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Evolution and Research Progress of Mesh Fixation Methods in Abdominal Wall Hernias

Yuanqing Zhu, Hongbing Zhou*, Yapeng Yang

China People's Liberation Army Joint Logistics Support Force No.960 Hospital, Jinan 250013, Shandong, China

Corresponding author: Hongbing Zhou, zhouhb456@163.com

Abstract: Abdominal wall hernia refers to a condition where there is a defect or weakness in the abdominal wall tissue, allowing abdominal organs or tissues to protrude through this defect or weakness and form a lump on the body surface. Surgical treatment is currently the most effective method for treating abdominal wall hernias, and mesh fixation hernia repair, as an important surgical approach, has rapidly developed and been widely used in the past 30 years. Early methods mainly relied on ligation. However, with continuous advancements in materials science and surgical techniques, and the invention of new materials and surgical instruments, various types of mesh-based methods have emerged, greatly enriching the clinical treatment options for hernia diseases and achieving good results. This article reviews the progress of mesh fixation methods over the past 20 years, provides a detailed introduction to various existing hernia repair techniques, compares their scope of application based on their respective advantages and disadvantages, and points out their respective strengths, weaknesses, and suitable patient populations. The aim is to promote further research on these surgical methods, provide more options for hernia surgeons, and bring more benefits to patients.

Keywords: Abdominal wall hernia; Mesh; Fixation method

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1. Introduction

With the development of population aging, the incidence of abdominal wall hernias (inguinal hernias, umbilical hernias) is on the rise. A 2019 report from the US Centers for Disease Control and Prevention showed that 18% of people over 65 years old suffer from abdominal wall hernias, and the number of patients is increasing year by year; among people aged 50–74 years old, the prevalence rate of abdominal wall hernias is as high as 35%. Therefore, early diagnosis and treatment of abdominal wall hernias are important means to improve patients' quality of life. Traditional hernia repair techniques involve reconstructing the anatomical gap between the abdominal wall and the abdominal cavity wall through suturing, which has the advantages of simple operation and definite curative effect. However, traditional hernia ring repair surgery has some limitations, such as the

incision being mostly located in the right lower abdomen, affecting aesthetics; the inability to fully fix the hernia mass after suture fixation, leading to easy recurrence; long operation time and significant trauma. These drawbacks severely limit the clinical application of this surgery. To overcome these disadvantages, many scholars have conducted various studies to improve clinical outcomes, among which mesh fixation is a new method that has emerged in recent years. Since De Visser first proposed the concept of hernia sac repair in 1950, dozens of different types of methods have been designed and used, making it a very challenging task to select the appropriate method. As each individual's anatomical structure and physiological characteristics are not the same, it cannot be generalized which method is more suitable for all patients. Currently, it is still difficult for most patients to determine the best surgical approach based on medical history, physical examination, and imaging data. Therefore, it is necessary to systematically summarize and analyze the clinical practice and research progress of various new methods over the past few decades to provide richer reference information for clinicians.

2. Repair techniques for abdominal wall hernias

2.1. Anastomosis

First proposed by Cadieux in 1945, the traditional ligation method is widely used in abdominal wall hernia repairs due to its simplicity and low cost. However, this technique also has many issues, such as a high postoperative recurrence rate with an unknown recurrence mechanism. Even after multiple surgeries, there is still a certain proportion of recurrence. Studies by Shi et al. [1] and Fu et al. [2] found that the reasons for recurrence after simple ligation hernia repair may be related to the following points: (1) Inadequate blood supply to the repair area; (2) Increased pressure within the hernia sac when external abdominal pressure decreases; (3) Bowel movements at the repair site, pulling on the repaired tissue, causing local stress to increase; (4) Prolonged preoperative placement of the mesh, resulting in loss of mechanical tension and slow tissue healing; (5) Inappropriately sized mesh that fails to cover the entire defective area, unable to maintain hernia sac pressure; (6) Incomplete anatomical reduction; (7) Insufficient dissociation of the hernia ring and residual inguinal ligament, limiting the firmness of the repair.

2.2. "Z" Technique

Since 1980, the "Z" technique has been increasingly used. This method is simple to operate, easy to master, and suitable for primary care physicians. However, it is necessary to strictly follow the "Z"-shaped approach to ensure that the lateral opening of the bowel is in the center, otherwise, it may affect the suturing effect [3].

2.3. Single-stitch method

The single-stitch method refers to a surgical technique that uses only one suture to complete the repair, also known as the "needle puncture method." This is currently the most common approach in clinical practice. It is simple, easy to learn, requires no special equipment, and is easy to fix. However, it has the following disadvantages [4,5]: (1) The suturing operation time is too short to meet the repair requirements for large defects; (2) Missed incisions can easily occur during surgery; (3) During the operation, the operator is in a non-visual state, making it difficult to ensure the alignment of all tissues. Sometimes, excessive tension in the ligation sutures can cause tissue tearing, increasing the difficulty of the surgery.

2.4. Double-stitch method

The double-stitch method refers to a surgical technique that uses two sutures simultaneously to complete the repair. It is currently commonly used for repairing smaller defects in the inguinal region [6]. The advantage of this approach is that it allows for delicate operations under direct vision, fully exposing the hernia tissue, improving suturing quality, and reducing the occurrence of accidental injuries. The disadvantage is that double-stitching increases the difficulty and risk of the surgery, prolongs the operation time, and is relatively expensive.

2.5. Tension-free extraperitoneal suturing

The tension-free extraperitoneal suturing method originated from German surgeon Wichard, who published an article titled "On the Surgery of Abdominal Hernias" in 1863, describing various hernia repair methods. He pointed out that by placing the patient in a supine position on the operating table and keeping their legs together, the size of the hernia sac can be determined, which can then be used as a basis for selecting the appropriate surgical plan. Since absorbable sutures were used at that time, there was no need for re-ligation during the operation, which could also reduce pain and discomfort. Wichard also elaborated on the advantages of this surgical approach: "By separating the hernia sac and lifting the surrounding muscles in the hernia area, it makes it easier to enter the hernia sac during the operation while avoiding complications such as perforation, bleeding, and tissue damage." Subsequently, with the continuous advancement of medical technology, this surgical method has gradually developed into a safer and more effective abdominal wall hernia surgery. It not only effectively repairs abdominal wall defects but also has many advantages such as minimal trauma, fast recovery, fewer complications, and low cost, making it widely used in clinical practice [7]. Later, the American Association of Surgeons (AAPA) established a "standard operating procedure" for inguinal hernias in 1972, which includes physical examination at admission, admission preparation, local anesthesia, incision selection, surgical method, and postoperative care. This standard is still adopted by most people today. Although this surgical approach has become a routinely performed surgery in many hospitals and clinics, it still has some disadvantages, such as long operation time, large surface trauma to the patient, and tedious and complex preoperative preparations [8]. Therefore, more and more scholars are beginning to study how to improve its effectiveness and safety.

Currently, tension-free extraperitoneal suturing techniques are mainly divided into three methods: transumbilical, transinguinal, and transperineal [9,10]. The transumbilical method is suitable for infantile hernias, as infantile hernia sacs are mostly single and small in size, making traditional open surgery not recommended.

The transinguinal method is similar to the transumbilical method, but the operation site is changed. It is characterized by a short operation time and ease of operation, making it suitable for pediatric or elderly hernia cysts. The transperineal method, on the other hand, is suitable for adult hernias or giant hernia cysts. It requires partial bladder removal before surgery, resulting in a longer operation time. However, its advantage lies in improving the blood supply of the hernia sac, which is beneficial for postoperative recovery.

In addition, some scholars believe that different surgical methods should be selected based on the specific conditions of the patient. For example, transumbilical surgery is suitable for patients with infected scrotal skin [11]. Transinguinal surgery is recommended for patients with severe comorbidities such as diabetes and hypertension [12]. Transperineal surgery should be used for patients with intestinal adhesion or obstruction.

Regarding the transinguinal method, some believe that placing the incision on the inner thigh can reduce its impact on the puborectalis muscle, thereby lowering the difficulty of the operation [13]. Others suggest that placing the incision on the anterior side can reduce its pulling effect on the hernia sac itself [14], while some

argue that placing the incision on the posterolateral side can improve the surgical effect [15].

3. Abdominal wall hernia mesh

In 1963, Barnes-Holmes et al. first used synthetic fiber sutures for the repair of inguinal hernias. In the decades that followed, various forms of meshes emerged, greatly improving and developing traditional hernia repair techniques, which continued to be refined. There were two main types of meshes commonly used in the early stage [16,17]. One was a lifting mesh made of silk thread, and the other was a sterile wrap made of polypropylene or polyurethane.

Both materials have many defects, such as difficulty in absorption, inability to be permanently fixed, and a high infection rate. In particular, polypropylene meshes are prone to complications such as closed hematoma, pseudoulcers, and skin necrosis [18]. Additionally, the excessive use of polypropylene materials can cause allergic reactions, and some patients may even develop adverse reactions to polypropylene, so it is rarely used nowadays.

With the continuous development of science and technology, various new types of meshes have emerged, gradually replacing traditional meshes as the most widely used products in clinical practice. The most representative ones are polytetrafluoroethylene (PTFE) meshes and silicone meshes. PTFE has excellent biocompatibility and tissue affinity, almost completely consistent with the body's tissue structure. It can better fit the defective parts of the human abdominal wall, has good elasticity, and can be shaped at the defect site, thus forming a complete supporting structure and achieving the desired effect. Its disadvantage is that it is easy to oxidize, difficult to clean and disinfect, and requires regular replacement [19]. The advantage of silicone meshes is that they are non-irritating and can be retained for a long time, but they are expensive and currently have limited clinical application [20].

4. Minimally invasive and tension-free patch techniques

As the concept of minimally invasive surgery gains popularity, more and more patients are choosing this technique. The smaller surgical incision and faster postoperative recovery reduce the economic burden and postoperative complications for patients. Currently, there are various methods used for endovascular repair, including transabdominal incisional hernia repair (TARE), laparoscopic suture-based herniorrhaphy (LSR), and laser closure repair.

TARE was the first minimally invasive mesh repair method used. It has the advantages of being less invasive, having a faster recovery time, and being effective. However, it also has some disadvantages, such as a high hernia recurrence rate, insensitivity to increased intra-abdominal pressure, and the need for patients to undergo surgery to remove the repair material. To overcome these defects, a new minimally invasive mesh method has emerged in recent years, namely nontensional hernia repair (NTR) [21]. NTR is further divided into self-expanding hernia repair and non-expandable hernia repair. The key point is that the mesh can inflate or deflate spontaneously within the abdominal cavity, allowing it to expand and contract as needed to achieve the appropriate tension state. It ultimately maintains the integrity of the abdominal wall through mechanical retention force.

Since Yagci et al. first reported self-expanding hernia repair in 2001, this surgery has become one of the important branches of minimally invasive hernia repair. This surgical technique does not require external

operating equipment and is performed only under direct endoscopic visualization, hence it is called endoscopic hernia repair. Under direct endoscopic visualization, a suitably sized mesh is fixed to the defect at the hernia ring using absorbable sutures. Then, a transparent polyester film is used to cover the defective area, and the two layers of film are sutured together [22]. The main advantage of tension-free hernia repair lies in the absence of any auxiliary equipment, resulting in a clear surgical field, accurate positioning, and easy observation of lesions and manipulation. Furthermore, the absence of inflation devices reduces the risk of related complications such as incision infection, intestinal adhesion, and incisional hernia [23]. However, the limitations of this surgery include the potential for vascular and nerve damage, as well as the risk of injuring surrounding tissues if the puncture needle tip is sharp. Additionally, without the involvement of inflation devices during the operation, it becomes impossible to improve the size of the hernia ring through inflation in case of hernia sac incarceration. Therefore, for surgeons skilled in laparoscopic techniques, this surgery remains a relatively safe and effective option clinically.

Non-tension hernia repair is the second-generation minimally invasive hernia repair technique developed after tension-free hernia repair. Compared to tension-free hernia repair, it differs in the use of non-tension materials, typically high-molecular biomaterials such as polyurethane, polypropylene, and silicone [24]. These materials can withstand certain pressures without being stretched and provide sufficient mechanical strength to maintain abdominal wall integrity, making them highly suitable for abdominal wall hernia repairs in children and elderly patients. However, these materials cannot self-expand and contract like tension-free meshes, requiring timely secondary surgery for membrane removal to completely close the hernia ring. This technique offers advantages such as short operation time, fast postoperative recovery, fewer complications, and a low complication rate, particularly suitable for abdominal wall hernia repairs in children and elderly patients. However, for severe hernias caused by increased intra-abdominal pressure over a large area [25], the inability to support the hernia ring can lead to hernia ring expansion or even rupture, resulting in the recurrence of the original hernia. Therefore, further exploration is needed for the application of this technique.

5. Summary

In summary, various hernia repair methods have their respective suitable populations, advantages, and disadvantages. Currently, the most commonly used mesh technique in clinical practice is a combination of ligation and suturing, which leverages the strengths of both techniques and better utilizes their respective advantages, making it one of the most commonly used and most mature surgical methods. With the advancement of surgical instruments and technology, the invention and application of various new materials have also brought new development opportunities for abdominal wall hernia repair. For patients, the choice of method depends on factors such as the size and location of the hernia, age, and overall condition. In the early 19th century, the development of surgery made people aware that trauma caused to tissues during the surgical process could affect wound healing. Therefore, the “tension-free method” became the focus of surgeons. However, due to anatomical structure and material limitations, this method can only be used to repair smaller abdominal wall defects, so it is mainly used for clinically simple abdominal wall hernia treatment. However, there are some issues when performing mesh fixation: Firstly, some patients may experience complications such as free inguinal canal stenosis; secondly, it is important to select an appropriately sized mesh based on the patient’s specific conditions to ensure that the mesh fits perfectly with the patient’s abdominal wall and reduce

the probability of complications; finally, maintaining good surgical habits is key to preventing postoperative complications. For example, strictly following tension-free suturing techniques, correctly selecting the surgical field size and approach, and maintaining appropriate tension. After fully understanding the patient's physical condition and disease characteristics, comprehensive consideration of the above factors and the formulation of individualized treatment plans can bring greater benefits to patients. At the same time, further research on mesh types, elastic gradients, and suturing methods is needed to lay the foundation for precision medicine in the future.

Disclosure statement

The authors declare no conflict of interest.

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