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Meshing around: high-risk hernias and infected mesh

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SUMMARY

Open laparotomy carries a risk up to 20% for an incisional hernia, making repair one of the most common operations performed by general surgeons in the USA. Despite a multitude of mesh appliances and techniques, no size fits all, and there is continued debate on what is the best mesh type, especially in high-risk patients with contaminated hernias. Infected mesh carries a significant burden to the patient, the surgeon and overall healthcare costs with medical legal implications. A stepwise approach that involves optimization of patient comorbidities, patient selective choice of mesh and technique is imperative in mitigating outcomes and recurrence rates. This review will focus on the avoidance of mesh infection and the selection of mesh in patients with contaminated wounds.

INTRODUCTION

The use of mesh is common for general surgeons around the world. When the operation goes well, and the patient has no issues, both the surgeon and the patient are satisfied with the results. It is estimated that after major trauma and abdominal surgery, the incidence of hernia formation is between 10% and 15%.[1] Choice of mesh for hernia repair is important. The requirements for mesh prosthesis were first described in the 1950s.[2 3] These requirements include induction of minimal host response and adhesions, vascularization, good host tissue incorporation and resistance to infection.[4] Mesh complications include migration, seroma, foreign body reactions, dehiscence, fistulas, pain, small bowel obstruction and infection.[5] Mesh infection is a serious and potentially devasting complication of hernia repair. Although uncommon in the groin, with an estimate of 2%–4% of cases overall, risk of mesh infection increases up to 10% in abdominal wall hernias.[6] When the laparoscopic approach is employed for incisional hernias, the incidence is noted to be 3.6% overall.[7 8] The complexity of repair and risk of infection worsen with hernias that have strangulated bowel and contaminated wounds since bacteria are present early in the course of the disease.

MESH INFECTION

Bacterial propagation mechanisms in mesh infection

There are stages of prosthetic infection after the patient has a hernia repair. Although surgeons try to make sure there are no organisms introduced into the mesh, sadly the moment of infection occurs when the mesh is implanted. The bacteria are typically introduced in the operating room from many sources including the skin, mucosa, hands of the operating surgeons or from the environment.[9] It only takes a few organisms in the wound to start the infection, and once present on the mesh, cause a change in the host response such as reduced phagocytic activity of the immune system against the invading bacteria. This reaction allows the active bacteria to express protective mechanisms.[10]

There are two factors that help the bacteria infect the mesh over time. The first mechanism is a reversible interaction between the bacteria and the mesh surface mediated by physiochemical factors in the mesh. These factors are secondary to chemotaxis, gravitational and other factors and they are reversible. The other factor is related to the irreversible adhesion of the bacteria to the mesh which is aided by cell wall and molecular factors in the patient.[11] Once the bacteria adhere to the mesh, they have the capacity to form communities of microorganisms that bind together and form a biofilm. The biofilm has multiple strains of bacteria in it that form an extracellular matrix, which helps to encapsulate and protect the bacteria so that they can multiply and develop resistance to the use of antibiotics. These incorporated bacteria form their own community and can act differently since they genetically modify themselves to confer resistance to the use of antibiotics. The bacteria in the biofilm have a different phenotype than their counterparts that do not exist inside a mesh. When a mesh infection develops biofilm, it is difficult to eliminate and typically requires complete mesh removal.[12]

There is a complex environment that allows the biofilm to exist when it develops. Each biofilm has an induced mechanism which is known as quorum sensing.[13] This pathway allows the bacteria to communicate with other organisms in the biofilm through channels for water nutrients, oxygen and waste products. Each biofilm has a different geographic area corresponding with oxygen affinity; some are internal (anaerobic) and some are external (aerobic). One of the amazing features of the biofilm is that organisms have the ability to detach and move around to other regions within the biofilm.[14 15] Many of these biofilm-forming bacteria are associated with hospital-acquired infections and surgical site infections. These organisms include *Staphylococcus aureus* and *Staphylococcus epidermidis*, which are the two main organisms responsible for mesh infection.[16 17] The two other organisms involved in mesh infection are *Streptococcus* and *Enterobacter*.[18]

Types of mesh

There are two large categories for prosthetic mesh: synthetic (table 1) and biological (table 2). Synthetic mesh (table 1) is often classified as microporous, macroporous or composite. Microporous mesh

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Table 1 Examples of synthetic mesh

Brand name	Manufacturer	Features
Soft Mesh	Bard	Lightweight, macroporous, polypropylene
Ventralight ST Mesh	BD	Uncoated medium weight monofilament polypropylene on anterior side with absorbable hydrogel barrier (Sepra Technology) on posterior side
Ultrapro	Ethicon	Macroporous, partially absorbable and lightweight polypropylene

includes monofilament and double filament polypropylene (PP) with large pore sizes which allow tissue ingrowth (increase in scar tissue).[19] Macroporous mesh does not include tissue ingrowth and therefore has a lower affinity for adhesions.[19] Composite materials combine the different qualities usually on different sides of the mesh to take advantage of the benefits and minimize the side effects of the mesh composition.[19] Mesh can have antiadhesive coatings that are absorbable (ie, polyurethane) or non-absorbable (ie, collagen hydrogel).[19] Synthetic mesh can also be categorized by weight (light, medium, heavy).[19]

Biological mesh (table 2) is categorized as acellular dermal matrix obtained from human (allografts) or non-human (xenografts) sources.[19–21] Sources of biological mesh include human dermis or fascia lata, porcine dermis or intestine and bovine dermis or pericardium.[19–21] Alteration of the extracellular matrix through manufacturing techniques (decellularization, cross-linking and/or sterilization) can impact cellular infiltration and neovascularization.[19–21]

Properties of mesh as it relates to infection

There are several factors that promote mesh infection in patients. The environment that the mesh resides in is moist and promotes the development of bacterial growth. These conditions promote the adherence of bacteria to the mesh once they are in position. The type of biomaterial that the mesh is created from is also a factor with respect to the development of mesh infection.

Synthetic mesh

Synthetic mesh can be woven, knitted or have yarn configuration. The monofilament or multifilament nature of the mesh can influence adhesions of the bacteria on the mesh and the complexity of the mesh can promote infections.[22–24] Multifilament mesh is more susceptible to biofilm than monofilament prostheses.[22–24]

Pore size is a key factor, as larger pores have less contact area, and may be less prone to bacterial colonization than mesh with smaller pores, also called heavyweight mesh.[25] Three types of synthetic mesh as they relate to infection will be discussed: reticular, laminar and composite. Each one has different properties that affect their susceptibility to infection.

Table 2 Examples of biological mesh

Brand name	Manufacturer	Features
Strattice	Life Cell Corp	Non-cross-linked, porcine dermis
AlloDerm	Life Cell Corp	Non-cross-linked, donated allograft human dermis
Permacol	Medtronic	Cross-linked porcine dermis
Surgimend	Integra Life Sciences	Fetal bovine dermis

Reticular synthetic mesh materials are commonly non-absorbable. These types of mesh include PP, polyester (PE) or polyvinylidenfluoride yarns. PE mesh is made up of lactic acid, glycolic acid and trimethyl carbonate (TMC) and is more susceptible to infection and bacterial adherence. There is discussion in the literature about the use of these types of mesh in the setting of an infected field, but it is controversial.[26]

Laminar synthetic or sheet prostheses are made of polytrerafluoriethylene or TMC. These types of mesh have larger surface areas and are more susceptible to mesh infection and colonization. The essential fact is that this type of mesh has micropores which provide a fertile ground for bacteria to proliferate. When the bacteria settle into the micropores, they are protected against the action of macrophages, which help fight off infection. The use of non-porous materials is thought to reduce the risk of infection and can be used in an infected area.[27]

Composite synthetic mesh is complicated in structure. One side is reticular or woven or knitted and non-absorbable and the other side is absorbable. The data in the literature suggest that these types of mesh are more susceptible to infection than other types. Because of their construction, they have a larger surface area, which allows biofilm to adhere to the mesh and produce infections.[28]

Biological mesh

Biological mesh is also known as bioprosthetic and is made of several diverse types of products such as dermis or small intestine.[29] These are decellularized tissues that are rich in collagen. There are two groups biological mesh. One group has covalent bonds between the molecules that are cross-linked, and the second group have no cross-linked bonds.[30] These cross-linkages are mediated by matrix metalloproteases and can affect susceptibility to infection. There is controversy surrounding use of biological mesh in the setting of hernia repair due to the high incidence of recurrence rates and complications.[31]

Patient risk stratification and optimization for minimizing mesh infection

The Carolinas Equation for Determining Associated Risks (CeDAR) calculator, originating from the Carolinas Medical Center, is a mathematical model to predict wound infections in patients following complex hernia repair. The score includes the following: uncontrolled diabetes, tobacco use, previous hernia repair, entry into the bowel, active abdominal wall infection, need for skin or subcutaneous flaps, component separation and body mass index. The data are inputted, and the risk is calculated for each patient. In the paper by Augenstein *et al*, they found that the incidence of wound complications could be reliably predicted in their cohort of patients using the CeDAR calculator.[32] As it is an application on iTunes and Android, it can be easily used in clinic when discussing potential complications associated with hernia repair in high-risk patients.

When deciding what type of mesh to use, it is important to first identify the patients' risk factors for infection. There are several meta-analyses that have looked at the incidence of mesh infection after abdominal reconstruction. A recent study of 2418 mesh hernioplasties discovered an infection rate of 7.2%.[33] Risk factors for mesh infection increase with advanced age, American Society of Anesthesiology score >3 and tobacco smoking. Out of all these factors, tobacco use portends the greatest risk for infection.[32] Patients with prior mesh placement, uncontrolled diabetes mellitus, obesity and chronic obstructive pulmonary disease also have an increased risk of mesh infection. When planning for

surgery, it is important to discuss risk factor modifications with patients upfront. These can include weight loss prior to surgery, improving control of diabetes and smoking cessation. Some authors have suggested use of antibiotics postoperatively may be helpful in high-risk patients.[1]

Operative techniques, prolonged or emergent repair and inadvertent enterotomies may contribute to risk of mesh infection. Mesh infection can occur either in open surgery or laparoscopic surgery. When the laparoscopic approach is used, the incidence of infection has been noted to be 0%–3.6% compared with 6%–10% after open procedures.[34] Although mesh can be placed in several positions in the abdominal wall, several meta-analyses have shown that the placement mesh in the retro rectus position is helpful in reducing risk of mesh infection from 26% to 2%.[35 36]

Mesh utilization and options for repair in high-risk hernias

Surgeons must usually operate on patients who present with emergent high-risk hernias. With no time to optimize patient risk factors, surgeons are faced with making decisions on mesh utilization in a contaminated hernia. Mesh explantation due to infection, although a dreaded complication, is overall a rare occurrence given the commonality of herniorrhaphy in practice.[37] Regardless of practice pattern, surgeons will employ mesh. Using a stepwise approach in contaminated hernias may help mitigate morbidity and plan for future repair.

Definition of contaminated field

The Centers for Disease Control and Prevention wound classification has been found to be a marker for patient readmission with surgical wounds that are anything other than class I (clean) wound. Most acute care surgeons operate on patients with class II (clean contaminated), class III (contaminated) and class IV (dirty/infected) wounds which portend a significantly higher risk of infectious complications and 30-day readmission.[38] Surgeons must be familiar with different techniques and risk of mesh utilization to soften the risk that is inherent to the wound even prior to surgical intervention.

Skin-only closure with planned ventral hernia repair

Closing the abdominal wall defect with skin is a reasonable option for patients with multiple comorbidities and it does not impede on future repairs. The skin is the ideal biological dressing with no extra cost and one stage repair, which allows for earlier extubation and enteral nutrition. The need for subcutaneous flaps and drains can lead to higher morbidity with postoperative pain, infection, seroma, hematoma or flap necrosis.[39] There has been literature to suggest that skin-only closure can lead to abdominal compartment syndrome. A study done in patients with abdominal aortic aneurysm repair has shown skin closure to be a viable option, although with an elevated risk of patients being discharged with a planned ventral hernia.[40] Of the 14 patients who were discharged with a planned ventral hernia repair, 11 did not report significant morbidity related to the hernia and did not opt for a hernia repair.[40]

Primary repair

Primary repair does eliminate the use of mesh but has high recurrence rates. Studies have looked at type of suture and technique to decrease hernia rates. The use of triclosan-coated suture in emergent surgery has been shown to reduce the incidence of incisional surgical site infections and evisceration when compared with polydioxanone suture.[41] The small bites versus large bites for closure of abdominal midline incisions trial showed risk of an incisional hernia at 1 year was lower in the small bites group (5 mm by 5 mm) versus the large bites group (1 cm by 1 cm).[42] While the primary repair technique eliminates the use of mesh, it has high recurrence rates.[43 44] Arroyo *et al* showed that in the suture-only group, there was an 11% hernia recurrence versus the mesh group that had 1%.[43] Comparable results were shown in the paper by Burger *et al*.[44] Most experts will agree that mesh repair is superior to primary repair in decreasing hernia recurrence rates.

Bridge or reinforce with mesh

There are four classic planes for mesh position in ventral hernia repair: onlay/overlay, bridged/inlay, sublay/retromuscular underlay and intraperitoneal/preperitoneal underlay. Surgeons should be comfortable in operating in all these planes as each has advantages and disadvantages and can be legitimate options in proper patient selection.[45] Fascial bridge using prosthetic mesh is a reasonable option if there is tension and the abdominal fascia will not come together.[46] Although sublay repair has low surgical site occurrence and recurrence rates, it is a complex procedure that requires high surgical skills and may cause devastating abdominal wall complications, such as abdominal wall ischemia and is usually employed for abdominal wall reconstruction in an elective/delayed fashion.

Planned ventral hernia and abdominal wall reconstruction

Most experts will agree that abdominal wall reconstruction should not be employed in the acute phase as it might preclude future repair. This is usually attempted in the outpatient setting as a planned ventral hernia repair. Newer techniques such as the transverse abdominus muscle release to obtain tension-free reconstruction with component separation in complex and large abdominal wall hernias are proving to have low morbidity and recurrence rates.[47 48] Repair in the elective phase still does not eliminate contaminated spaces as many hernioplasties involve concomitant ostomy takedown and mesh explantation. Studies have shown that even in the contaminated planned herniorrhaphy, the use of synthetic mesh can be employed safely, decrease recurrence rates and be cost-effective when compared with biological mesh.[49] There is still need for continued research comparing one-stage and two-stage abdominal wall reconstruction.[50]

Use of synthetic versus biological mesh in a contaminated ventral hernia

Inconsistent literature has supported the opinion that synthetic mesh used in a contaminated hernia leads to high rates of surgical site occurrence (surgical site infection, seroma, wound dehiscence and enterocutaneous fistulae) and need for mesh explantation.[19 20] Common practice has been to implant a biological mesh in patients with high-risk hernias to reduce the incidence of mesh infection, however, recent literature has shown biological mesh to have increased rates of recurrence and cost compared with synthetic mesh.[37 49]

The PRICE (Preventing Recurrence in Clean and Contaminated Hernias Using Biologic Versus Synthetic Mesh in Ventral Hernia Repair) Randomized Clinical Trial by Harris *et al*, compared biological versus synthetic mesh for ventral hernia repair in adults.[37] Eight surgeons performed an open technique of their choice on randomized patients with clean (class I) and contaminated (class II–IV) wounds. Risk of recurrence at 2 years was double in the biological group (statistically significant).[37] Interesting findings showed that mesh explantation was overall exceptionally low in both groups; <5% in the class I wounds (all

in the synthetic group) and <8% in the class II–IV wounds.[37] In total, six mesh had to be explanted; five in the synthetic group, all due to chronic mesh infection, and one in the biological group due to an enterocutaneous fistula with a leak.[37]

Rosen *et al* performed a similar randomized controlled trial comparing biological versus synthetic mesh for contaminated (class II and class III) ventral hernia repairs.[49] Eight surgeons, all with fellowship training in abdominal wall reconstruction did a retromuscular repair.[49] Recurrence rate at 2 years was lower in the synthetic group (6%) vs the biological group (21%), which was statistically significant.[49] There was no major difference in surgical site infection between the two groups.[49] Cost was 200 times higher in the biological group (US$17 000), vs the synthetic group (US$105) and the sole driver in doubling the 30-day hospital cost.[49]

CONCLUSION

Mesh infection continues to be a complicated surgical problem to deal with after herniorrhaphy. Having an organized approach that considers the patient's physiological state and the type of mesh used is critical. Patient risk factor modification is crucial in addition to choosing a mesh that has less chance of getting infected. Some types of mesh are more susceptible to biofilm formation than others. It is suggested that lightweight mesh with larger pore size may work as they may be less susceptible to infection than heavy weight mesh with larger pore sizes.

If you are practising acute care surgery, chances are you will be dealing with high-risk hernias in a contaminated field. Despite not being able to optimize patient risk factors, employing options allows for the acute phase to be managed without impeding on future repairs. Recurrence rates are lower with sublay mesh repair, but this is a complex operation that might be best served in the delayed and elective phase. Despite controversy, recent literature has shown synthetic mesh use in contaminated ventral hernias is not unsafe, has half the recurrence rates and is significantly cost-effective when compared with biologic mesh.

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