How to Choose a Mesh in Hernia Repair

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Since the introduction of polypropylene (PP) mesh for hernia repair [1], surgeons continue to discuss the use of mesh in a variety of settings for one of the most common operations performed by general surgeons—hernia repair. This discussion has involved raw materials, cost, and outcomes and for many years referred to only a few products, as manufacturing was limited. Nowadays, with multiple permanent, absorbable, biologic, and hybrid products on the market, the choice of mesh for a hernia repair can be daunting. Increasing clinical complexity further emphasizes the need for individualizing care, but more frequently, hospital supply chain personnel institute product procurement procedures for cost control, limiting mesh choice for surgeons. This can force surgeons into a "one-size-fits-all" practice regarding mesh choice, which may not be ideal for some patients. Conversely, current literature lacks definitive evidence supporting the use of one mesh over another, a fact that has not escaped the radar screen of the hospital supply chain and mesh industry, both of which attempt to limit vendor and mesh choice for financial gain. It is unlikely that this type of "proof" will ever come to fruition. This leaves us with choosing a mesh based on an algorithm that is centered on the patient and the patient's unique clinical scenario [2]. This algorithm (Fig. 8.1) will culminate in mesh choice, but could also apply to non-mesh techniques as well.

Below are generic two examples, based on real cases, which will serve as background information. I will refer to these examples throughout the chapter to highlight how an algorithmic approach to mesh choice can be utilized.

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1. Identify goals of hernia repair
    a. Explicitly ask patient about their goals – symptom relief, prevention, or both.
    b. Align those goals, and discuss the likelihood of their realization with hernia repair.
2. Evaluate the clinical scenario
    a. Is the case elective, urgent, or emergent?
    b. Is the case clean, contaminated, or potentially contaminated?
    c. Is the patient a better candidate for local or general anesthesia?
    d. Does the patient's history suggest higher likelihood of future operation? (e.g. pregnancy, Crohn's disease, ostomy closure)
    e. Evaluate the hernia details –previous repairs, location, size of defect, size of sac, associated skin issues.
3. Choose a technique
    a. A technique that is most likely to meet the goals in the given clinical scenario should be chosen. In the event this technique is not the one the surgeon is the most comfortable with or has the adequate resources, referral or a different technique and rationale should be discussed with the patient, and a joint decision can be made about how to proceed. This is obviously limited in emergency situations.
4. Choose a mesh designed for use with the chosen technique
    a. Consider the raw material –permanent, absorbable, synthetic, biological, hybrid
    b. Consider the design –A high priority should be placed on the relative strength of the mesh, data that can be difficult to obtain. Porosity, fiber size, and barrier coating are also important to evaluate, as each mesh performs differently in different locations (e.g., intra-vs extra-peritoneal, bridging vs support).
5. Preoperative planning
    a. Plan enhanced recovery strategies with anesthesia, and coordinate regional anesthetic blocks as necessary.
    b. Define need for multidisciplinary coordination before you start, such as plastics, colorectal, gynecology, and urology.
    c. Make sure the mesh you have chosen is available, and in a variety of sizes.
    d. Have an alternate plan and/or mesh available in the event intraoperative findings dictate a change.

Fig. 8.1 Algorithm for mesh choice for hernia repair

Example 1: A 70 year old patient who works as a physician presents with a small, asymptomatic incisional hernia after a laparotomy. The patient has a BMI of 26. The patient is concerned it will grow, as it seems to have grown from the size of a marble to that of a golf ball in a short period of time. There is no pain. The surgeon may tell the patient not to worry about the hernia unless it starts causing problems. As the hernia sac grows, the patient returns with an enormous hernia sac, associated with overlying skin excoriation.

Example 2: A 60 year old obese patient (BMI 52) with multiple medical problems and actively smoking is concerned about progressively worsening pain from an intermittently incarcerating primary ventral hernia, requiring two visits to the emergency room within the past month. The patient noticed the symptoms for several months before the ER visits, but the pain was never that severe. The intermittent pain seems to be increasing in frequency and severity. The patient would like to relieve the symptoms and avoid a life-threatening emergency. The bulge is barely noticeable and located in the midline epigastrium. CT scan reveals the defect is 6 × 6 cm and contains omentum and a portion of the transverse colon.

Step 1: Goals of the Hernia Repair

It is important to identify the patient goals for the operation. Regarding hernia repair, this is usually associated with symptom relief, prevention of developing symptoms (including acute incarceration), or both. Symptoms include discomfort, pain, abnormal abdominal wall contour, skin changes, intermittent bowel obstruction, and limitations of important activities. Prevention is typically the goal associated with asymptomatic hernias found during a routine physical exam or during an imaging study performed for another problem. Often, a patient with mild, but slowly progressive symptoms, desires both to alleviate the current symptoms and avoid waiting until they become so severe it will compromise their care.

Once the goals of the repair are identified, the surgeon must align those goals with the healthcare team. This will allow the surgeon to identify and address unrealistic goals, and formulate a strategy of repair, including mesh choice, which will most likely meet the goals. It is also important to explicitly discuss the likelihood of meeting the patient's expectations, as patients and surgeons may have different perceptions of what is important [3, 4].

In example 1 (asymptomatic, marble-sized incisional hernia; goal is to prevent it from getting worse), there are a variety of techniques and mesh options available. As the hernia defect and/or sac enlarges, or if the hernia becomes acutely incarcerated with compromised bowel, the number of acceptable options dwindles, which affects the choice of mesh.

In example 2 (obese patient, escalating symptoms, 6 cm primary defect; goals are pain relief and avoidance of an emergency operation), one option for the surgeon is to recommend weight loss before an elective hernia repair is considered, as

the risk of repair is perceived to be too high for this BMI. The patient may be told to call back when 50 lb of weight have been lost. While this may be effective, patients may feel their problem is being dismissed due to their obesity. A possible outcome in this scenario is that the patient returns to the ER 6 weeks later with an acutely incarcerated hernia containing ischemic transverse colon, requiring laparotomy, partial colectomy, and colostomy. This series of events may then lead to a clinical situation where options are extremely limited and include only major abdominal wall reconstruction techniques, with or without concomitant colorectal procedure. While it's true there is an increased risk of complications with open ventral hernia repair in this population, 85% of patients with a BMI >50 will not have any complications according to a recent review of more than 100,000 open ventral hernia repairs in the American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) database [5]. And this risk is even lower with a laparoscopic approach [6].

Even though the patient did not present with an emergency, the progressive nature of the symptoms usually warrants an approach on an urgent basis, without enough time for proper preparation, such as weight loss. In this case, even without weight loss, both open and laparoscopic options could have been pursued in the face of a high BMI with a reasonable expectation of success.

Step 2: Clinical Details

Important clinical details regarding mesh selection include (1) operative urgency, (2) past history (medical problems, prior hernia repairs), (3) outlook for the future (Crohn's disease, pregnancy), and (4) hernia details (location, size, etc.). While we all perform a complete history and physical, we tend to focus our evaluation on the hernia details, which should only be done in the context of the primary goal(s) of the hernia repair.

Operations are performed in one of three scenarios—elective, urgent, and emergent. The following definitions will be used for the purposes of this manuscript. Elective cases will refer to those operations that can be booked at any time, even up to a year in advance, or observed without operation. These cases allow ample time to identify and discuss the goals, review old records, prepare for operation with weight loss and smoking cessation, participate in multidisciplinary collaboration, obtain a variety of imaging studies as necessary, utilize preoperative botulinum toxin A, participate in enhanced recovery programs, travel as necessary, and arrange for postoperative care. Urgent operations will refer to those that need to be accomplished within 1–4 weeks of the initial evaluation due to symptom escalation and/or impending complications such as skin necrosis or progressively more frequent and/or severe symptoms, such as bouts of incarceration or bowel obstruction. Emergent operations will refer to those that must be performed within hours to less than 1 week and include patients with acute incarceration with significant pain, unrelenting bowel obstruction, impending bowel ischemia, cellulitis, and/or perforation of the GI tract.

Prior surgical history is always important to obtain, and impacts mesh choice for hernia repair. Efforts should be made to review the details of the prior hernia repairs. This may yield information regarding the difficulty level of the operation, including the amount and density of adhesions. Information about the postoperative course may also lend clues to an otherwise unpredictable course. Finally, the history may allow identification of how a particular mesh performed after implantation. For example, if a patient had an exaggerated inflammatory response to a particular mesh used for a previous repair, avoiding this mesh for the current repair would be logical. Conversely, if a patient had a prior repair with a mesh that performed very well (no shrinkage, seroma, or exaggerated inflammatory response) in another location, the use of the same mesh would also be expected to be associated with a good outcome with regard to the host response to the mesh.

Potential need for future operation is also an important clinical detail and includes C-section, ostomy closure, or operation for Crohn's disease [7, 8]. Higher-risk or known planned future operations should factor into the decision for technique and mesh choice. For example, techniques using intraperitoneal mesh should generally be avoided if possible, as they would be expected to increase the risk and difficulty of subsequent operations [9–11].

Laparoscopic inguinal hernia repair, however, should not be considered a contraindication for men due to the low risk of developing prostate cancer, and the fact it does not unreasonably complicate future prostatectomy [12].

Consider hernia repair in women of childbearing age before, during, and after pregnancy. There is no consensus whatsoever regarding hernia repair timing or technique. Using an algorithmic approach, addressing the patient's goals and discussing the pros and cons of repair type, timing, and mesh use should lead to the best decision and plan for that patient. The surgeon should not prevent access to hernia care for women of childbearing age, nor proceed with hernia repair without a proper informed consent that includes pregnancy-related issues [13, 14].

Finally, the hernia details are clearly important. Hernia *location* is important, as it will dictate the type of fixation points and amount of overlap available. Consider a midline hernia near the umbilicus. There is plenty of room for wide overlap, as well as available abdominal wall muscle/fascia for fixation. If the midline defect is near the pubic bone, the amount of inferior overlap will be limited, but the available structures for fixation (pubic symphysis and Cooper's ligaments) are much stronger than muscle and fascia, mitigating the need for larger amounts of overlap. If the midline defect was near the xiphoid, bony fixation is more limited, but surface area for more overlap is available, with the ability to drape the mesh high on the diaphragm, taking care to avoid fixation to the pericardium. Hernia defect *size* is a very important detail, as it relates directly to technical difficulty of the operation and risk of recurrence [15, 16].

Through clinical experience, I have found that midline hernias can generally be categorized into small, medium, and large, depending on their transverse dimension. Small defects (<5 cm in width) have many viable options. They can usually be closed primarily without adjunct techniques such as component separation or BTA

Table 8.1 Clinical concerns with small, medium, and large hernia defects

Small	<5 cm	• Many options for repair available • Can usually close primarily without adjunctive techniques • Mesh choice less critical
Medium	5–10 cm	• Many options for repair available • Ability to close defect is more variable, and highly dependent clinical scenario, patient history, defect location, and body habitus • Mesh choice highly dependent clinical scenario, patient history, defect location, and body habitus
Large	>10 cm	• Fewer options available for repair • Defect closure usually requires adjunctive techniques • Mesh choice more critical

injection. They are also easily bridged if necessary and have lower recurrence rates compared to larger defects [15, 16]. Medium defects (5–10 cm in width) are more dependent on the clinical scenario, patient's medical history, and body habitus. While they may be bridged, larger mesh is required, and adjunct techniques such as component separation or BTA injection may be necessary. Large defects (>10 cm in width) are typically very difficult to bridge given the limitation of the size of the abdominal wall (Table 8.1). Additionally, large defects usually require adjunct techniques to close them, such as component separation, preop BTA injection, or both. Lastly, hernia details should include *associated problems* such as skin excoriation, prior skin grafts, large hernia sacs, and disfiguring scars, all of which will help guide technique and subsequently mesh choice.

Step 3: Choose a Technique

With knowledge of the patient's goals, the clinical scenario, the medical history, and the details of the hernia, a technique can be chosen that will be most likely to be successful at realizing the goals of repair. For ventral hernias, if restoration to normal abdominal wall contour is one of the main goals of repair, techniques that involve defect closure will be more likely to achieve success compared to bridging techniques. If the primary goal is pain relief, bridging techniques can be as effective as techniques that utilize defect closure, and this will drive prosthetic choice. If part of the goal is revision of a disfiguring laparotomy scar/skin graft, or removal of excess skin and subcutaneous tissue (e.g., panniculectomy), an open approach will likely be more appropriate than a laparoscopic approach, and the prosthetic choice will be dependent on the specific open technique and placement location of the mesh.

In example 1, (asymptomatic, marble-sized incisional hernia; goal is to prevent it from getting worse), many options are available with open and laparoscopic techniques. In this case, clinical details related to the medical history and physical examination will be important guides to choosing the best technique. The technique with the lowest chance of recurrence would be most appropriate for the goal of prophylactic hernia repair, and the technique chosen will drive mesh choice.

In example 2 (obese patient, escalating symptoms, 6 cm primary defect; goals are pain relief and avoidance of an emergency operation), a laparoscopic bridging technique is a good option, as it lowers the risk of wound complications and doesn't require defect closure, simplifying the operation and having a high probability of success. This choice of technique would then guide mesh choice.

Step 4: Choose a Mesh

Once the goals have been established, clinical details sorted out, and a technique chosen that will most likely realize the goals while minimizing risk, it is time to choose a mesh. While there is no agreement as to which mesh is the "best," there are some details that bear emphasis and require a knowledge of mesh devices that many surgeons dismiss as unimportant, unproven, and/or unknown. Further, since there is no consensus regarding which mesh feature is most important to evaluate, consider what we are doing—implanting a mesh device to support soft tissue where weakness or defects occur. Therefore, biocompatibility and strength should be at the top of the list informing surgeons about mesh choice, with mesh strength being most important.

While biocompatibility is important to consider, all mesh devices have already been determined to be biocompatible through the approval process by the US Food and Drug Administration. Furthermore, the individual biocompatibility for a particular mesh in a unique host is unpredictable, unless there is previous exposure to the product, with a known response.

Therefore, strength becomes the number one metric surgeons should be concerned with when choosing a mesh. Given this logic, it is surprising that strength data is rarely reported in a manner that surgeons can access and use clinically, or to accurately compare mesh devices. A shining example of the misunderstanding of mesh strength data is the recent manufacturer recall of Physiomesh™ (Ethicon, Inc., Cincinnati, OH, USA) [17]. The ultralightweight [2], coated PP mesh was designed for intraperitoneal use and was marketed for use for all types of ventral hernias, including bridging techniques in all types of defects and patients, large and small. The PP component of Physiomesh™ has a weight of <30 g/m^2 and can be manually torn in half with ease. This means that the choice of an ultralightweight mesh for bridging techniques will have a higher risk of recurrence compared to a stroinger mesh. For context, Marlex™ (CR Bard, Warwick, RI, USA) uncoated PP mesh, considered by most classification systems to be "heavyweight," is 95 gm/m^2.

It is important to point out, however, that weight (typically reported in g/m^2) is only a surrogate for mesh strength and is only useful for mesh comparison when considering the same polymer or different polymers with the same density. The units of measurement are also important to consider making accurate comparisons among products. The different densities among polymers may have significant implications for mesh strength [18]. For example, a denser polymer will weigh more per area, and thus could have thinner, weaker fibers, yet still have the same weight/area as a less dense mesh which may be stronger. The weight of a knitted mesh can be altered by increasing the number of fibers (which reduces pore size)

and/or increasing the fiber diameter (which may decrease pore size to a lesser extent, but can increase strength). Recently, Deeken and Lake have published a manuscript detailing these issues, which can serve as an excellent, independent resource for clinical decision-making [19]. These authors have also contributed a chapter dedicated to this topic later in this book.

Mesh strength can be measured with a variety of methods. However, none of the methods take into account the host reaction for an individual patient, and none of the methods can precisely extrapolate their data into real-life clinical situations. The missing clinical data include patient activity and body habitus, variable tissue quality, and the heterogeneous group of hernia defects that present with many sizes and variable locations. In vitro, or bench testing, maneuvers such as tear strength, suture pull through, and ball burst are common, but not standardized. When comparing studies however, details of how this data were obtained are critical. Strength data are dependent on equivalent methods of mesh fixation to the tensiometer, speed and direction of load application, and reporting in the same units of measurement [19].

Recognizing that this data is not practical for surgeons to review, and that there is no ideal mesh for all cases, it is helpful to avoid extremes. This is particularly important when relying heavily on the mesh for repair, such as with bridging techniques for larger ventral hernia defects. Even knowing the relative weights, and by inference strength, it becomes obvious that an ultralightweight mesh should be avoided in patients with large defects when used with a bridging technique. Strength is probably less important for bridging techniques with inguinal hernias, as the defects are all relatively small and proximate to rigid tissues surrounding the myopectineal orifice such as the pelvis, inguinal ligamnent, and psoas muscle. Making strength comparisons more difficult are mesh products designed to remodel (biologic) or absorb (synthetic) completely. The ultimate strength of repair for a given individual with these types of mesh is totally unpredictable. For inguinal hernia however, the defects are generally not closed, making use of absorbable or remodeling mesh more prone to recurrence, particularly for direct defects using an open technique [20, 21]. Laparoscopic techniques utilizing biologic mesh intended to remodel have been reported, and initial results in one small series of ten patients revealed a 9% recurrence rate at 14 months [22], and one small series of ten patients operated on for non-palpable tears in the transversalis associated with groin pain in athletes (“sports hernia”) revealed an 80% chance of pain relief and no evidence of hernia at 12 months telephone follow-up [23].

In example 2 (obese patient, escalating symptoms, 6 cm primary defect; goals are pain relief and avoidance of an emergency operation), if a laparoscopic bridging technique is chosen, using a permanent mesh with the lowest available weight/strength or synthetic absorbable/biologic mesh would be associated with the highest risk of recurrence and should be avoided. Additionally, if an intraperitoneal placement was planned, a mesh of sufficient strength that is also designed for intraperitoneal placement would be most appropriate.

In addition to strength data, each prosthetic has a list of features designed to address a specific clinical issue. Examples include designs for use specifically

within the peritoneal cavity, or for use as an adjunct to repair instead of bridging a defect. Again, using example 2 (obese patient, 6 × 6 cm defect, progressive bouts of acute incarceration and pain; goal is to treat episodes of incarceration, i.e., avoid recurrence), if the surgeon chose a laparoscopic technique without defect closure, placing the mesh intraperitoneally, a mesh should be chosen that is designed specifically for the intraperitoneal location, and is not the weakest mesh on the market. This approach would meet the primary goals of the patient, with the least overall risk, provided the surgeon has the appropriate training and experience in this technique. An alternative strategy would be an open repair with defect closure and mesh. If the retrorectus space was to be used for mesh placement, and the defect could be closed, a bare polypropylene mesh of any weight should suffice, as the anticipated stress on the mesh would be low. The open approach would however increase the risk of wound complications.

Finally, there are two major categories of mesh available—permanent and nonpermanent. Of those that are not permanent, some are absorbable (synthetic), and some are designed to remodel into host tissue (biologic). If the technique chosen is a bridging technique, an absorbable or remodeling type of mesh is probably not the most appropriate choice if hernia recurrence is to be minimized. This includes both inguinal and ventral hernias [20, 21, 24]. For bridging techniques, permanent mesh would be expected to have the lowest risk of failure, and mesh designed to remodel (typically biologic mesh) would be somewhere in between, depending on the size and location of the defect being bridged. In example 1 (thin patient, asymptomatic, small, midline incisional hernia), mesh choice for bridging would include permanent and remodeling type mesh or absorbable mesh used as an adjunct to primary repair. In example 2 (obese patient, 6 × 6 cm defect), bridging with an absorbable or remodeling type mesh would have a much higher risk of failure compared to a permanent mesh of sufficient strength.

Step 5: Preoperative Planning

Once the patient has been fully evaluated, and an operative plan crafted, the reaminder of the preoperative process begins. There are many aspects of the preoperative planning process, but one important and sometimes overlooked aspect is mesh availability. This not only concerns the mesh type that has been chosen for repair, but also must include a variety of sizes, as intraoperative findings may change the plan. Additionally, a backup mesh should be available in the event the wound classification of the case changes unexpectedly, or the mesh needs to be placed in an area it was not designed for. In example 1 (thin patient, asymptomatic, small, midline incisional hernia), the surgeon may be planning a laparoscopic approach (with or without robotic assistance) with defect closure and *extra*peritoneal mesh placement. The mesh chosen was a lightweight, macroporous, bare PP mesh. Intraoperatively however, it may become apparent that the mesh cannot be placed in the extraperitoneal location and/or the defect cannot be closed. In these cases, a mesh appropriate for intraperitoneal use and/or bridging mesh should be available.

Summary

In summary, there are many hernia repair mesh products available on the market, and there is no proof that one device is better than another. It is clear, however, that certain types of mesh are more appropriate in certain circumstances, which is why an algorithmic approach is so important. While the algorithm does require some knowledge of the features and strength specifications of mesh devices, the knowledge does not have to be encyclopedic. The surgeon should at least know the basics regarding strength, design features with respect to mesh position, and how these features fit with the technique being used for repair, in the specific clinical circumstance of their individual patient.

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