MODERN MATERIALS APPLIED IN HERNIoplastY

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The problem of effective hernia repair frustrates a large number of surgeons who represent various levels of experience and skills. The revolution in herniology was started in 1887 by Bassini. Having better understanding of the anatomy of the groin, he developed a method of operation which became the standard method of surgery of this area for many years. This does not mean that no attempt has been made to introduce materials for the reinforcement of hernia portals. The first implants made of metal (steel wires, tantalum plaque, silver ribbons) caused such an enormous damage in the surrounding tissues that their use was quickly abandoned. It was only in the fifties of the twentieth century that Usher produced and applied the first mesh made of polypropylene, which, however, did not change the approach to hernioplasty (1-4). A method which was simple to control contributed to the essential change in 1989, when it was developed by the team led by Lichtenstein. Even now, it is the “gold standard” in the surgery of inguinal hernia, reducing the recurrence rate to single-digit values (5, 6).

The increasing level of health care and the dissemination of surgical procedures contributed to the growth in the number of hernia surgeries. The past century made even the most devoted followers of tissue repairs aware that implants are necessary to cover or reinforce the defects of the stomach walls. The primary repair of hernias with portals larger than 4 cm can be associated with a risk of recurrence equal to almost 50%, which, in turn, is associated with many factors such as: technical errors (use of incorrect suture material, improper suturing, incorrect ratio of the length of the suture to the length of the wound), risk factors associated with the patient (obesity, malnutrition, chronic coughing, smoking, advanced age, ascites, steroid therapy, chemotherapy, renal failure, diabetes) and disorder of the proportions of the respective types of collagen (I and III) (7, 8, 9).

Accordingly, the issue of reinforcing plastic surgeries of stomach hernias with an implant commonly known as the “grid” should not be disputed. The choice of the method of surgery should be given consideration: placement of the implant on the abdominal superficial fascia (on-lay) or behind the muscles (sub-lay), the open position of the intra-abdominal implant (open IPOM), laparoscopic repair of the abdominal hernia (laparoscopic IPOM), or hybrid surgery (lap/open, open/lap, lap/open/lap) and the so-called sandwich techniques (open on-lay/sub lay sandwich, open on-lay/lap IPOM sandwich) (10, 11). Each of these methods requires the surgeon to possess thorough knowledge of the anatomy of the area operated, proficiency in the use of both open and laparoscopic methods and the access to a wide range of ready-made implants which are offered by medical corporations. The choice of material should be made based on its characteristics such as the shape of the implant, the structure and nature of the fibre from which it has been made. If one also considers the strictly engineering-like nomenclature accompanying the description of medical products, a conscious selection of the type of implant
which would be optimal for a particular patient seems a very difficult task, but is not impossible.

Types of materials used

The evolution process of the views concerning the use of synthetic implants observed in recent years, which turned from skepticism to wide acceptance, proceeded very slowly in the past century. Thanks to clinical trials as well as trial and error methods, numerous biomaterials have been introduced over many years. Today, surgery is based on four types of implants. These are the following materials: synthetic and non-absorbable (uncoated, coated), partly synthetic and absorbable, synthetic and absorbable, and finally biological implants.

The “oldest” group of implants that survived the initial period and has gained wide acceptance are the non-absorbable synthetic materials made of polypropylene (PP), polyester (PES) and expanded polytetrafluoroethylene (ePTFE). The most popular and most widely used material for the production of implants is polypropylene (4, 11, 12). This material has good biocompatibility. It is also stable, flexible, well-tolerated by the body and is not biodegradable. The strong fibre reaction results in the development of a substantial scar, which is sometimes the reason of discomfort or even pain felt by the patient. Polyester is less commonly used today – it is a material which is susceptible to biological degradation to some extent. From a clinical point of view, PES has properties similar to PP. You should remember that the above-mentioned materials cannot be used to fill cavities of walls characterised by full thickness due to the high risk of adhesions and intestinal fistulas (13, 14).

A new material used for the production of implants – expanded politertrafluoroetylen (ePTFE) – does not have such properties, which reduces tissue ingrowth due to its microporous structure and thus reduces the risk of adhesion formation. The microstructure of implants made of ePTFE also has some disadvantages. It prevents immune cells of the host from entering the area, which sometimes favours the development of infection. Systemic antibiotic therapy also does not prevent the infection of implant in clinical conditions as drugs do not penetrate the biofilm produced by bacteria on their surface. One example of such a material is Dualmesh – a soft mesh which has two surfaces: a smooth one from the intra-abdominal side and a textured one which allows the ingrowth into the abdomen (fig. 1).

Currently, ePTFE implants impregnated with bacteriostatic agents (silver and chlorhexidine) are available on the market, which can reduce the incidence of bacterial colonization and the subsequent infections (e.g. Dualmesh Plus). Numerous publications document the efficacy of these materials (12, 15-18).

A significant increase in the use of implants in the surgical treatment of groin and abdominal hernias resulted in significant commercial interest in this segment of the market. This has led to the formation of many varieties of the three basic materials and products which are a combination of different types of meshes. System meshes consisting of several pieces (planes) have been created. A PHS/UHS (Prolene Hernia System/UltiPro Hernia System) implant consists of a flat circular mesh insertable into the preperitoneal space, a connecting part inside the deep inguinal ring and a flat spindle mesh insertable into the inguinal canal (fig. 2). Another type of implant is used during the mesh-plug method, in which a conical mesh plug seals the inguinal ring, and a flat mesh is placed in the inguinal canal (fig. 3). It is worth noting that the use of this type of implant system is designed to simplify the open method operation and improves treatment outcomes, but the exploration of both spaces (the preperitoneal space and the inguinal canal) complicates the procedure in the event of a recurrence (19, 20).

Fig. 1. Synthetic implant made from ePTFE (Dualmesh)
The development of laparoscopic techniques and studies on bioactivity of the meshes in the tissues and the role of inflammatory response in the process of implant healing resulted in the creation of implants that can be placed securely from the intraperitoneal side. One way to reduce the inflammatory response of the recipient, thereby reducing the risk of adhesion formation, is to coat polypropylene or polyester materials using various substances such as silicone, collagen, oxidized regenerated cellulose (e.g. Surgimesh XB, Parietex, Proceed) (tab. 1). Some companies offer even more technologically advanced implants designed to be stiff in the early stages and to gain flexibility after the loss of some components (e.g. monocryl and PDS in the case of Physiomesh) or to be initially flexible and to stiffen in time along with the migration of connective tissue (e.g. Ventralight ST or Parietex Composite). Attempts have also been made to cover the implants with omega-3 acids from fish oil or beta-glycan (10, 11, 21, 22, 23). It seems that an implant impregnated with antimicrobial substances which allow the ingrowth of fibrous tissue in an organised manner on one side and show non-stick properties on the other side would constitute an also perfect material for the reconstruction of the layers of the abdominal wall. The incorporation of genes into the implant that promote or regulate the inflammatory response as well as the synthesis and metabolism of collagen will theoretically speaking improve the characteristics of the products available.

Another type of implants – implants partially absorbable – are a group of products consisting of two types of materials – unabsorbable (PP or PES) and absorbable (i.e. polyglactin, poliaic acid as in the Progrip implant or monocryl in the UltraPro implant). After the absorption (which usually takes 90–120 days), the main mass of the product is reduced, it becomes more flexible and the scar is not as “hard”. Today, when the use of synthetic meshes is the “gold standard” in the plastic surgery of inguinal hernia, these materials are perfectly suitable for this type of operation. In addition, the use of PLA hooks in the production of the Progrip mesh makes the implant fix itself, which significantly shortens the time of surgery and reduces long-term incidence of chronic pain (24).

<table>
<thead>
<tr>
<th>Synthetic material type</th>
<th>Product name</th>
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<tbody>
<tr>
<td>Polypropylene (PP)</td>
<td>Marlex, Prolene, Surgimesh, Ultrapro, Parietene Light</td>
</tr>
<tr>
<td>Polyester (PES)</td>
<td>Mersilene, Parietex Mono</td>
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<tr>
<td>ePTFE</td>
<td>Dualmesh, Mycemesh</td>
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<tr>
<td>PP + collagen</td>
<td>Parietene Composite</td>
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<tr>
<td>PES + collagen</td>
<td>Parietene Composite</td>
</tr>
<tr>
<td>PP + silicon</td>
<td>Surgimesh XB</td>
</tr>
<tr>
<td>PES + silicon</td>
<td>Intramesh W3</td>
</tr>
<tr>
<td>PP + PDS + oxidised regen cellulose (ORC)</td>
<td>Proceed</td>
</tr>
<tr>
<td>PP + polyvinylidene fluoride (PVDF)</td>
<td>Dynamesh</td>
</tr>
<tr>
<td>PP + propylene glycol + gel</td>
<td>Adhesix coating of polyvinlypyrrolidone (PVP)</td>
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<tr>
<td>monocry + PDS + PP + monocryl</td>
<td>Physiomesh</td>
</tr>
<tr>
<td>PP + PGA + hydrogel</td>
<td>Ventralight ST</td>
</tr>
<tr>
<td>PP + ePTFE</td>
<td>Composix, Intramesh T1</td>
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The idea of the creators of absorbable implants is to invent materials which provide sufficient mechanical performance in the early postoperative period and stimulate the host to produce natural structures in the operated area before they are absorbed. Manufactured from polyglactin or polyglycolic acid (e.g. Safil Mesh), they are well-tolerated by the host organism, stimulate fibroblasts and minimise the risk of infection. It turned out, however, that their use is associated with a high risk of relapse – comparable to that after the supply of the hernia without an implant (18, 22, 25).

Construction of synthetic implants

In the nineties of the twentieth century, Parviz Amid divided meshes into four groups according to mesh size. The modern division includes microporous meshes (<100 µm), small meshes (100 – 600 µm), large meshes (1000 – 2000 µm) and very large meshes (mesh diameter > 2000 µm) (26). Another division of the meshes is according to their density: light (<35 g/m²), medium (35 g/m² to 80-90 g/m²) and heavy (> 80-90 g/m²) (27, 28). A better understanding of the biomechanics of the abdominal wall and the impact which the presence of a synthetic implant exerts on it led to the commonly believed idea that “less is better”. A mesh with lower density, which is lighter and has a larger mesh (i.e. macropore mesh) heals better, provides better flexibility of the coating, inflicts pain, and the scar formed is flexible and shrinks only slightly, in approx. 5%. Unlike close-woven meshes with large weight (>100 g/m²) that form a compacted scar during the overgrowth with tissue which makes the implant shrink and reduces its surface by up to 20-30%. After the initial period of excitement with the “light” macroporous implants, reports of an alarming proportion of recurrent hernias after using these products appeared. Reports of the Polish Hernia Study Group proved that the appropriate, slightly modified way of suturing lightweight synthetic implants during surgery using the Lichtenstein method is characterized by a recurrence rate of not more than 3% (10, 29, 30). Implantation of light meshes is still recommended by EHS in the highest class of recommendations (31).

One should also pay attention to the structure of the fibre which is used to weave the implant. This structure can be mono-, di- or multifilament. The size of the sinuses in multifilament implants constitutes a barrier for immune system cells and not for bacteria, which increases the risk of contamination. Currently, most implants are manufactured from monofilament fibre.

Biological materials

The use of modern synthetic materials in order to improve the results of treatment of hernia does not make all the difficult clinical problems disappear, especially in the reconstruction of the abdominal walls in contaminated conditions or infection of the surgical field. The desire to overcome this problem led to the development of biological materials that would be suitable for use in adverse clinical trials. One of the first products of this type are materials made from porcine small intestine submucosa (SIS), the human skin acquired from corpses (AlloDerm) or slightly newer implants made from dermal porcine collagen (Permacol) (fig. 4) or making use of bovine pericardium (Periguard) (fig. 5) (tab. 2). All of these materials are processed in order to obtain a cell-free collagen matrix which initially retains its tensile strength while allowing angiogenesis and tissue ingrowth of the host, which leads to the formation of a new biocompatible fascia consisting of collagen and the recipient’s own tissues (7, 32-37). Given the goal that guided the creation of this type of product, recent reports are at least worrisome.
10-year-long experiences using the Permacol matrix in a contaminated environment have been published and the authors noted an unacceptably high recurrence rate. Similarly, when comparing the use of AlloDerm and FlexHD matrices, a recurrence rate was noted which reached 30 and 100%, respectively (10, 38, 39). Apart from the high price, it seems that the widespread use of biological materials in hernioplasty will not take place within the next dozen years or so. The lack of specific assessment of use, especially in terms of the latest biological implants, should encourage operators to perform balanced and critical qualification oh these implants in specific clinical situations.

Summary

The repair of hernia, especially abdominal postoperative hernia, is one of the most underrated, undervalued and unpopular treatments of modern surgery. Thanks to the rapid development of new technologies, the implants available – albeit imperfect – are safe, easy to use materials which help shorten the duration of operation. The decision on the selection of material for the closure of hernia is affected by the subjective feelings of the operator in terms of the comfort to manipulate the implant and fix it during surgery, as well as its availability. A considerable limitation of the use of modern implants is their price, which – given today’s reimbursement system of hernia repair procedures – makes them completely unprofitable.

The “ideal” material to supply hernias has been sought since the times of Billorth. In order to make a step ahead, we should improve the biomaterials used in surgery based on further research in terms of the parameters applied for the construction of implants and the body reaction. Still, a prudent surgeon should remember that even the most advanced implant cannot replace in-depth knowledge about the anatomical causes and the pathomechanism of hernia formation or the eternal principles of the surgery art.

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