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Lichtenstein tension-free hernioplasty: Its inception, evolution, and principles

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Parviz K. Amid was born in Iran and graduated from Tehran University School of Medicine in 1965. After his military service (1965–1967), he completed his surgical training at Mount Sinai Hospital of Detroit, Mich., USA (a Wayne State University and University of Michigan-affiliated hospital) in 1972. Subsequent to that, he was engaged in the private practice of general surgery at Mount Sinai and William Bowmen Hospital in Detroit, Mich., until 1981, when he moved to California. In California, after a short period of general surgery practice, in the mid 1980s, he joined Dr. Irving Lichtenstein and Dr. Alex Shulman in founding the Lichtenstein Hernia Institute and limited his practice exclusively to the field of abdominal wall hernia surgery. In the late 1980s and early 1990s, he conducted and successfully completed two research projects to circumvent the problem of adhesion of the intestine to the mesh for the repair of incisional hernias and (b) proving shrinkage of mesh after its implantation in vivo. In 1998, he was awarded a fellowship to the Royal College of Surgeons of England. His works have been published in more than 150 articles (translated into several languages) and book chapters, including the fourth and fifth editions of Nyhus and Condon's *Hernia Book and Mastery of Surgery*. He has given lectures and live-surgery demonstrations across the United States and Europe and in numerous other countries around the globe. In addition, along with his surgical career, he pursued his lifelong interest in philosophy by taking university courses in ontology, astronomy, and philosophy of science, mathematic, and physics (from Greek to Quanton). His most valued honors are several lecturing assignments in the general session of the American College of Surgeons meetings, several video presentations of the tension-free hernioplasty (inguinal and ventral) during the Cine-Clinic and Film Festival of the American College of Surgeons meetings (videotapes are available through the educational archive of the American College of Surgeons), awarded Fellowship to the royal college of England, being a founding member of the American Hernia Society, and receiving a medal of honor from the University of Padua, the home of the father of hernia surgery, Eduardo Bassini.

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Abstract To circumvent the degenerative nature of inguinal hernias and adverse effect of suture line tension, the Lichtenstein tension-free hernioplasty began in 1984 and evolved (between 1984 and 1988) to a procedure that is now considered the gold standard of hernia repair by the American College of Surgeons. The objective of this paper is to outline the reasons behind the minor changes made during the short, 4-year evolution of the technique, describe the key principles of the operation, and introduce a new mesh that, if elected to be used,

automatically satisfies all the key principles of the procedure and guides the surgeon to perform the operation correctly. The worldwide reported result of the operation by experts and nonexperts alike is a recurrence and complication rate of less than 1%. When the key principles of the procedure, which, as reported by many authors, are easy to learn, perform, and teach, are respected, the operation results in an effectiveness (external validation) that is virtually the same as its efficacy (results of the experts), attesting to the simplicity of the procedure.

Keywords Lichtenstein tension-free hernia repair · Meshoma · Biomaterial classification · Mesh shrinkage · Radical prostatectomy after preperitoneal inguinal hernia mesh repair

Introduction

Today, understanding the role of impaired collagen metabolism in the pathogenesis of groin hernias has lead to a new grasp of the pathology of groin hernias and the causes of their surgical failure [1, 2]. These changes lead to weakening of the fibroconnective tissue of the groin and development of inguinal hernias. To use this already defective tissue, especially under tension, is a violation of the most basic principles of surgery.

This type of thinking inspired investigators to develop a host of prosthetic materials. Many were associated with disastrous complications related to rejection and infection. Usher is credited with popularizing the use of polypropylene mesh, which has been in use since the mid-1950s with a negligible complication rate.

In 1984, the metabolic nature of inguinal hernia and adverse effect of suture line tension prompted our group to popularize routine use of mesh, coining the term ''tension-free'' hernioplasty [3].

In 1989, Nyhus removed the fear of infection and rejection when he stated, ''My concerns relative to the potentially increased incidence of infection or rejection of the polypropylene mesh have not been warranted to date'' [4].

In the tension-free hernioplasty, instead of forcefully suturing anatomical structures that are not normally in apposition, the entire inguinal floor is reinforced by insertion of a sheet of mesh. The prosthesis, which is placed between the inguinal floor and the external oblique aponeurosis, extends well beyond the Hesselbach's triangle in order to provide sufficient mesh-tissue overlap. Upon increased intra-abdominal pressure with straining, contraction of the external oblique applies counterpressure on the mesh, thus using the intra-abdominal pressure in favor of the repair. The procedure is both therapeutic and prophylactic in that it protects the entire susceptible region of the groin from herniation due to future mechanical and metabolic adverse effects.

Evolution of the tension-free hernia repair from 1984–1988

Lichtenstein tension-free hernioplasty began in 1984. In the late 1980s, analyzing data from our own hernia registry, published in 1987 [5], we identified the following flaws (Fig. 1):

1. The mesh was not extended beyond the pubic tubercle to overlap the pubic bone.
2. The mesh was too narrow (only 5 cm) to provide enough mesh tissue contact above the inguinal floor.

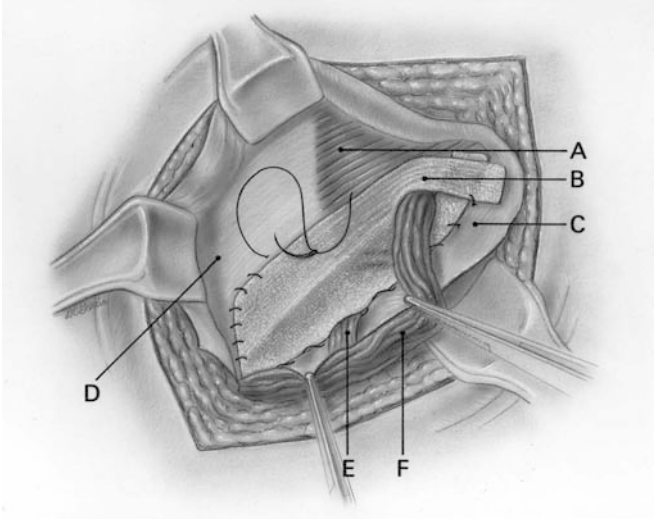

Fig. 1 Illustration of the tension-free procedure from our preliminary report of 1996 and before its modification in 1998: A—internal oblique muscle, B—polypropylene mesh, C—inguinal ligament, D—internal oblique aponeurosis, E—Lesser cord containing the genital nerve, F—spermatic cord

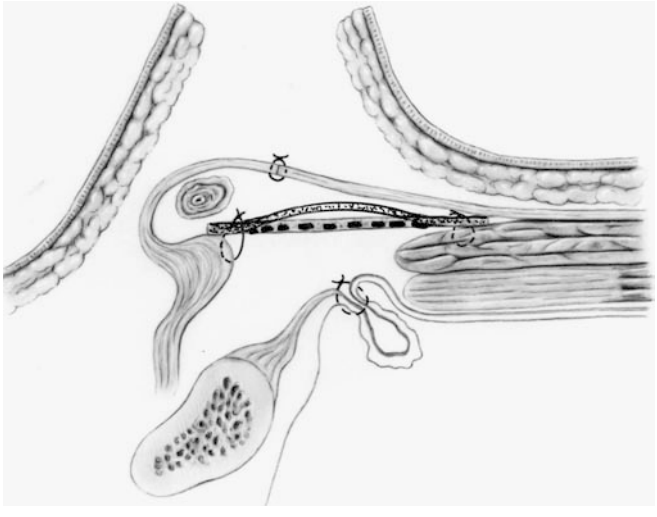

Fig. 2 Cross section of the tension-free repair demonstrating an inverted direct hernia sac and the dome-shaped laxity of the mesh versus a completely flat mesh (*dotted line*)

3. The mesh was kept flat (Fig. 2, *broken line*), and, therefore, was subject to tension when the patient stood up from the supine position of the operation.
4. The upper edge of the mesh was fixed using a continuous suture, which potentially left the iliohypogastric nerve at risk.
5. Passing the genital nerve and external spermatic vessel through a gap along the suture line of the mesh with inguinal ligament exposed the nerve to potential risk of entrapment.

In 1989, to correct the above said problems, a set of principles (outlined below) was established by our group, employed with satisfactory results, and reported in 1993 [6]. In the same year, in another publication [7], we introduced the standard shape and size (7×16 cm) of the mesh for our procedure. The standard shape, which resembles the tracing of a footprint, has remained the same since its introduction in 1993 and is used in 95% of cases, regardless of the size of the hernia, much the same as the standard shape and size of the mesh in laparoscopic hernia repair. The medial end of the mesh has a sharp curve (on the great toe side of the foot), which fits in the angle between the inguinal ligament and the anterior rectus sheath and a wider curve (on the little toe side of the foot), which spreads over the rectus sheath.

The key principles of the standard Lichtenstein tension-free hernioplasty

As the name implies, the main goal of the tension-free hernioplasty is achieving a repair that is free of all tension, not only on the operating table, where the patient is in a supine position but also postoperatively despite adverse effects, such as the intra-abdominal pressure gradient and contraction of the mesh.

Intra-abdominal pressure gradient

Drye's study of intra-abdominal pressure [8] demonstrated a mean pressure of 8 cm H_2O with the subject supine. When the subject was standing, intra-abdominal pressure in the pelvic area increased to 12 cm H_2O. Various activities, such as straining and vomiting, increased pressure to more than 80 cm H_2O. Increased intra-abdominal pressure causes forward protrusion of the lower abdominal wall, particularly the transversalis fascia. If the repair is to be completely tension-free, then forward protrusion of the transversalis fascia must be addressed.

Mesh shrinkage

Mesh contraction must also be considered during tension-free hernia repair. According to our laboratory and clinical studies reported in 1996 [9], the mesh shrinks by approximately 20% in both directions after implantation, a conclusion confirmed by Klinge et al. in 1998 [10]. In order to circumvent the adverse effects of increased intra-abdominal pressure and shrinkage of mesh, the following key principles have been integral parts of our operation since 1988:

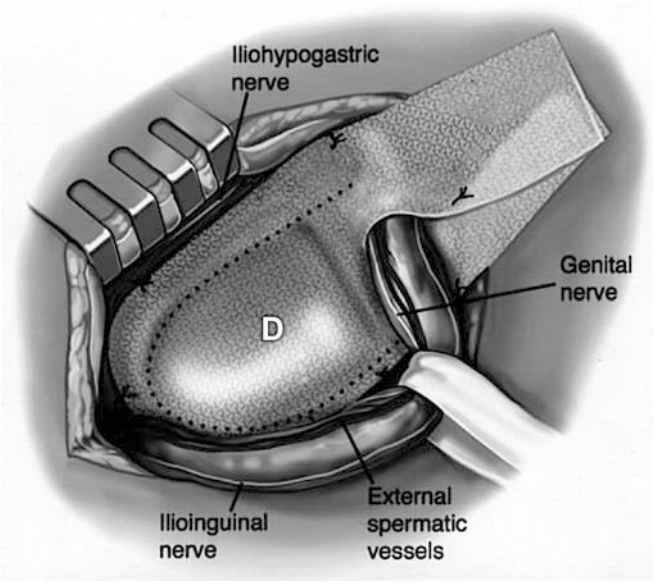

Fig. 3 Extension of the mesh beyond the boundary of the inguinal floor (*dotted line*) and the dome-shaped center of the mesh (D)

1. Use a large sheet of mesh (with the above described standard size and shape) that will extend approximately 2 cm medial to the pubic tubercle, 3–4 cm above the Hesselbach's triangle, and 5–6 cm lateral to the internal ring (Fig. 3). We suggest using a 7×15 cm sheet of mesh for easy handling, then trimming 3–4 cm from its lateral side.
2. Cross the tails of the mesh behind the spermatic cord to avoid recurrence lateral to the internal ring (Fig. 3). Suturing the tails together in a parallel position, without crossing, is a known cause of recurrence in the internal ring area.
3. Secure the mesh with two interrupted sutures on the upper edge and one continuous suture with no more than three to four passes on the lower edge of the mesh to prevent folding and movement of the mesh in the mobile area of the groin (Fig. 3). Fixation of the mesh prevents movement, folding, and wadding of the mesh (meshoma) (Fig. 4), which can cause chronic pain and recurrence of the hernia.
4. Keep the mesh with a slightly relaxed, tented up, or dome-shaped configuration (Fig. 2, Fig. 3, Fig. 5) to counteract the forward protrusion of the transversalis fascia when the patient stands up from the intraoperative supine position, and, more importantly, to compensate for contraction of the mesh. The extra mesh of the dome has two functions: (1) Before the mesh is infiltrated by the patient's tissue, the intra-abdominal pressure is applied only on the mesh-tissue suture line.

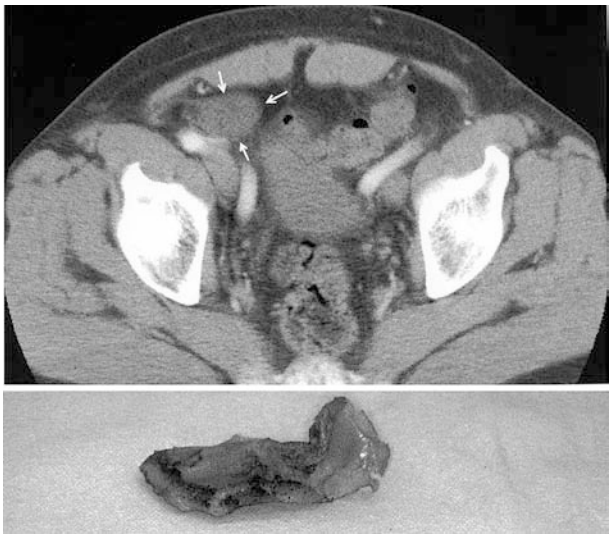

Fig. 4 CT scan image of a meshoma (*above*). The explanted meshoma (*below*)

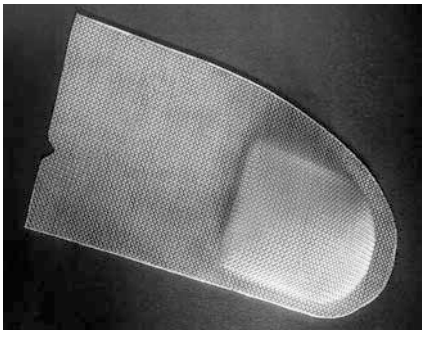

Fig. 5 A recently developed mesh with a built-in dome-shaped configuration to compensate for the increased intra-abdominal pressure upon straining and the mesh shrinkage

During this phase of the postoperative course, the extra mesh of the dome protects the repair by buffering the forward protrusion of the transversalis fascia caused by increased intra-abdominal pressure; (2) Approximately 1 month postoperatively, when the tissue has infiltrated the mesh and the implanted mesh contracts because of the scarring process, the extra mesh of the dome compensates for the contraction.

5. Identify and protect the ilioinguinal, iliohypogastric, and genital nerves throughout the operation. The iliohypogastric nerve can be identified easily, while the external oblique aponeurosis is being separated from the internal oblique layer to make room for the 7-cm-wide mesh (Fig. 3). Because of a natural anatomic cleavage, separation of these two layers from each other is easy, fast, and bloodless. The genital nerve is protected by keeping the easily visible blue external spermatic vein (the blue line) with the spermatic cord while it is being lifted from the inguinal floor (Fig. 3). Keeping the external spermatic vein with the cord protects the genital nerve, which is always next to the "blue line." Inadequate dissection and visualization of the nerves (the so-called minimal dissection) is the most common cause of nerve injuries and chronic postherniorrhaphy neuropathic pain.

A recently developed prosthesis (Davol, Cranston, R.I., USA), which features the exact shape and size of the area of the groin that should be covered and a built-in, dome-shaped laxity (Fig. 5), addresses all the key principles of the open tension-free hernia repair and, in fact, guides the surgeon to perform the operation correctly. Because the required laxity of the mesh is built in, there is no need to construct the needed laxity. In addition, if so elected, suturing the lower edges of the tails of the mesh to the inguinal ligament (as is needed when a regular flat sheet of mesh is used to tent up the mesh and contribute to its needed laxity) can be omitted. Instead, the two tails can simply be sutured together with only 0.5–1.0 cm of crossing, thus further simplifying the operation (Fig. 3).

Selection of prosthesis

Choosing the proper biomaterial has an important role in the success of the operation and requires in-depth knowledge and understanding of the physical properties of prostheses, of which, porosity and pore size of the materials are of paramount importance. Classification of available biomaterials for hernia surgery is essential for the everyday practical use of prostheses. Based on their pore size, the most frequently used materials in hernia surgery can be grouped into four types [9]:

1. Type I: Totally macroporous prostheses, such as Atrium, Bard mesh, Prolene, monofilament Surgipro, and Trilex. These prostheses contain pores larger than 75 μ, which is the required pore size for admission of fibroblasts (fibroplasia), collagen fibers, blood vessels (angiogenesis), and macrophages into the pores, which is essential for a strong repair with an insignificant rate of complications [9].
2. Type II: Totally microporous prostheses, such as expanded e-PTFE (Gore-Tex, and Dual-mesh). These prostheses contain pores that are less than 10 μ in at least one of their three dimensions. This group of prostheses, by admitting bacteria but excluding macrophages, harbors and promotes infection.
3. Type III: Microporous prostheses with multifilamentous or microporous components, such as e-PTFE mesh (Teflon), braided Dacron mesh (Mersilene), braided polypropylene mesh (multifilament Surgipro) and perforated e-PTFE patch (MycroMesh). This group, although associated with sufficient fibroplasia and angiogenesis due to their microporous component, can harbor and promote infection.
4. Type IV: Biomaterials with submicronic pore size, such as silastic, polypropylene film, Preclude Pericardial membrane, and Preclude Dura-substitute. These are not suitable prostheses for hernia repair; however, in combination with Type I biomaterials,

they can provide adhesion-free composites for intraperitoneal implantation [11].

Technique of the operation

Following is a step-by-step description of the Lichtenstein tension-free repair, as practiced by us since 1988. Local anesthesia is preferred for all reducible adult inguinal hernias [12]. It is safe, simple, effective, economical, and without the side effects of nausea, vomiting, and urinary retention. Furthermore, local anesthesia administered prior to making the incision produces a prolonged analgesic effect via inhibition of the build-up of local nociceptive molecules. Several safe and effective anesthetic agents are currently available. Our choice, however, is a 50:50 mixture of 1% lidocaine (Xylocaine, Astra Pharmaceuticals, L.P., Wayne, Pa., USA) and 0.5% bupivacaine (Marcaine, Abbott Laboratories, North Chicago, Ill., USA), with 1/200,000 epinephrine. A 5–6-cm skin incision, which starts from the pubic tubercle and extends laterally within the Langer's line, gives excellent access for extension of the mesh 2 cm or more medial to the pubic tubercle. After skin incision, the external oblique aponeurosis is opened and its lower leaf freed from the spermatic cord. The upper leaf of the external oblique is then freed from the underlying internal oblique muscle and aponeurosis for a distance of 3–4 cm above the inguinal floor. The anatomic cleavage between these two layers is avascular, and the dissection can be done rapidly and non-traumatically. High separation of these layers has a dual benefit, as it visualizes the iliohypogastric nerve (Fig. 3) and creates ample space for insertion of a sufficiently wide sheet of mesh that can overlap the internal oblique by 3–4 cm above the upper margin of the inguinal floor. The cord with its cremaster covering is separated from the floor of the inguinal canal and the pubic bone for a distance of about 2 cm beyond the pubic tubercle.

The anatomic plane between the cremasteric sheath and the attachment of the rectus sheath to the pubic bone is avascular, so there is no risk of damaging the testicular blood flow. When lifting the cord, care should be taken to include the ilioinguinal nerve, external spermatic vessels, and the genital nerve with the cord. This assures that the genital nerve, which is always in juxtaposition to the external spermatic vessels, is preserved (Fig. 3). I have found this method of preserving the genital nerve safer and easier than the originally described "lesser cord" (Fig. 1) method [a method in which the genital nerve and external spermatic vessels are separated from the cord in the form of a bundle referred to as "lesser cord" and passed through a gap along the suture line of the mesh with the inguinal ligament (Fig. 1)]. The iliohypogastric nerves should also be identified and protected particularly by not suturing the prosthesis to the internal oblique muscle to avoid injury to the intramuscular part of the nerve.

To explore the internal ring for indirect hernia sacs, the cremasteric sheath is incised longitudinally at the deep ring. Complete stripping and excision of the cremasteric fibers is unnecessary and can result in injury to the nerves, small blood vessels, and vas deferens. Furthermore, it can lead to the testicle hanging too low.

Indirect hernial sacs are freed from the cord to a point beyond the neck of the sac and inverted without ligation. Due to mechanical pressure and ischemic changes, ligation of the highly innervated peritoneal sac is a major cause of postoperative pain [13]. To minimize the risk of postoperative ischemic orchitis, complete nonsliding scrotal hernia sacs are transected at the midpoint of the canal, leaving the distal section in place. However, the anterior wall of the distal sac is incised to prevent postoperative hydrocele formation.

In the event of direct hernias, if large, the sacs are inverted with an absorbable suture (Fig. 2). A thorough exploration of the groin is necessary to rule out the coexisting intraparietal (interstitial), low-lying spigelian or femoral hernias. The femoral ring is routinely evaluated via Bogros' space through a small opening in the canal floor. A 7×16-cm sheet of mesh is used. We prefer monofilamented polypropylene meshes because their surface texture promotes fibroplasia and their monofilamented structure does not perpetuate or harbor infection [9]. With the cord retracted cephalad, the lower medial corner of the mesh is placed over and extended medial to the pubic tubercle, overlapping the pubic tubercle by 1.5–2.0 cm. Extension of the mesh medial to the pubic tubercle, which is a critical step of the operation, is easy to achieve and only requires starting the skin incision from the pubic tubercle (for easy access to the pubic tubercle) and separation of the spermatic cord and lateral crus of the external ring from the rectus sheath. The medial corner of the mesh is then sutured to the rectus sheath above the pubic bone, carefully avoiding the periosteum of the bone. This suture is continued (as a continuous suture) to attach the lower edge of the mesh to the inguinal ligament up to a point just lateral to the internal ring. Suturing the mesh beyond this point is unnecessary and could injure the femoral nerve. If there is a concurrent femoral hernia, the mesh is tailored to have a triangular extension from its lower edge (Fig. 6). The edge

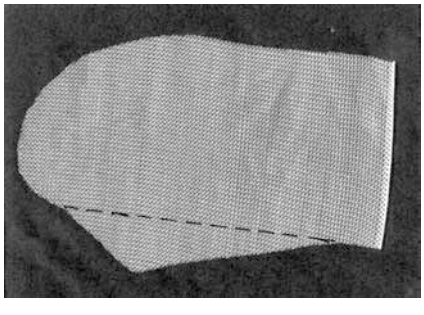

Fig. 6 Shape of the mesh for the repair of inguinofemoral and isolated femoral hernias. The long side of the triangular extension of the mesh is sutured to the Cooper's ligament, and the body of the mesh is sutured to the inguinal ligament along the *broken line*

of the dropped down triangle is then sutured to the Cooper's ligament (after opening the posterior wall, reducing the femoral hernia and exposing the Cooper's ligament) and the body of the mesh is sutured to the inguinal ligament along the dotted line (Fig. 6).

A slit is made at the lateral end of the mesh, creating two tails, a wide one (two-thirds) above and a narrower (one-third) below. The upper wide tail is grasped with a hemostat and passed toward the head of the patient from underneath the spermatic cord; this positions the cord between the two tails of the mesh (Fig. 3).

With the cord retracted downward and the upper leaf of the external oblique aponeurosis retracted upward, the upper edge of the patch is sutured in place with two interrupted absorbable sutures, one to the rectus sheath and the other to the internal oblique aponeurosis, just lateral to the internal ring (Fig. 3). It is important to avoid passing sutures through the internal oblique muscle (regardless of tissue, mesh, or plug repair) in order to avoid entrapment of the intramuscular part of the iliohypogastric nerve. While the mesh is fixed in place, it is critically important to give the mesh a dome-shaped laxity (Fig. 2, Fig. 3, Fig. 5). With the new mesh (Fig. 5), which has a built-in dome shape, this step of the operation is automatically achieved. This laxity assures a true tension-free repair despite the increased intra-abdominal pressure upon resuming an upright position and straining. Its importance can be appreciated even during the operation, when the patient is asked to strain while on the operative table. More importantly, it compensates for the future contraction of mesh.

Using a single nonabsorbable monofilamented suture, the lower edges of each of the two tails are fixed to the inguinal ligament just lateral to the completion knot of the lower running suture (if the new mesh is used, this part can be simplified by only suturing the two crossed tails together). This creates a new internal ring made of mesh.

The excess patch on the lateral side is trimmed, leaving at least 5 cm of mesh lateral to the internal ring. This is tucked underneath the external oblique aponeurosis, which is then closed over the cord with an absorbable suture. Fixation of the tails of the mesh to the internal oblique muscle, lateral to the internal ring, is unnecessary and could result in entrapment of the ilioinguinal nerve with the fixation suture.

Technical considerations

1. Medial extension of the mesh beyond the pubic tubercle and the dome-shaped laxity of the mesh (also referred to as ripple, sagitation, tenting, or buckling in our other publications), which have been an integral part of the operation since the late 1980s, are crucially important. A mesh that is completely flat (as shown with the *broken line* in Fig. 2), with no laxity in a patient under sedation and in supine position will be subject to tension when the patient stands or strains and particularly after shrinkage of the mesh. These refinements, which have been deployed by us in more than 6,000 patients (including large direct and femoral hernias) and by thousands of other surgeons around the globe, have virtually eradicated the pubic tubercle recurrence and recurrence above or below the mesh.
2. Although a sound concept, mesh placement underneath the transversalis fascia in the preperitoneal space (via open or laparoscopic approach) requires unnecessary dissection of this highly complex anatomical space and leads to obliteration of the spaces of Retzius and Bogros. This problem has led to a growing concern by urologists and vascular surgeons because of severe adherence of the mesh to the iliac vessels and the prostate area, rendering subsequent urological and vascular surgeries, particularly radical prostatectomy and lymph node dissection extremely risky and difficult, if not impossible [14, 15, 16]. These problems, however, can be prevented by using the same precaution taken for preventing adherence of the mesh to the intestine during laparoscopic ventral hernia repair [17, 18, 19, 20], by using composite meshes (such as Composix and Composix EX) that are made of a layer of polypropylene mesh, for achieving complete and strong tissue incorporation, coupled with a layer of nonabsorbable and tissue-impervious barrier to avoid adherence of the mesh to the adjacent iliac vessels and prostate area.
3. Proper fixation of the mesh is another important step in the prevention of recurrence. Nonfixation or poor fixation of mesh leads to wrinkling of the mesh, which can continue until the entire mesh is wadded to a ball of mesh to which, elsewhere, I have referred to as "meshoma" (Fig. 4).
4. As long as the principles of the operation are not violated, when needed, the procedure is yielding to minor changes. For example, in case of a massive indirect inguinal hernia, the hernia sac can be resected or the internal ring can be tightened, or if a nerve is in the way of the repair, it can be resected with ligation and proximal end implantation [21].

Conclusion

More than 18 years after the introduction of the tension-free hernioplasty in 1984, the operation has been thoroughly evaluated in large series and has been universally accepted, and, in fact, it is considered the gold standard of hernia repairs by the American College of Surgeons [22]. The worldwide effectiveness of the operation (a recurrence and complication rate of approximately 1% in the hands of nonexperts [23]) is virtually the same as its reported efficacy (a recurrence and complication rate of 1% or less in the hands of experts) [24].

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