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NEW SYSTEM OF MESH FIXATION FOR „ONLAY HERNIA REPAIR“, BASED ON A NEW PRINCIPLE – „THE EQUALLY-DISTRIBUTED-TENSION PRINCIPLE“ – INNOVATIVE SURGICAL TECHNIQUE

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Abstract

Introduction. This article presents a new mesh fixation technique for „onlay hernia repair“, based on a new principle – the „Equally-Distributed-Tension Principle“.
Methods. The fixation technique is based on a continuous suture, different from any other continuous suture, with no stiffened points of attachment. It allows a slight glide of the thread, making possible the equally-distribution of tension. Based on this technique it is possible to realize a mesh fixation under tension. The „tension-free“ concept is not suitable for ventral hernias. The mesh should be sutured under tension – the only way to remove the tension from the midline suture and offer the posibility for the aponeurotic layer to heal and regain its strenght. A new fixation system is necessary, a more efficient one, that will sustain this tension, without failure. In the same time, this system is the only one capable to realize an uniform distribution of tension.
Results. Between February 2016 and November 2018, 49 patients were treated by this method in the Ilfov County Emergency Hospital, Bucharest, Romania, with only one recurrence until now (a bridging technique was used in this case).

Résumé

Nouveau système de fixation de la prothèse pour la réparation des éventrations et hernies de la paroi abdominale par la méthode „onlay“, basée sur un nouveau principe – le „principe de la Tension-Egalement-Répartie“ – technique chirurgicale innovatrice

Introduction. Cet article présente une nouvelle technique de fixation de la prothèse pour la réparation des éventrations et hernies de la paroi abdominale par la méthode „onlay“, basée sur un nouveau principe – le „principe de la Tension-Egalement-Répartie“.
Méthode. La technique de fixation est basée sur une suture surjet, différente de tout autre surjet, sans points d'attache bloqués. Il permet un léger glissement du fil, rendant possible la distribution égale de la tension. Avec cette technique, il est possible de réaliser une fixation de la prothèse en tension. Le concept „tension-free“ (sans tension) ne convient pas aux éventrations et hernies de la paroi abdominale antérieure. La prothèse doit être suturée en tension – le seul moyen de supprimer la tension de la suture médiane et d'offrir la possibilité au plan aponévrotique de guérir et de rétablir sa résistance. Mais pour ça, il

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Conclusions. The new suture system is very easy to apply, very fast, extremely reliable and offers the posibility to manage a large variety of ventral hernias.

Keywords: continuous thread fixation, transversal loops threads.

est nécessaire un nouveau système de fixation, plus efficace, pour maintenir cette tension sans défaillance. Dans le même temps, ce système est le seul capable de réaliser une distribution uniforme de la tension.
Résultats. Entre février 2016 et novembre 2018, 49 patients ont été traités par cette méthode dans l'Hôpital d'Urgence, Ilfov, Bucarest, Roumanie, avec une seule récidive jusqu'à présent (une technique "en pont" a été utilisée dans ce cas).
Conclusions. Le nouveau système de suture est très facile à appliquer, très rapide, extrêmement fiable et offre la possibilité de gérer une grande variété d'éventrations et hernies ventrales.

Mots-clés: fixation de prothèse de type surjet, boucles transversales.

Introduction

Abdominal wall hernia is a very common general surgical condition and implies high socioeconomic costs and impairment of the quality of life[1].

Hernia repair is one of the most frequently used surgical procedures, but despite the important progress made lately, the results remain behind the general expectation.

The recurrence rate following a seemingly successful incisional hernia repair is between 10 and 60%[2].

An expert review in 2001 concluded that the results of the onlay technique and sublay technique were similar regarding recurrence rates and percentage of wound healing complications[3].

In the last 20 years, retro-muscular mesh placement has become the standard of care for ventral hernias, due especially on historical grounds – the popularization of Rives repair[4] in the USA.

In spite of lower recurrence rates advocated for sublay repair, the recurrence rates for onlay repair reported by different authors are similar:

- Chevrel – 4.9%[5];
- Kingsnorth – 3.4%[6];
- Köckerling – 9.9% (mean value for the recurrence rate in a meta-analysis)[7];
- Cano-Valderrama – 4.2%[8]
- Venclauskas – 11%[9].

The advantages of onlay hernia repair are:

- the simplest and fastest technique;
- no contact of mesh with viscera;
- mesh preservation in case of infection;
- possibility to easy perform subsequent surgery.

Today there is no consensus on the ideal location for mesh positioning[10], mesh type[11] and operation method.

Material and methods

We propose a new system of mesh fixation for „onlay mesh hernia repair", based on a new principle – „the Equally-Distributed-Tension Principle". This is a personal series of 49 patients treated by this method. In 24 cases, a midline closure was not possible – the bridging technique was used. No preoperative optimization plan was used, no weight-loss program was utilized for obese patients and no smoking cessation was imposed.

Technique Description

After incision, limited lateral lipo-cutaneous flaps are raised, the hernial sac is completely dissected and opened, adhesions are lysed and the hernia defect is delineated. A running, monofilament, slowly resorbable suture is used to close the midline (if possible) and macro porous, light weight, very flexible, polypropylene mesh is used in the onlay method.

Fixation is realized by two concentric rows of nonabsorbable polypropylene no. 0 continuous suture:

- if a midline aponeurotic closure is possible, the first row is placed at 0.5 cm from the closure line, on each side – this suture is realized under *moderate* tension – and the second row at 1-2 cm from the first row – *minimal* tensioning on the second- row suture;
- if a midline aponeurotic closure is not possible, the first row is placed on the edge of the parietal defect (0.3- 0.5 cm from the edge) – this suture is realized under *moderate* tension – and the second row at 1-2 cm from the first row – *minimal* tensioning on the second- row suture;
- the mesh extends 2 cm beyond the second row, which reduces the overlap of the midline closure to 4-4.5 cm, decreasing the extent of subcutaneous dissection.

The new technique uses a different type of continuous suture – a suture that follows the edges of the parietal defect, parallel with these edges (or midline closure line), biting alternately the mesh and the tissue „in direct line", without returns and loops perpendicular to the parietal defect line, like in classical continuous suture. The suture is similar, in some way, with the purse-string suture used for Stamm gastrostomy.

This particular pattern makes possible an easy glide of the thread through tissues and mesh, allowing the redistribution of tension at the attachment points, with tension equalization (Fig. 1).

Suture starts from one point, advancing by 1 cm bytes on the aponeurotic layer (large bytes decrease the possibility of aponeurotic tearing, by increasing the surface of tissue on which the force is exerted) and 1 cm bytes on the mesh. The suture runs around the parietal defect and comes back to the initial point, where the mesh fixation is completed by tying the two ends of the thread, without any fixation to tissues. During the suture process, the assistant will manage to keep the mesh stretched.

The surgeon will apply moderate force tensioning when tightening the knot. This is very important because the squeezing will straiten and determine a small contraction of the central area, enough to relieve the tension from the midline suture.

This is a major difference from other techniques – the mesh sutured under tension to relieve the tension from the midline musculoaponeurotic suture (Fig. 2).

There is no point where the thread is anchored to tissue by a knot. The suture thread can glide through the tissues and mesh, after fixation, allowing short displacements of the mesh (the glide potential is evident when pulling the two ends of the thread). This enables the uniform distribution of tension from thread and mesh to tissues, during body position changes and muscles contractions, until the final equilibrium is obtained (ideal position of mesh and thread). The whole tension from the central area is distributed uniformly to the lateral areas of the mesh and fascia. This is another major difference in mesh-fixation – the uniform distribution of tension to tissue (fascia) (Fig. 3).

The equally distributed tension method is completed, for large ventral hernias, when a midline musculoaponeurotic suture is not possible, by a series of transversal loops (1-3 loops, depending on the longitudinal length of the mesh), with the suture thread passed only through the mesh and not the underlying tissue (no bytes on the underlying tissue). The tissues are left untouched under the mesh (otherwise the thread will tear the tissue postoperatively and the mesh will be exposed to intraperitoneal content) (Fig. 4).

The final tensioning of the abdominal wall, in the transversal direction, is obtained by transversal loop's knots tightening, done after the mesh fixation. This will:

- narrow the transversal parietal opening by folding the mesh,
- reduce the distance between musculoaponeurotic edges,
- increase the stiffness of the mesh in the respective areas, preventing it to bulge and offering a stronger support (some similarities with the transversal tendinous bands/tendinous intersections of the rectus abdominis muscle, that acts as transverse anchor points).

The surgeon can adjust the degree of mesh tensioning by adjusting the tension of knot tightening for each transversal loop, making the maneuver very versatile and adaptable for each case. The mesh must be very flexible – a macroporous, light weight polypropylene mesh, for which the plication does not affect the incorporation of the mesh (Fig. 5).

Results

Clinical experience

Between February 2016 and November 2018, 49 patients were treated by this method at Ilfov County Emergency Hospital, Bucharest, Romania.

In 24 cases, a midline closure was not possible – the onlay bridging technique was used.

1. Multisaccular ventral incisional hernia – 8 (3-10 sacs).
2. Unisaccular ventral incisional hernia – 23.
3. Free evisceration, acute parietal infection – 3.
4. Umbilical hernia with colon perforation and abscess in the hernial sac – 1.
5. Double hernia: umbilical and supraumbilical – 2.
6. Umbilical hernia – 6.
7. Right subcostal incisional hernia – 2.
8. Iliac fossa incisional hernia – 4.

Three special cases – due to postoperative parietal infection, a free evisceration occurred (total wound dehiscence with exteriorization of bowel loops). In one case, two injuries of the small bowel (the parietal suture thread used after an oncologic surgical intervention did cut the bowel during wound dehiscence) led to fecal peritonitis.

We practiced viscerolysis, excision of necrotic musculoaponeurotic tissue, lavage, suture of the musculoaponeurotic plane, onlay mesh fixation by two continuous rows of polypropylene thread, placed 0.5 cm and 2 cm from the suture line and drainage of the supraaponeurotic space with drain tubes (in the

peritonitis case we first performed small bowel resection with anastomosis and peritoneal drainage). After surgery, infection persisted for about 3 weeks, after which healing occurred without any other incident. Patients were examined at 2 year – 2 patients and at 1 year – the patient with bowel fistulas, without any evidence of parietal defects.

Another interesting case – a large left flank hernia, extended beyond the midline, with important muscular atrophy (about 0.4 cm thickness of musculoaponeurotic plane) – the onlay bridging technique, with transversal loops was used; recurrence free at 1 year.

Only one recurrence until now – in the bridging group. The recurrence occurred 22 months after surgery in a patient with 3 previous recurrences, a heavy smoker with permanent chronic cough, pulmonary tuberculosis sequelae, chronic obstructive pulmonary disease and obesity. Unfortunately, a reintervention was not possible, because the patient presented with severe pulmonary disease, with FEV1/FVC=27%.

Discussion

Considerations concerning the technique

The Equally-Distributed-Tension Principle sustains the possibility of suturing the mesh under tension, in contradiction with the „tension-free principle" of mesh fixation in hernia repair. Our opinion is that „tension-free" concept is not suitable for ventral hernias.

„Tension-free" refers only to the moment of mesh fixation, because afterwards, when standing and during musculature contractions, the mesh, fixation threads and tissue fixation points are subjected to various forces and tensions, so we can't talk of „tension-free" anymore. It implies „tension-free" fixation, but unpredictable tension afterwards, with high variation in the distribution of this tension to the attachment points.

There are two distinct situations:

1. If it is posible to close the aponeurotic layer (onlay) or the posterior layer and anterior layer separately (sublay), a mesh sutured without tension will provide no support for aponeurotic structures; the mesh can not remove the stress from the midline suture.

The aponeurotic structures will suport all the tension from intraabdominal pressure variations and musculature contractions and in many cases will tear. Because it is sutured „tension-free", the mesh will sustain the tension only after aponeurotic plane dehiscence; only after this moment it will be put under tension.

Another interesting observation is that, in the sublay method, the mesh is sutured only to the anterior aponeurotic layer and the posterior layer will remain without any support from the mesh and it is this layer that will be submitted to the abdominal pressure, which makes it very susceptible to failure.

Chevrel made a similar observation long time ago: „*the posterior sheath becomes the layer which separates the prosthesis from the peritoneum and the viscera, and the first to sustain the action of the intraabdominal pressure*" with referral to the sublay repair. He goes on to conclude: „*this layer is thus weaker than the underlying prosthesis and will give way under an increase in intraabdominal pressure, risking exposing the viscera to the prosthesis.*"[5].

The solution is a change of mesh fixation principle: the mesh should be sutured under tension, so as to remove the tension from the aponeurotic midline suture and offer the posibility for the aponeurotic layer to heal and regain its strenght (minimum 30 days).

Also, a new fixation system is necessary, a more efficient one, that will sustain this tension, without failure. Mesh fixation under tension was not possible until now because of the fixation system used, which could not sustain the tension and leaded to recurrences by tissue tearing and desinsertion of the mesh.

2. In the case of a large hernia, when it is not possible to realise a midline aponeurotic suture (even with separation of components) a „tension-free" mesh will not bring back the aponeurotic structures toward the midline, to restore the phisiology of the abdominal wall – the edges of the parietal defect will remain in the same position after the „tension-free" mesh fixation as they were before the mesh application (the „tension-free" concept).

Because the fixation points are situated much laterally, both onlay and sublay „tension-free" methods will lead to ventral bulge of the mesh with exteriorization of abdominal content outside the abdominal contour, causing static problems, vertebral column strain and in some cases respiratory dysfunctions.

Bulging is also an important issue in laparoscopic repair of large hernias[12]. Kurmann reported abdominal bulging in 56% of cases[13]. Fascia closure can reduce bulging[14,15], but is often difficult to achieve and is associated with significant tension of the sutures.

The „tension-free" technique can not provide a stable central structure for the stabilization of lateral abdominal musculature, like the physiologic structure of linea alba and hence can not prevent further muscular atrophy (a large ventral hernia represents a large desinsertion of the lateral muscular aponeurosis from the central complex; the fibers lack a central fixation point for their contraction, leading to atrophy).

Also postoperatively, the muscular contractions will exert huge stress mainly on some fixation points, leading to tissue tearing and mesh desinsertion; the

pattern of tension distibution is unevenly and impossible to predict.

When the body position changes, there is a change in the pattern of forces exerted by the musculature on the mesh, which leads, in the interrupted suture technique, to a reduction of stress on some attachment points, but also to an increase of the stress on others points, which favors the tearing of tissue at this level and the hernia recurrence.

The classic running suture, with loops perpendicular to the musculoaponeurotic edges, is similar enough to the interrupted one, because the thread cannot glide through the tissue due to the direction of loops and length of the thread; the thread is stiffened up in many areas.

With the new fixation system, the relative movement of the thread in relation to the mesh allows the equalization of forces exerted on fixation points, providing an „equally-distributed-tension" on mesh and tissues.

In interrupted suture the tissue fragments caught and squeezed by the knots, will eventually tear under the tension exerted by the mesh. Novitsky noted: „the problem with mechanical fixation is that one relies on inherent tissue strength to support the mechanical anchoring"[2].

A possible way to reduce recurrence rate is by minimizing the forces exerted on tissues at the points of mesh attachment. The thread tension is transmitted to the tissue and the parietal stress can be expressed by a pressure-type formula: the force exerted / tissue area.

A reduction of the recurrence rate can be achieved by:

- Increasing the tissue surface to which the thread tension is transferred. In interrupted suture, a very small area is subjected to the tearing forces on each attachment point. Because the knot must be tied, the byte on the tissue is small and so is the tissue surface. When tightening the knot, the tissue is compressed, which means suplemental stress. In our method, the distance between entry and exit points is about 1 cm, resulting in a much larger aponeurotic area on which the force is exerted. Also, no tissue is crushed by knots.
- Reducing the force exerted on the attachment points by increasing the number of attachment points.
- The uniform ditribution of forces (tension) from mesh to tissues – this goal is achieved by the new proposed continuous suture.

Uniform distribution of tension is impossible in classic suture, because it is impossible to establish the ideal attachment points. Every small deviation from the ideal suture point will determine a stretch of the mesh and consequently the force exerted on that attachment point will be much bigger. While other attachment points will be submitted to a lesser tension, the displaced point will hold a huge tension increase.

Another problem is determined by the fact that the suture is realized in clinostatism and in circumstances of muscular relaxation. This means that even if we could establish, during the surgical intervention, the ideal attachment points for a uniform distribution of forces to the tissues, this would be true only for clinostatism. In orthostatism, there will be an important shift of force/tension distribution, due to the change of the relative position of the parietal defect/abdominal wall/abdominal content.

In other words: we perform the surgical intervention and mesh fixation in clinostatism and muscular relaxation, but the mesh should sustain the forces and tensions exerted in orthostatism and during muscular contraction.

Novitsky made a similar observation: „*in my opinion, the appropriate tension estimated by the surgeon in the operating room with the patient supine, and under general anesthesia, is inaccurate as it does not take into account postoperative tension*"[2].

All these problems can be solved by the new technique that we propose for the mesh fixation, based on the „Equally-Distributed-Tension Principle". In this technique the thread is not immobilized, because it is not fixed in any point. This makes possible a glide of the thread and consequently a limited glide of the mesh, until the final equilibrium is obtained (ideal position of mesh), leading to equalization of forces acting on each attachment point.

Conclusions

The Equally-Distributed-Tension Principle sustains the possibility of suturing the mesh under tension, which is the only way to remove the stress from the midline suture closure.

Innovations brought by the „Equally-Distributed-Tension" system:

1. Particular pattern – two row concentric mesh-suture (purse-string-like), making possible an easy glide of the thread through tissues and mesh – the only system that allows the redistribution of tension at the attachment points, with tension equalization.
2. The inner row sutured under moderate tension will determine a small contraction of the aponeurotic central area, relieving the tension from the midline suture.
3. Large bytes on the aponeurotic layer decrease the possibility of aponeurotic tearing, by increasing the surface of tissue on which the force is exerted.

4. The transversal loops (used in onlay bridging) that narrow the transversal parietal opening, reduce the distance between musculoaponeurotic edges and increase the stiffness of the mesh in the central area, preventing it to bulge. Thanks to the equaly-distribution of tension,the mesh support is much more efficient than in the classic suture system.

Advantages of the new technique

1. Significant reduction of operating time. Such a continuous suture is much faster, reducing the time needed for mesh fixation, which can be done in 4 – 6 minutes.
2. Uniform distribution of tension along the suture thread and uniform distribution of tension to tissues. The ability to redistribute the forces exerted on tissues, during posture changes and various activities, by the equalization of tensions at the level of all attachment points, avoiding the increase of the stress in some critical attachment points. It solves the problem of mesh bulging and exteriorization of the abdominal content outside the abdominal contour for giant ventral hernias, by the system of the horizontal loops.
3. It makes possible the treatment of giant hernias by midline aponeurotic suture under tension (tension removed by the subsequently suture of the mesh under tension). While midline advancement is important, any component release process weakens the abdominal wall. In many cases the lateral abdominal musculature atrophy will lead to a very thin abdominal wall, making the separation of components impossible.
4. It is very easy to apply by any surgeon.
5. It requires less mesh overlap which implies less dissection and consequently a reduction in seroma occurrence.

Compliance with Ethics Requirements:

„The author declares no conflict of interest regarding this article“

„The authors declare that all the procedures and experiments of this study respect the ethical standards in the Helsinki Declaration of 1975, as revised in 2008(5), as well as the national law. Informed consent was obtained from all the patients included in the study“

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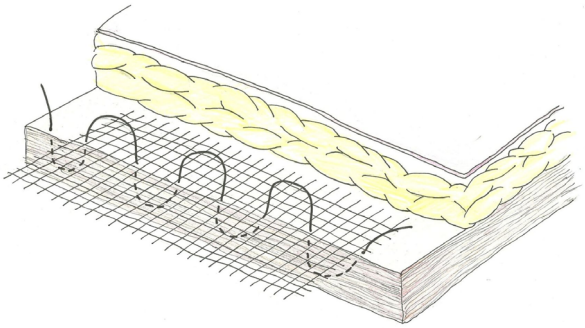

Fig.1. The continuous suture runs parallel to the edges of the parietal defect, biting alternately the mesh and the tissue „in direct line".

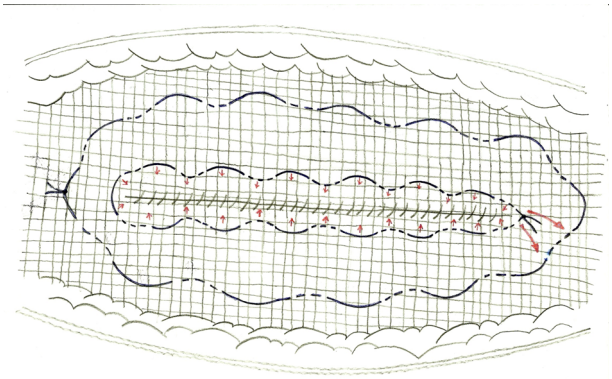

Fig. 2. Fixation is realized by two concentric rows of nonabsorbable polypropylene nr. 0 continuous suture.

Fig.3. Suture completed (two rows) – intraoperative image.

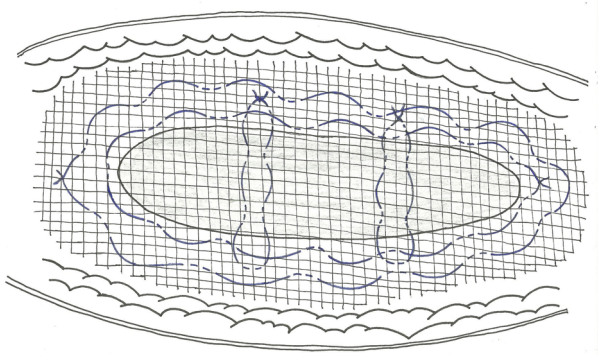

Fig. 4. Fixation in Onlay Bridging EDT (two rows and two transversal loops).

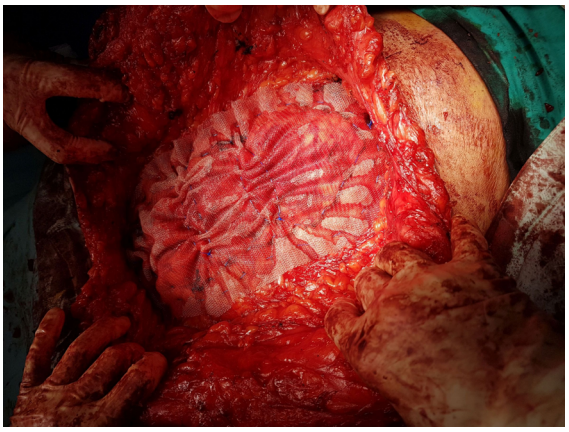

Fig. 5. Suture completed in Onlay Bridging EDT (two rows and two transversal loops) – intraoperative image