, 11[k2]]. The Salute stainless steel construct differs from all of the other fixation products in that it is not a preformed device (Figure 9). This is the only reusable instrument; it utilizes a spool of wire that delivers the construct at the site of fixation as the instrument is fired. The spools that deliver the coils are available to deliver either 20 or 50 constructs. The latest addition is the EndoAnchor, which is also unique in that closure of the firing mechanism does not release the fixation device but, instead, causes a large needle to exit the end of the instrument. Within it is the nitinol anchor, which is deployed when the handle is released (Figure 10).

Results

We have had a keen interest in this procedure since our first trials of its utility in 1991. We continue to monitor closely the results of our patients, and we have published the results from our first 100 and second 100 patients. We modified the technique based on the results observed during the follow-up of these patients. Initially, the use of transfascial sutures was not considered important; however, in the first group the recurrence rate was 13% without the use of them, whereas no recurrences were noted in the patients in whom they were used. Additionally, we noted that the fascial overlap required to perform an adequate operation must at least 3 cm. Subsequent to changing the technique so it incorporated these important tenets, the recurrence rate dropped to 2% among patients in whom there were no true technical errors. The

Fig. 3. Ethicon EMS stapler.

second series of patients included two individuals who developed infections that involved the patch, which required explantation, resulting in reherniation. Two other recurrences were noted: One occurred along the incision that was not covered by the original patch. Another resulted from intraoperative clamping of a transfascial suture, causing its fracture; this is turn caused the patch to pull off the fascia shortly after the operation. Modification of our technique to address these factors has diminished and use of the antimicrobically impregnated DualMesh has virtually eliminated any infections. We have had to explant the mesh in only a few patients in whom a bowel injury occurred during the original procedure.

The most common postoperative complication remains a seroma. It is seen in almost all patients but is clinically significant in only approximately 8% of them. Aspiration is rarely needed but is required if the patient experiences significant pain or a poor cosmetic result. Persistent pain at a suture site has been noted in about 1.5% of the patients. More often that not, this pain can be controlled by a trial of antiinflammatory agents with or without injection of bupivacaine at the painful suture site. If this fails, operative extraction of the offending suture is required, but this is an infrequent occurrence.

The long-term follow-up of our patients has confirmed that there are three critical considerations regarding this procedure. First, using a biomaterial that has sufficient ingrowth to allow permanent fixation and minimal adhesion formation is paramount. Second, the overlap of the fascia must be at least 3 cm for all patients but should be 4 to 5 cm if the hernia is recurrent or the patient is morbidly obese. Finally, the use of staples or tacks alone is insufficient to ensure adequate fixation of the patch and to prevent recurrence. Transfascial sutures must be placed no more than 5 cm apart along the entire periphery of the patch to ensure sufficient attachment to the anterior abdominal wall. Although some studies have contradicted this statement, there are none that have the length of follow-up that is required to verify the recurrence rate.

Numerous studies have reported experience with this procedure, but many have included few patients and operations that were performed in the early experience of the surgeons. A literature review has resulted in the series listed in Table 3, all of which have an experience of more than 50 cases. Authors that have published more than one paper on their series are shown with the latest update of that data.

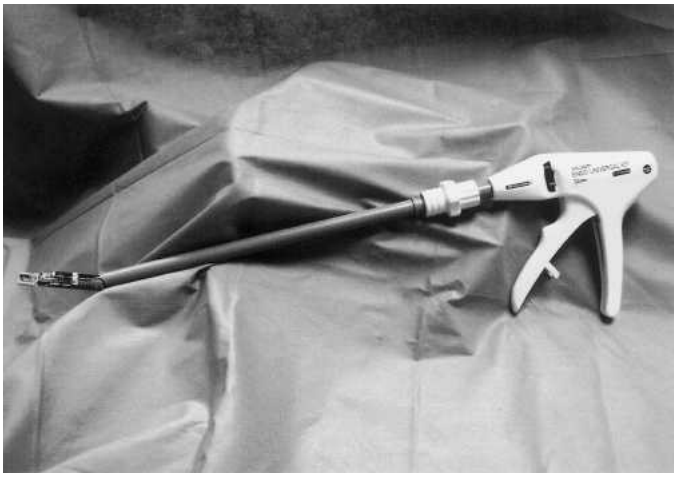

Fig. 4. AutoSuture Universal stapler.

Fig. 5. Protack (Tyco/US Surgical).

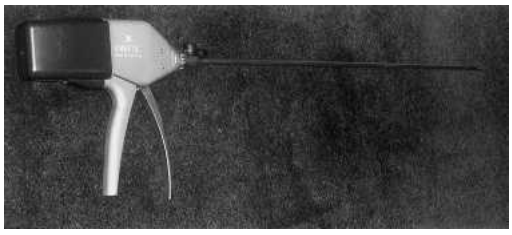

Fig. 6. Salute (CR Bard).

A total experience of 3434 patients has been reported in these series. As shown, 82% of these patients underwent a repair with the single ePTFE product. This represents an extremely favorable record with this prosthesis. Most of the authors included the use of transfascial sutures as a method of fixation of the patch. A careful review of these articles does not clearly identify an absolute need for suture fixation. However, none of these articles included a prospective trial with and without the use of the sutures. My own bias remains that the use of the additional sutures seems prudent. There is a significant need for a prospective randomized trial investigating the use of transfascial sutures in this operation. Since our early experience, newer biomaterials and better fixation devices may negate the need of the sutures, which seem to predispose to more postoperative pain. However, firm clinical evidence is lacking at this time. It is uncontested that a minimum follow-up of 36 months is required to access accurately the recurrence rate of hernias. Therefore, the series that do not meet this criterion cannot be used to determine the final outcome.

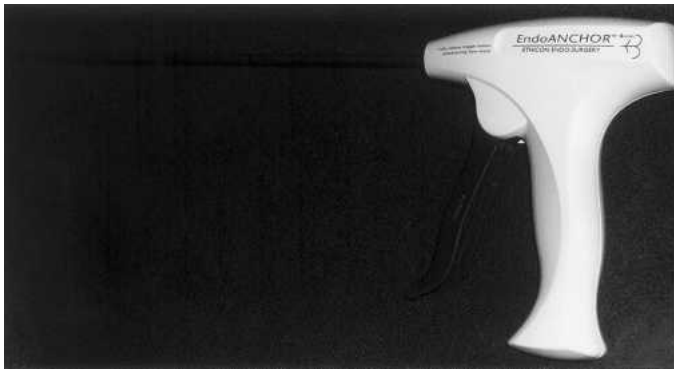

Fig. 7. EndoAnchor (Ethicon Endosurgery).

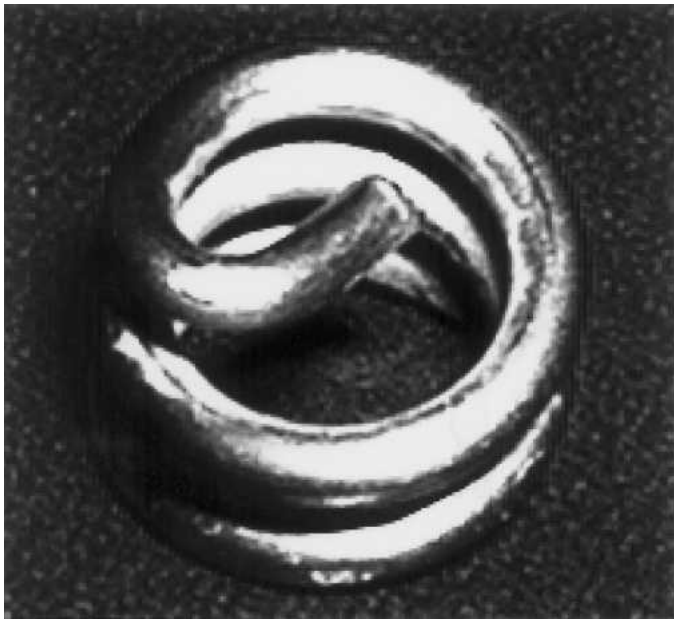

Fig. 8. Titanium tack of the Protack.

Fig. 9. Stainless steel construct of the Salute.

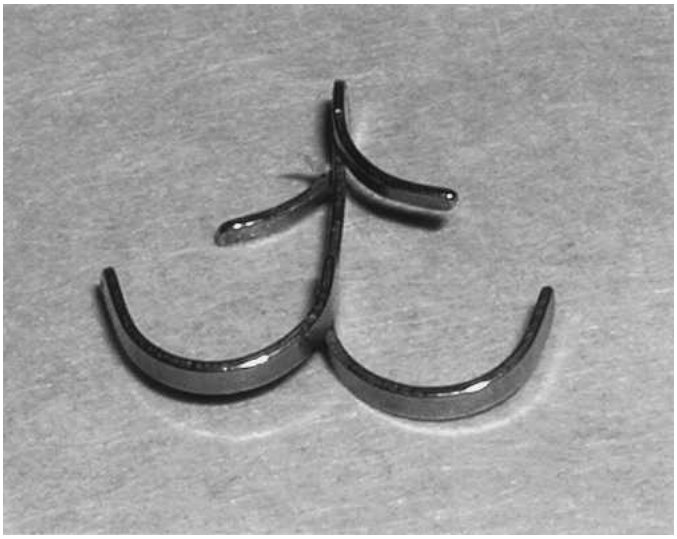

Fig. 10. Nitinol anchor of the EndoAnchor.

The averages of these series are shown in Tables 3 and 4. The operating time is comparable to that of the open procedure, as is the overall defect size. From the ranges of defect sizes reported in these series, even extremely large hernias have been proven to be repairable with the laparoscopic methodology. The conversion rate of 2.4% is low considering the fact that many of these patients had numerous prior procedures, including a hernia repair with PPM. Several of these series converted to the open procedure because of an observed enterotomy. Most important in these data is the fact that an average of 1.8% of these cases are complicated by an enterotomy. Most are detected and the appropriate repair performed; If unrecognized, however, this injury can result in death.

The noted complications of seroma and infection are quite low (Table 4). There is a larger incidence of seroma formation but the low number reported is related to the varying clinical definition of this complication. It is generally agreed that this entity is insignificant if the patient is asymptomatic or if no intervention is required. The incidence of infection is low, as expected. If one develops, the ePTFE patch generally requires excision.

The gold standard of comparison for this operation is the recurrence rate. In these reports, this rate was a low 4.2% (Table 4). Most of these series included the early experience of the authors; therefore this figure is even more impressive compared to the known rate of recurrence for open prosthetic repair 10–25%. There is a large variation (from 1% to 16%) in these reports, but it reflects the early experience of the authors. Given the length of follow-up of many of these publications, one should assume that this may represent the accepted rate of failure of this procedure in experienced hands.

Table 3. Published results of laparoscopic ventral hernia repair: perioperative findings.

Study	Patients (no.)	Hernia size (cm^2)	Operating time (min)	Conversion rate (%)	Enterotomy rate (%)
Toy [14]	144	98	120	–	1.4
Kyzer [15]	53	–	89	4	3.6
Roth [16]	75	101	105	3	2.7
Chowbey [17]	202	-	50	0	0
Birgisson [18]	64	119.2	130	0	3.1
Bageacu [19]	159	–	89	14	1.9
Ben-Haim [20]	100	89	114	3	6.0
Berger [21]	150	89.5	87.5	0	2.0
Aura [22]	86	26.5	110.3	1.2	0
Gillian [23]	100	–	–	0	3.0
Eid [24]	79	103	110	1.25	2.5
Chelala [25]	120	–	75	0	0
Carbajo [26]	270	145	85	0.3	1.1
LeBlanc [27]	200	111	83.5	3.5	0
Heniford [28]	850	118	120	3.6	1.5
Bower [29]	100	124.4	–	1.0	0
Sánchez [30]	90	69	101	5.8	3.3
Franklin [31]	384	–	68	2.9	1.3
Frantzides [32]	208	173	126	0	1.0
Average	181	105.1	97.8	2.4	1.8

Table 4. Published results of laparoscopic ventral hernia repair: postoperative findings

Study	Seroma rate (%)	Infection rate (%)	Recurrence rate (%)	Prosthesis used	Transfascial sutures	Average follow-up (months)
Toy [14]	16.0	3.0	4.0	ePTFE	+ (4)	8.0
Kyzer [15]	–	2.0	2.0	ePTFE	+ (4)	12.0
Roth [16]	4.0	4.0	9.0	ePTFE, PPM	+	–
Chowbey [17]	18.0	2.0	1.0	PPM	–	35.0
Birgisson [18]	5.0	4.0	2.0	ePTFE	+	10.0
Bageacu [19]	16.0	3.0	16.0	ePTFE	+	49.0
Ben-Haim [20]	11.0	1.0	2.0	ePTFE	+	19.0
Berger [21]	92.7	0	2.7	ePTFE	–	–
Aura [22]	14.1	0	7.0	ePTFE	+ (4)	37.0
Gilliant [23]	–	0	1.0	ePTFE + PPM	–	–
Eid [24]	3.8	0	5.0	ePTFE	+/–	34.0
Chelala [25]	5.0	0	0.8	Polyester + collagen	+	10.0
Carbajo [26]	11.8	0	4.4	ePTFE	–	44.0
LeBlanc [27]	7.5	2.0	6.5	ePTFE	+	36.0
Heniford [28]	2.6	0.7	4.7	ePTFE	+	20.2
Bower [29]	1.0	2.0	2.0	ePTFE	+	6.5
Sánchez [31]	9.0	0	3.5	ePTFE	–	18.0
Franklin [31]	3.1	0.3	2.9	PPM, collagen	+	47.1
Frantzides [32]	0	0	1.4	ePTFE	–	24.0
Average	13.0	1.9	4.2			25.8

Discussion

There are many aspects of this technique that could be discussed, but such a discussion is beyond the scope of this article. Suffice it to say that this is an acceptable method for addressing the complex problem of incisional herniation. The technical skills needed to complete this operation successfully can be learned by most laparoscopic surgeons. In fact, I believe that the procedure will become the standard of care in the not too distant future.

There has not been an extensive discussion in the literature regarding case selection among the patients who present with hernias that may be amenable to this technique. Most of the surgeons in the series already discussed did not perform any additional operative procedures during the hernioplasty. However, several authors, including us, perform cholecystectomy or additional hernia repairs if indicated. Only a few of the authors have performed intestinal resection during repair of the hernia that included placing a prosthetic biomaterial. Incarceration is not a contraindication to this technique.

Hernia defect size should be considered carefully, especially early in one's experience. In our own series, the average size of the defects that were repaired was 111 cm^2 but ranged from 2.25 to 600 cm^2. Currently, the only patients who are not offered this procedure by our group are those who have obvious loss of domain (which prohibits introduction of the trocars lateral to the fascial edges of the hernia) or an infection. These cases are repaired with an open technique that incorporates relaxing incisions or the component separation technique, although we have repaired a few of them with the use of a prosthesis that incorporates a tissue-separating layer of absorbable material.

Although the dimensions used in this decision process are not specifically addressed in the cited articles, there are several that included measurements of the defects that were treated. The sizes of these hernias ranged from 2.25 to 160 cm^2, with an average range of 40.6 to 150 cm^2. The average size, as shown in Table 1, is 105.1 cm^2. The success of these authors lends credence to the general applicability of this operation. It is apparent, however, that use of this methodology does not restore the normal anatomy with the prerequisite normal physiologic function. Although this has caused many surgeons to criticize the technique, no series published thus far has experienced any adverse pulmonary outcome because of lack of reconstruction of the linea alba. Further study in this area is still warranted, however.

The current recommendations to ensure the success of this hernioplasty can be summarized as follows.

1. Complete dissection of the entire anterior abdominal wall to expose all hernia defects.
2. Careful measurement of the fascial defects
3. Selection of a clinically proven prosthetic biomaterial
4. A minimum of a 3 cm overlap of all fascial borders with a larger area for obese patients or large recurrent hernias
5. Fixation of transfascial sutures and a metal fixation device

The future of incisional hernia repair is evolving. Some authors have successfully repaired these complex hernias using robotic devices. This may or may not prove beneficial in the further study of these methods. Of more importance is the continuing development of newer prosthetic biomaterials. The ideal product has yet to be realized in the clinical setting, as all have some aspect of imperfection or acceptance by the surgical community. Ultimately, I believe the answer may lie in the production of genetically reengineered collagen from the patient's own fascia that will be enhanced and strong enough to be used for repairing fascial defects. Maybe then our ultimate goals of no recurrences and no complications with the operation will be close to realization.

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