Strategies for Mesh Fixation in Abdominal Wall Reconstruction: Concepts and Techniques

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Summary: Ventral hernias have numerous causes, ranging from sequelae of surgical procedures to congenital deformities. Patients suffering from these hernias experience a reduced quality of life through pain, associated complications, and physical disfigurement. Therefore, it is important to provide these patients with a steadfast repair that restores functionality and native anatomy. To do this, techniques and materials for abdominal wall reconstruction have advanced throughout the decades, leading to durable surgical repairs. At the cornerstone of this lies the use of mesh. When providing abdominal wall reconstruction, a surgeon must make many decisions with regard to mesh use. Along with the type of mesh and plane of placement of mesh, a surgeon must decide on the method of mesh fixation. Fixation of mesh provides an equal distribution of tension and a more robust tissue-mesh interface, which promotes integration. There exist numerous modalities for mesh fixation, each with its own benefits and drawbacks. This Special Topic article aims to compare and contrast methods of mesh fixation in terms of strength of fixation, clinical outcomes, and cost-effectiveness. Methods included in this review are suture, tack, fibrin glue, mesh strip, and self-adhering modes of fixation. (*Plast. Reconstr. Surg.* 147: 484, 2021.)

Ventral hernias are common sequelae of abdominal surgery; studies have shown that the incidence of ventral hernias after midline incision laparotomies averages 9.9 percent (range, 2 to 20 percent).[1–3] These hernias also stem from infections, impairment of collagen metabolism or expression, and congenital diseases such as gastroschisis.[1,4,5] It is crucial to effectively manage advanced hernias, thereby preventing visceral eventration, restoring physiologic tension, and providing dynamic muscle support. Failure to repair ventral hernias can result in bowel incarceration, loss of domain, and poor quality of life.[6]

First used in the late 1800s and gaining popularity since the 1950s, mesh has become an important adjunct in complex abdominal wall reconstruction, providing superior reinforcement to suture-only repair.[7,8] With advancements in mesh materials and fixation techniques, surgeons are able to achieve durable repairs of complex abdominal wall defects that were previously inoperable. The placement of a mesh creates a more equal distribution of tension over the repair area, leading to decreased stress points and focal weaknesses.[9] Furthermore, studies have shown that ventral hernia repair with mesh leads to decreased hernia recurrence rates when compared to suture-only repair.[10,11]

There are many choices a surgeon must make when using mesh, with the first being mesh type. The surgeon must also consider the mesh material's porosity, thickness, coating, density, and cost.[12] The plane of mesh placement must also be taken into consideration. Although retromuscular and underlay mesh locations typically experience lower rates of complications and hernia recurrence compared to onlay or interposition,[13] factors such as speed, comorbidities, and prior component release also factor into this decision. After deciding on mesh type and plane of placement, the method of

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Table 1. Comparisons of Techniques for Mesh Fixation*

	Strength of Repair	Amount of Postoperative Pain	Speed	Cost†
Transfascial sutures	•••••	•••	•••	••
Tacks	•••••	••••	••	•••
Fibrin glue	•••	•	••••	•
Self-adhering mesh	••••	•	•••••	••
Mesh sutures	•••••	•••	••	•

*Derived through comparative literature review and author personal opinion.
†Increasing marker numbers indicate higher cost of technique.

fixation must be determined, including the choice of no mesh fixation at all.

The purpose of mesh fixation is threefold. First, by fixating the mesh, tensile forces are distributed across the mesh itself, leading to more favorable biodynamics through offloading of tension from the fascia, especially during the early phases of wound healing. Second, fixation achieves a more robust tissue-mesh approximation, leading to better mesh integration.[14] Finally, fixation limits mesh mobility, thereby reducing migration. Many methods of mesh fixation are available and can be divided into two major categories: penetrating (sutures, tacks, mesh strips) and nonpenetrating (fibrin glue, microgrips). The surgeon may also choose the option of no mesh fixation.

Studies comparing mesh fixation techniques to one another have been conducted, but no literature has synthesized these studies to compare and contrast the benefits and drawbacks of fixation techniques on the whole. This article aims to describe, compare, and contrast various forms of mesh fixation by reviewing the current literature on modes of mesh fixation.

TRANSFASCIAL SUTURES

The most common form of mesh fixation is suture fixation. In this method, sutures are passed across fascial planes and mesh. Each suture anchors mesh to healthy musculofascial tissue, promoting immediate fixation strength and durability. Although techniques for mesh placement in a retrorectus plane vary, most suggest transfascial placement of sutures lateral to the semilunar line. To do this, the retrorectus space needs to be developed to access the correct plane for mesh placement.[15,16] In this form of fixation, nonabsorbable sutures are typically used, and large bites are taken approximately 1 cm from the edge of the mesh to minimize suture pull-through. The historical need for extensive soft-tissue undermining to place transfascial sutures has been obviated with newer techniques using a laparoscopic suture passer.[16]

Many of the following forms of fixation in this review use this transfascial technique as a baseline of comparison for recurrence rates, clinical outcomes, and complications. A visual representation of these fixation strategies derived from a synthesis of the following literature can be found in Table 1. Furthermore, Table 2 highlights use cases and pros and cons for each fixation technique. The information in Table 2 has been adapted from the literature in this review and the experience of the senior author (J.E.J.).

TACKS

Along with sutures, tacks and screw-type fasteners are the most common method of mesh fixation in the underlay position. Primary advantages of tacks are ease of application and speed. Tacks have been shown to be 89 percent faster to place than sutures, saving on average 34 minutes per operation.[17] Tacks are divided into absorbable and nonabsorbable, with the former made from metal (usually titanium) and the latter from lactic or glycolic acid polymers.[18] The theory of tack fixation is similar to that of suture fixation: a method

Table 2. Characteristics of Fixation Techniques

Fixation Type	Frequency of Use for Plastic Surgeons	Best For	Pros	Cons
Transfascial sutures	••••	Repairs involving component separation; used in both retromuscular and intraperitoneal underlay repairs	Strength of repair, low learning curve	Time consuming
Tacks	•	Laparoscopic or robotic repairs, or onlay repairs using staples and fibrin glue	Strength of repair	Learning curve, limited use in open repair, pain
Fibrin glue	•	Onlay repairs in open ventral hernias and some laparoscopic repairs	Speed, ease of use, low cost	Reduced strength early in repair
Self-adhering mesh	••	Retrorectus repairs involving components separation	Speed, ease of use, reduced pain	Limited use case
Mesh sutures	•••	Repairs not needing component separation	Strength of repair, low learning curve	Time consuming, postoperative pain

of fixation penetrating both the mesh and tissue, although tacks do not span the entire thickness of the tissue (and transfascial sutures do).

Animal models have shown greater tensile strength of transfascial suture repair, as measured by force required for fixation pull-through, when compared to either titanium tack or absorbable tack repair.[19,20] However, even though tacks have inferior tensile strength, there are no significant differences in ventral hernia recurrence rates when comparing transfascial sutures and tack mesh-fixation.[19] This perhaps stems from the fact that, although tacks singularly are weaker than sutures, the composite strength of multiple tacks is similar. Tack fixation has also not been shown to result in different rates of surgical-site infection, seroma formation, or small bowel obstruction when compared to transfascial sutures.[21]

An important sequela of ventral hernia repair with mesh is chronic pain, with the incidence of chronic pain rising as high as 39 percent in patients undergoing this procedure.[22] Studies have shown that metal tacks lead to increased patient-reported pain in the immediate postoperative period up to 6 weeks when compared to transfascial sutures; however, there is no difference in long-term pain between these forms of fixation.[19,23] To our knowledge, there have not been any studies comparing pain in groups undergoing transfascial suture fixation versus absorbable tack fixation.

When comparing absorbable versus nonabsorbable tacks, one study found that absorbable tacks had higher hernia recurrence rates than nonabsorbable tacks; however, this study had short follow-up and used earlier iterations of absorbable tacks.[24] A recent meta-analysis of studies comparing mesh fixation using absorbable versus titanium tacks showed no difference in recurrence rates between the groups at a mean follow-up of 30 months.[25] Furthermore, this study showed no difference in secondary complication rates such as seroma formation, hematoma, or prolonged ileus. Regarding pain, patients in which mesh was fixated with absorbable tacks reported decreased early postoperative pain, up to 12 weeks earlier than in those who underwent titanium tack fixation.[26] However, with longer follow-ups extending past 13 months, there was no difference in chronic pain in patients undergoing either fixation method.[24]

Regarding cost-effectiveness, tack fixation has greater material cost than transfascial suture fixation: one study showed an average material cost for suture fixation of $32, versus $201 for tack fixation.[27] This study did not take into account the cost savings for operative time reductions when using tack fixation methods. Nonabsorbable tacks are 30 percent more costly than absorbable tacks.[28,29] However, when looking at the incremental cost-effectiveness ratios between fixation with absorbable versus nonabsorbable tacks, nonabsorbable tacks are more cost-effective than absorbable tacks.[29]

Our review finds that tacks provide comparable fixation strength and recurrence and complication rates compared to transfascial suture fixation. There have been no differences in reported incidences of chronic pain in tack versus transfascial suture groups. Therefore, clinical outcomes are indiscernible between transfascial suture mesh fixation and tack fixation. We suggest taking tradeoffs between these two methods of fixation into account: although tack fixation is speedier, it does come at a higher cost to the patient because of the increased material cost and the necessity for a tack applicator in most instances.[27] Tacks are also technically more challenging to place in open repairs versus laparoscopic repairs, because of the need for applicators and a correct angle of deployment to ensure sufficient approximation. Tacks are more suitable for laparoscopic and robotic repairs because they afford the advantage of ease of application with an applicator and speed as compared to the use of traditional suture.

FIBRIN GLUE

Fibrin glue—first used for mesh fixation in inguinal hernia repair—recently has been shown to have good results in ventral hernia repair in onlay and retrorectus techniques.[30] Fibrin glue is made up of fibrinogen and thrombin. When applied, it stimulates fibroblast promotion, ultimately leading to the creation of a fibrotic layer.[31] Creation of this fibrotic layer allows for an atraumatic mesh-fascial integration. For retrorectus mesh fixation, 10 to 20 ml of fibrin is applied with a spray applicator. [**See Video (online)**, which demonstrates a technique for application of fibrin glue for mesh fixation in a retrorectus repair.] If a transversus abdominis release is performed, a larger amount of fibrin glue is used to secure the mesh to the entire transversalis fascia.[31] In inguinal hernia repair, fibrin glue shows no difference in hernia recurrence, seroma, hematoma, or operative time when compared to staple mesh fixation,[32] although postoperative pain is decreased with the use of glue.[33]

In abdominal wall reconstruction, suture fixation has an increased strength of repair relative to

fibrin glue—which requires a lower shear strength to detach mesh from the tissue interface—within the first 24 hours of repair.[34] At 7 to 14 days, however, there is no statistically significant difference in the force required to dissociate tissue from mesh that has been fixated with fibrin glue or transfascial sutures.[34] A prospective study demonstrates the long-term durability of fibrin glue fixation: there were no reported hernia recurrences with either fibrin glue or transfascial suture fixation for retrorectus mesh repairs at a 1-year follow-up.[35,36] Furthermore, in rat models, fixation with fibrin glue in an underlay position led to more favorable adhesion profiles when compared to tack fixation.[37] To our knowledge, this has not been clinically shown in humans.

When comparing secondary outcomes of fibrin glue fixation in abdominal wall reconstruction, studies have shown similar incidences of seroma and hematoma formation, postoperative infections, and skin necrosis when compared to traditional fixation techniques.[35] Regarding pain, individuals undergoing abdominal wall reconstruction with fibrin glue mesh fixation were 12 times less likely to report pain at a 6-month follow-up as compared to those undergoing transfascial suture fixation.[36]

The use of fibrin glue to fixate mesh in either an onlay or retrorectus position has evidence with regard to strength, durability, and incidence of soft-tissue–related complications. Fibrin glue's advantage over transfascial suture and tack fixation lies in reduction of postoperative pain. If immediate strength of a closure is warranted, transfascial suturing provides an advantage to fibrin glue fixation. This should be taken into account in situations where the fascial closure is tight despite components separation, and tension offloading is needed. Finally, regarding cost, a 2019 study demonstrates that fibrin glue provides a more cost-effective form of fixation than suture fixation because of decreased operative time and length of postoperative stay, saving patients an average of $14,500 per operation for retromuscular hernia repairs.[38]

SELF-ADHERING MESH

Self-adhering mesh was developed in the early 2000s to satisfy the need for an easy-to-handle, atraumatic method of mesh placement in hernia repair. These meshes are laid onto native tissue without need for suture, tack, or glue fixation. Meshes such as Adhesix (C.R. Bard, Inc., Warwick, R.I.) rely on a polyethylene glycol/polyvinylpyrrolidone coating on the surface that interfaces with tissue, leading to reaction formation and integration when the surface comes into contact with moisture.[39,40] Other self-adhering meshes rely on mechanical processes: ProGrip (Medtronic, Minneapolis, Minn.) self-adhering mesh is coated with thousands of absorbable polylactic acid microhooks.[40,41] LifeMesh (LifeBond, Caesarea, Israel) is yet another self-fixating mesh, which uses a microbial transglutaminase and dry porcine gelatin coating that undergoes molecular crosslinking when contacting moisture.[14]

In an animal study, self-adhering mesh was found to have comparable strength to composite mesh fixated with transfascial nonabsorbable tacks at 28 and 90 days.[42] ProGrip has shown a similar strength of fixation to tissue compared to fibrin glue, whereas LifeMesh has shown a greater amount of force needed to dissociate mesh from tissue when compared to ProGrip and Fibrin glue.[14] Further studies comparing self-adhering mesh to fibrin glue have shown a shorter time needed to reach full fixation strength: approximately 5 days for self-adhering mesh and 2 weeks for fibrin-based sealants.[43]

Clinically, self-adhering mesh has shown good outcomes when compared to transfascial suture mesh fixation. A 2016 study showed no hernia recurrences in patients undergoing either suture fixation or self-adhering mesh fixation at a mean follow-up of 600 days.[44] In addition, a 2017 study showed a lower rate of hematoma formation with ProGrip when compared to polypropylene mesh fixated by transfascial sutures.[41] Seroma formation was also found to be low in patients undergoing large incisional hernia repairs with self-adhering mesh, with an incidence of 5 percent in a 2015 study.[45] This study also reported no recurrences of hernias at a 2-year follow-up.[45]

Self-adhering mesh has favorable pain outcomes when compared to both suture- and tack-fixation mesh.[41,44,46] Patients undergoing fixation with transfascial sutures were more than three times as likely as patients undergoing self-adhering mesh fixation to require high doses of postoperative narcotics.[47,48] Furthermore, those undergoing ventral hernia repair with a transfascial suture mesh fixation used twice as many milligram equivalents of morphine when compared to those undergoing the same procedure using ProGrip.[44] Therefore, patients repaired using self-adhering mesh experienced shorter lengths of stay, reduced immediate postoperative pain, and higher patient satisfaction scores than those undergoing transfascial suture fixation.[41,44]

No direct comparison of cost-effectiveness of self-gripping mesh versus other forms of fixation has been performed. There may, however, be theoretical savings from shorter intraoperative times and lengths of stay.[44]

Self-adhering mesh provides an easy-to-use and quick alternative to suture, tack, and fibrin-glue fixation. These meshes provide comparable to increased strengths of fixation when compared to tack and fibrin glue fixation (perhaps because of the greater surface area of fixation) and a shorter time to reach maximal strength when compared to fibrin glue. Further studies need to be conducted to assess the cost-effectiveness of self-adhering mesh compared to other forms of fixation.

MESH SUTURES

A new technique of mesh use in abdominal wall reconstruction uses strips of mesh tied as simple interrupted stitches for midline fascial approximation rather than sutures (Figs. 1 and 2). In a 2015 animal study, strips of polypropylene mesh exhibited greater pull-through strength than 5-0 polypropylene monofilament sutures in rats undergoing ventral hernia repair.[49] Strips of polypropylene mesh provide larger surface area interaction with tissue edges and therefore distribute forces more evenly at each site than a thinner suture. This leads to less pressure at the leading edge of each mesh strip placement and therefore a lower chance of mesh strip pull-through in vivo.[50] Because mesh strips are larger than sutures, the foreign body response to the

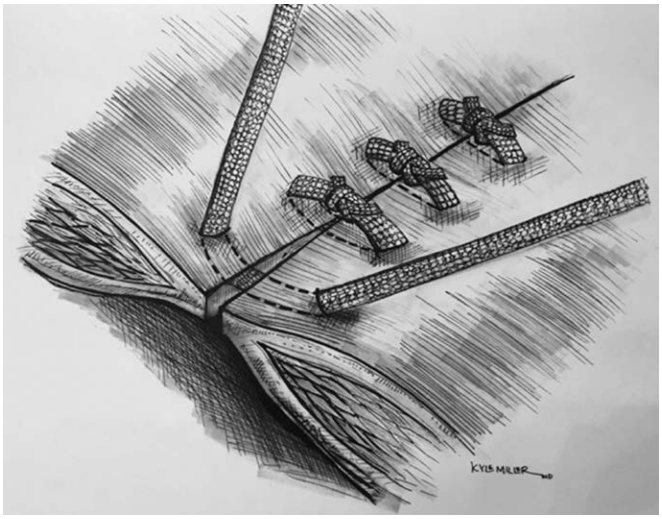

Fig. 1. Mesh strip method for mesh fixation. (Used with permission from Lanier ST, Dumanian GA, Jordan SW, Miller KR, Ali NA, Stock SR. Mesh sutured repairs of abdominal wall defects. *Plast Reconstr Surg Glob Open* 2016;28:e1060.)

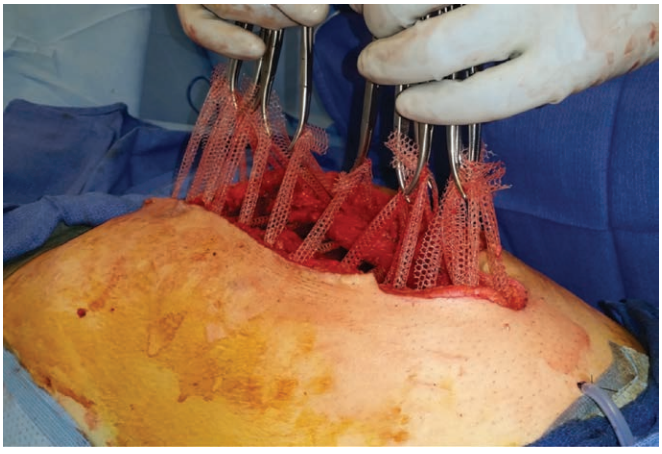

Fig. 2. Intraoperative mesh strip technique for mesh fixation.

material is greater, providing a strong integration into the native tissue.[50]

A 2016 study showed a hernia recurrence rate of 3.7 percent and a surgical-site infection rate of 4.6 percent during a mean follow-up period of 234 days.[51] In addition, mesh strip repair of contaminated ventral hernias showed a recurrence rate of only 6 percent.[52]

Mesh strips provide a cost-effective repair that is stronger than suture repair and has shown promising clinical results. There is no need for coating mesh with bioreactive materials or sealants to adhere the mesh to surrounding tissue. Furthermore, this technique requires only simple modifications of cutting the mesh into strips and threading the mesh strips through the tissue using a swaged suture or a Pulvertaft weaver.[53] Although they present an increased amount of foreign body response, studies have shown no increase in surgical-site infection when compared to traditional mesh repair.[51,52] The larger knot made by the mesh strip may lead to more awareness and pain at the site than a knot made by monofilament suture. To our knowledge, no study has compared chronic pain outcomes in this form of mesh use for abdominal wall reconstruction. From an economic standpoint, mesh strip repair represents a similar cost to traditional transfascial suture fixation of mesh, as typically the same amount of planar mesh is used, just in a different fashion.

NO FIXATION

The idea of a fixation-less placement of mesh has been studied in inguinal hernia repair. In inguinal hernia repairs, there is no significant difference in mesh migration in fixated versus nonfixated mesh groups.[54] In ventral hernia repair, the theory of this technique is predicated on a wide field of tissue undermining in the retrorectus plane. Once the wide dissection has been complete, a large piece of synthetic mesh is placed in this plane—offering a massive tissue mesh interface and promoting strong mesh integration and therefore repair. Although the operative technique has been described,[55] no studies have been conducted that show long-term follow-up complication or recurrence rates.

We posit that this technique affords cost savings to the hospital and patient through reduced material costs—as no materials are used to fixate the mesh. Furthermore, as there are no transfascial sutures or tacks, the patient theoretically would experience reduced postoperative pain. Finally, this operation for ventral hernia repair can be performed laparoscopically, reducing the need for a large abdominal incision.[56]

FUTURE

Research is currently being performed to augment current techniques of mesh fixation with stronger and easier-to-use methods of fixation with low complication rates. In tack fixation, new permanently capped helical coils are being tested, leading to less adhesion than their traditional counterparts.[57] Fibrin glue is being modified by adding mesenchymal stem cells, leading to a modulated inflammatory response toward a more regenerative—rather than inflammatory—profile, with belief that this will allow for better healing and less pain.[58] Finally, swaged needles are being developed for mesh strips that eliminate the need for bulky knots, perhaps leading to less pain and reduced foreign body response at the knot's tissue interface.[59] Meshes are also being created that have variations in shape and applicative technique. Octomesh (Insightra Medical, Inc., Clarksville, Tenn.) is an eight-limbed mesh that uses a specially developed passer to integrate the limbs into the rectus muscle in an onlay or sublay technique.

CONCLUSIONS

Each mesh fixation type has advantages and drawbacks. It is important for surgeons to fully understand these aspects when performing ventral hernia repairs. This allows for one to tailor the technique to each individual patient based on the defect complexity, patient comorbidities, and resources available.

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