20. Polyester, Polypropylene, ePTFE for Inguinal Hernias: Does It Really Matter?

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For over 20 years, following studies demonstrating the Lichtenstein technique, inguinal hernia repair has been routinely performed with the use of a prosthetic mesh device. The closure of inguinal hernias with mesh without tension has become the new standard of care for hernia repair. It is clear that tension-free hernia repair with mesh is superior to tissue repair alone, especially when considering the risk of recurrence. However, early studies did not differentiate between different mesh products, because at that time, few meshes were commercially available for surgeons to use. For instance, all original data demonstrating the effectiveness of the Lichtenstein repair is limited to the utilization of heavyweight polypropylene mesh [1].

Ever since the use of polypropylene mesh was described by Usher in 1959 for the repair of inguinal hernias [2], surgeons have been in search of the perfect mesh. Prior to the use of polypropylene, which has been the predominant mesh used in the repair of the inguinal hernia for the last 50 years, Koontz described the use of tantalum wire mesh in 1951 [3]. Numerous other materials have been described in the repair of inguinal hernias, including those comprised of nylon and stainless steel.

The ideal mesh needs to be strong enough to resist bursting pressures generated by the abdomen. It should be chemically inert, so as not to cause an inflammatory or foreign-body reaction, be noncarcinogenic, and lack properties that would cause allergic or hypersensitivity reactions. Mesh must have specific mechanical properties so that it can be easily and inexpensively fabricated, modified, or cut without unraveling or losing its shape. Mesh needs to have good handling features intraoperatively, be sterilizable, and be resistant to infection. Most

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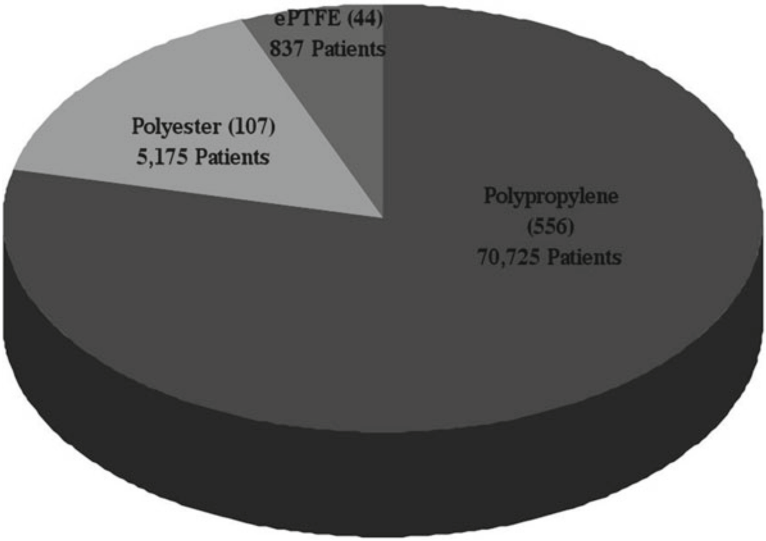

Fig. 20.1. Number of published studies based on mesh type. See Table 20.1 for details.

Table 20.1. Number of published studies based on mesh type.

	Polyester (107)	**ePTFE (44)**	**Polypropylene (556)**
# of patients	5,175	837	70,725
Recurrence (%)	0.7–3	1–4	1–9
Infection (%)	0–1	0–2	0–1
Chronic pain (%)	0.5–3	2–7	2–10

See Fig. 20.1

importantly, mesh must be able to be easily incorporated into the surrounding tissues and allow for long-term reinforcement of the tissues.

Recently, as new mesh options have become available and long-term follow-up has been performed, mesh material has been studied for its relative advantages, disadvantages, costs, and rates of recurrences (Fig. 20.1 and Table 20.1). Initially, studies only reviewed recurrence rates for a number of mesh products. As evidence was reported related to the likelihood of heavyweight polypropylene shrinkage while in the host body due to a severe reaction, new materials that were less likely to shrink began to be introduced. Shrinkage was not the only problem noted with traditional mesh use; rates of infection were also reviewed. Authors found that certain meshes were more likely to be colonized by bacteria, and clearance of bacteria was impossible in certain mesh types. Weight of the mesh contributed to chronic pelvic discomfort and pain, which was also noted in recent studies as a factor for choosing the proper mesh. Careful strength analysis of different types of mesh demonstrated that meshes were overengineered, and their relative thickness and constitutions were far heavier than the typical forces they were experiencing while implanted in the groin region. Finally, cost has recently become a determining factor in many institutions related to mesh choice, be it for contracting or other preferences. Only certain meshes are now available at hospitals, thus further limiting the choice of physicians in those institutions. New surgical techniques of mesh placement, such as using a plug in the indirect hernia space or placing the mesh in the preperitoneal space, has further complicated the best-mesh question as the performance of these meshes differ in the performance of traditionally anterior mesh patches as described by Lichtenstein.

Tissue Repair Versus Mesh Repair

Although some centers claim recurrence rates with primary tissue repairs that are equivalent to that of tension-free mesh repairs, large studies have shown inferior results with tissue repair. Proponents of tissue repairs cite the multiple but rare complications associated with mesh-like chronic pain or infection. However, a meta-analysis of over 11,000 patients showed that the use of mesh, placed either open or laparoscopically, decreased both the recurrence rate and the incidence of chronic pain [4]. And while it may be true that implantation of a foreign body might introduce some new complications like infection or migration of the mesh, it appears that these are rare events and occur in less than 1% of cases in which they are used. Since most tissue repairs are performed with suture made of the same material most mesh is made of, even tissue repairs have some degree of foreign-body reaction. It appears that in mesh repairs, the inflammatory reaction is short and self-limiting. In a study by Di Vita [5], inflammatory markers were measured following Bassini and Lichtenstein hernia repairs. They found a significant increase in leukocytosis 6 and 24 h after a Lichtenstein repair, but not in a Bassini repair. After Lichtenstein repair, the fibrinogen levels were significantly increased at 24 and 48 h, and the alpha-1 antitrypsin levels were significantly increased at 6, 24, and 48 h, without a corresponding increase seen in the Bassini repairs. Interleukin-6 (IL-6) and C-reactive protein (CRP) increased in both repairs but was significantly higher in the Lichtenstein group. Interestingly though, by postoperative day 7, the markers had returned to their baselines in both groups. Despite the increases in inflammatory markers, the patients in the Lichtenstein group had significantly less postoperative pain.

Choice of Mesh Repair

The choice of mesh is largely based on the technique being performed. The requirements for an intraperitoneal onlay mesh (IPOM) are significantly different than those for a recurrent hernia being repaired in an open Lichtenstein technique. All of the commercially available mesh products have literature to support their use and acceptable complication and recurrence rates. However, there is very little comparative data between the different mesh products. The three materials currently used in the majority of inguinal hernia repairs have more than a 40-year track record. Usher described the use of polypropylene in 1959, Calne described the use of polyester in 1967 [6], and Copello described the use of Teflon (PTFE) in 1968 [7]. However, polypropylene has approximately four times as many articles published about it than does polyester or ePTFE [8].

All of the current commercially available meshes have foreign-body reactions. Insertion of a prosthetic starts a biochemical cascade that leads to the eventual incorporation of the prosthetic. Fibrinogen, immunoglobulins, and albumin begin to coat the material after it is implanted. Cellular elements, including platelets, macrophages, and neutrophils, followed by fibroblasts and smooth muscle cells, then migrate into the prosthetic. However, the degree of this response and the overall result is significantly different between materials. While this inflammatory response may or may not benefit the strength of an inguinal repair, it has significantly different repercussions when it is placed in the vicinity of other tissue, for example, the iliac vessels, spermatic cord, or bowel.

In an attempt to optimize this inflammatory reaction, manufacturers have begun to coat the base mesh with several substances that would improve some characteristics of the mesh: fluoropolymers, titanium, D-glucan, silicone, and omega-3 fatty acids have all been used to try to decrease the inflammatory response to a mesh polymer, usually polypropylene.

When contact with the abdominal viscera is anticipated, be it from the rarely performed IPOM or during a preperitoneal open or laparoscopic repair in which the peritoneum is significantly torn and total coverage of the mesh is no longer possible, a mesh that does not react with the bowel is necessary. Until recently, microporous ePTFE was the only acceptable option. However, there are now multiple meshes that have a polypropylene or polyester base with some kind of anti-adhesion barrier (e.g., collagen, hyaluronic acid, omega-3 fatty acids, or cellulose) to prevent integration with the bowel. ePTFE is known for its relative inertness. It was initially developed as a vascular conduit because of this feature, but its use was soon expanded to tissue reinforcement. While inertness is a useful feature when near abdominal viscera, its inability to incorporate into surrounding tissues makes the repair rely heavily on the mesh fixation for durability.

In laparoscopic preperitoneal repairs, a major determinant of mesh selection is the handling properties of the material. Because of the limited space, especially in a total extraperitoneal (TEP) repair, a mesh with some memory favors deployment, retention, and fixation. However, with traditional polypropylene mesh, as memory is increased, the compliance decreases, which leads to an increase in foreign-body sensation. Several designs have been developed, be it anatomic or 3-dimensional shapes, which allow the mesh to rest in the myopectineal orifice, thereby allowing a lighter-weight polypropylene mesh to be used. Polyester mesh has good memory and increased compliance, which makes its use in TEP repairs appealing. Shah retrospectively compared polypropylene and polyester mesh used in laparoscopic repairs [9]. The authors conclude that polyester had a significantly lower incidence of chronic pain and foreign-body sensation as well as the sensation of a mass in the groin compared with polypropylene.

While mesh infection in inguinal hernia repair is uncommon, mesh that would be completely resistant to infection would be ideal [10]. There are several characteristics of a mesh that affect its resistance to infection. Microporous meshes which have pores less than 10 μm cannot accommodate macrophages but can allow the passage and presence of bacteria, leading them to be more susceptible to infection. This is the reason that infected ePTFE requires removal to clear the infection. Also, the construction of the mesh can provide interstices in which bacteria can "hide" and lead to persistent infection. Multifilament, woven, or knitted meshes like Dacron and some other polyester and polypropylene meshes have been reported to have this bacterial harboring effect. The use of monofilament polypropylene in infected fields has been described, with successful outcomes at times. It appears that with the development of biologic prosthetics, the use of synthetic prosthetics in infected fields will become more of historical interest.

The overall result in hernia repair is to obliterate the defect and relieve the symptoms of the patient. The cure cannot be worse than the disease. Therefore, in an attempt to decrease the symptoms of the repair, namely, pain and foreign-body sensation, lightweight meshes have gained popularity recently. The density of a mesh seems to have a role in how a prosthetic behaves once it is implanted. Less dense mesh can minimize contracture and pain; however, the optimal density and pore size are yet to be determined. In an innovative study by Agarwal [11], patients with bilateral inguinal hernias underwent TEP repairs with heavyweight polypropylene mesh implanted in one groin and reduced-polypropylene large-pore lightweight mesh implanted in the other groin, thereby serving as the control. All the patients reported a difference between the two sides, and there was less foreign-body sensation in the lightweight polypropylene side in the short term. At 1 year, the incidence of pain was similar for both heavyweight and lightweight polypropylene. In a meta-analysis that evaluated heavyweight, lightweight, and partially absorbable meshes performed by Markar, they found that prolonged pain and foreign-body sensation was almost double in the heavyweight mesh group, while the recurrence rates were the same between all the classes of mesh [4].

While it seems logical that strength would be a major determinant in mesh choice, the breaking strength of most of the commercially available meshes far exceeds the forces generated by the abdominal cavity. However, with the transition toward more lightweight meshes, there are several meshes available today that are equal to or slightly less than the burst strength of the abdominal wall. A comprehensive study by Deeken [12] was performed looking at nine different FDA-approved meshes. Suture retention exceeded 20 N, the tear strength of the abdominal wall, in all of the meshes except for the polypropylene-poliglecaprone mesh. Tear resistance was less than 20 N in woven PTFE, two configurations of lightweight polypropylene, and polypropylene-poliglecaprone. To further complicate the issue, for some meshes, the suture retention strength, tensile testing, and tear resistance were different based on the orientation of the mesh. However, strength alone cannot be the determinate for an appropriate mesh. Mesh that is overly stiff can lead to the sensation of a foreign body. Tantalum and stainless steel wire meshes were some of the initially described hernia meshes, but they were rapidly abandoned,

Table 20.2. Cost of mesh per cm^2[a].

Company	Weight	Dominant material	Design	Cost per cm^2
Covidien	Medium	Polyester	Multifilament	$0.44
	Light	Polyester	Monofilament	$0.46
	Light	Polyester	Self-fixating	$1.54
	Heavy	Polypropylene	Mono/multi	$0.68
	Heavy	Polypropylene	Open weave	$0.98
Ethicon	Light	Polypropylene	Monofilament	$0.53
	Heavy	Polypropylene	Knitted	$0.31
	Light	Polyester	Knitted	$0.51
Bard Davol	Light	Polypropylene	Monofilament	$0.24
	Heavy	Polypropylene	Monofilament	$0.38
	Medium	Polypropylene	Knitted monofilament	$1.42
	Light	Polypropylene	Knitted monofilament	$1.69
Columnar	Heavy	Polyester	Mosquito net	<$0.01
Gore	Medium/heavy	PTFE (teflon)	Knitted monofilament	$0.86

[a]All costs are approximate retail catalog prices

partially due to their rigidity and the chronic discomfort they imposed on the patient. The development of biologic prosthetics opens a new area of research into inguinal repairs. The proponents of biologics state that the use of mesh combines the benefits of both tissue and mesh repairs. The use of the biologic prosthetic allows for a tension-free repair. The mesh leaves no foreign body behind as the biologic is replaced with native collagen. When new collagen is produced in a wound, it has a strength of approximately 75% of the native connective tissue, which would seem to favor the use of prosthetic mesh for the foreseeable future. It may be that the selection of mesh is more of an academic problem. There have been multiple studies showing successful and durable repairs with minimal complications using such low-cost materials like nylon or polyethylene mosquito netting [13]. The use of mosquito netting sheds light on an important but frequently overlooked concept in mesh repairs—cost. As newer mesh is developed with features such as self-adhering cleats, partially absorbable mesh, and impregnated mesh, one needs to weigh the improvement in performance and intraoperative handling over the increase in cost (Table 20.2). There is also data that seems to suggest that choice of mesh may outweigh the operative technique. Champault looked at both laparoscopic and open Lichtenstein repairs that used either polypropylene or beta-D-glucan-coated lightweight polypropylene mesh. While the incidence of chronic pain was the same between the two techniques, the incidence of chronic pain was less in patients with the D-glucan-coated mesh independent of the technique [14].

Conclusion

Considering that factors such as the fibril size, pore size, and pliability within the same material all play into the behavior of a prosthetic, it quickly becomes near impossible to fully elucidate a comparison between different prosthetics. Even though multiple prosthetics are made from the same material, there are other factors, such as geometry of the weave and size of the fibers, that will cause two meshes made of the same material to behave very differently once implanted into a patient. The majority of the inguinal hernia literature as it pertains to mesh is between different manufacturing techniques within the same material (heavyweight vs. lightweight mesh). In the short term, it appears that lightweight mesh may be less symptomatic, but long-term benefits seem to be less apparent as many implanted heavyweight products have led to terrific results when used by experienced hands.

Differences in mesh material, technique, and location of mesh all contribute to the difficulty in deciding what specific mesh product to use. In conclusion, the surgical technique and the overall size of the mesh placed during a laparoscopic inguinal hernia repair matter more so than the actual mesh material.

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