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Open, Laparoscopic, and Robotic Approaches for Inguinal Hernia Repair: A Comprehensive Review

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ABSTRACT

Introduction and Purpose

Inguinal hernia is one of the most common surgical conditions, affecting 27% of men and 3% of women over a lifetime. The mainstay of treatment is surgical repair, which prevents complications such as strangulation and bowel obstruction. This study aims to provide a comprehensive review of inguinal hernia pathophysiology, risk factors, diagnostic strategies, and treatment options, focusing on open, laparoscopic, and robotic repair techniques.

Description of State of Knowledge

The development of inguinal hernias is associated with connective tissue abnormalities, with studies showing an increased ratio of type III to type I collagen. Diagnosis relies primarily on clinical examination, with imaging techniques such as ultrasonography and MRI used in complex cases. Lichtenstein repair remains the standard open approach, offering low recurrence rates, while laparoscopic techniques (TAPP, TEP) are preferred for bilateral and recurrent

hernias due to faster recovery and reduced chronic pain. Robotic-assisted repair provides enhanced precision and ergonomics, but current evidence shows no significant clinical advantage over laparoscopy, with higher costs and longer operative times.

Conclusions

Surgical repair is the gold standard for inguinal hernia treatment, with the choice of technique depending on patient factors, hernia characteristics, and surgical expertise. Lichtenstein repair remains the preferred open approach, while laparoscopic techniques (TAPP, TEP) are recommended for bilateral and recurrent cases due to their faster recovery and lower risk of chronic pain.

Keywords: Inguinal hernia, laparoscopic hernia repair, robotic hernia repair

1.Introduction and purpose

An inguinal hernia is a protrusion of the peritoneum through the inguinal canal, occurring above the inguinal ligament. It is a common surgical condition, with a lifetime incidence of inguinal hernia repair estimated at 27% in men and 3% in women [1]. Inguinal hernias can be classified into medial (direct) and lateral (indirect) types based on their anatomy [2]. Numerous risk factors contribute to its development, including genetic predisposition, patent processus vaginalis, higher work activity , and chronic obstructive airway disease [3]. Hernioplasty is one of the most frequently performed procedures in general surgery, with various surgical techniques available, including open and laparoscopic approaches. The introduction of tension-free mesh repair has significantly improved surgical outcomes by reducing recurrence rates and post-operative complications. The aim of this study is to summarize the etiology, risk factors, and variations in the management of inguinal hernias, providing insight into current surgical approaches and emerging treatment strategies.

2. State of knowledge

2.1 Pathophysiology

The pathophysiology of hernia is a combination of altered connective tissue and increased intra-abdominal pressure. At the molecular level studies showed that patients with inguinal hernias exhibit higher levels of type III collagen relative to type I collagen. Since type I collagen provides greater tensile strength, a shift toward type III collagen weakens connective tissue integrity, increasing the susceptibility to herniation and recurrence [4]. In addition to connective tissue abnormalities, lateral (indirect) inguinal hernias can be congenital or acquired, with congenital cases resulting from a patent processus vaginalis (PPV). The PPV, which normally closes after birth, can remain open, creating a pathway for abdominal contents to herniate [5].
Acquired cases have risk factors that can be divided into patient-related and external factors. Patient-related risk factors include male sex, as inguinal hernias are approximately six to ten times more common in men than in women, older age, low BMI, and systemic connective tissue disorders such as Ehlers-Danlos syndrome and Marfan syndrome, which further weaken the abdominal wall [2, 6] . Obesity (BMI > 30 kg/m²) is paradoxically associated with a lower risk of developing a hernia but carries an increased risk of complications when a hernia does occur [7]. External risk factors also play a significant role, with smoking being a major contributor to hernia recurrence due to its detrimental effects on collagen synthesis and wound healing. Additionally, chronic conditions that elevate intra-abdominal pressure, such as heavy lifting, chronic cough (COPD), constipation, and pregnancy, are more strongly associated with lateral (indirect) hernias, as they place sustained stress on the abdominal wall and inguinal canal [6, 8].
Anatomically, inguinal hernias are classified into lateral (indirect) and medial (direct) types. Lateral or indirect inguinal hernias occur when abdominal contents pass through the deep inguinal ring and follow the inguinal canal, with possibility for extending into the scrotum in males or the labia in females. This type of hernia follows the embryological pathway of the processus vaginalis and is more common in younger patients [9]. Medial or direct inguinal hernias protrude through a weakened transversalis fascia within Hesselbach's triangle, an area bordered by the rectus abdominis, inferior epigastric vessels, and inguinal ligament. Unlike indirect hernias, direct hernias do not pass through the deep inguinal ring and rarely extend into the scrotum [10].

Inguinal hernias can also be classified based on their position relative to the inferior epigastric vessels - indirect hernias occur lateral to the vessels, while direct hernias occur medial to them [11].

2.2 Symptoms and diagnosis

The most common method for diagnosing an inguinal hernia is a thorough patient interview and physical examination, with a sensitivity of 75% and a specificity of 96%, making it a highly reliable diagnostic approach [12]. Patients often present with a lump in the groin, localized pain and mild to moderate discomfort, which may worsen with Valsalva maneuvers like physical activity, prolonged standing, or lifting heavy objects [13]. Over time, the likelihood of pain, irreducibility, and functional limitations increases, affecting daily activities and work performance [14]. While inguinal hernias typically present with localized symptoms, they may also manifest as referred pain from other systems, leading to chronic abdominal pain, urinary symptoms, genital pain and tenesmus [15]. One of the most serious complications of an inguinal hernia is strangulation, where the herniated bowel segment becomes trapped, leading to vascular compromise and ischemia. The incidence rate of strangulation varies between 0.29% and 2.9%. Patients typically present with sudden, severe pain, nausea, vomiting, fever, and signs of bowel obstruction, such as bloating and an inability to pass gas or stool. Local symptoms include swelling, redness, edema, and tenderness over the hernia site [16]. To ensure accurate diagnosis and timely intervention, a systematic physical examination is essential in evaluating suspected inguinal hernias. The patient should be examined in a standing position, as hernias are often more prominent due to the effects of gravity. The inguinal and femoral regions should be carefully inspected for visible bulges, and the patient should be asked to perform a Valsalva maneuver (straining) to increase intra-abdominal pressure, which may reveal a previously undetectable hernia. If no bulge is observed during this maneuver, the likelihood of an inguinal hernia is low. Diagnosis in female patients can be more challenging, as their anatomical differences may obscure the presence of a hernia [17]. Although imaging is not routinely required, it can be valuable in specific scenarios, such as recurrent hernias, inconclusive physical exams, sports-related groin pain, or suspected complications like hydroceles . Ultrasonography is a commonly used in such cases, demonstrating a sensitivity of 86-90% and a specificity ranging from 77% to 86% for detecting groin hernias [12, 18, 19].

The differential diagnosis for inguinal hernia includes a range of conditions that can mimic its symptoms. Femoral hernias, which occur below the inguinal ligament, are often mistaken for inguinal hernias but carry a higher risk of strangulation. Sports hernias (athletic pubalgia), a

condition involving muscle or tendon injuries in the groin region, can also cause similar pain but lack a visible bulge. Other possible differentials include testicular torsion, epididymitis, hip joint pathology, “Gilmore's groin,” and osteitis pubis, all of which can present with groin pain. Therefore, a careful history, physical exam, and appropriate imaging studies are essential to accurately diagnose inguinal hernias and differentiate them from other potential causes of groin discomfort [17, 20, 21].

2.3 Treatment

2.3.1 Management

All symptomatic inguinal hernias are indications for surgical repair to prevent complications such as strangulation and bowel obstruction. The type of surgical approach depends on factors such as symptom severity, urgency, and patient preference. For symptomatic unilateral inguinal hernias, the recommended techniques are Lichtenstein repair (open tension-free mesh repair) or an endoscopic approach, including laparoscopic or robotic transabdominal preperitoneal (TAPP) or totally extraperitoneal (TEP) repair. In bilateral hernias, an endoscopic approach is preferred. In cases of recurrent hernia, the choice of surgical technique depends on the previous repair method—if the initial repair was an anterior approach (e.g., Lichtenstein), an endoscopic approach is recommended, whereas if the previous repair was a posterior technique (e.g., TEP/TAPP), a Lichtenstein repair is preferred to avoid re-entering the same surgical plane. Strangulated hernias require emergency surgery, a non-mesh repair should be considered if there is a high risk of infection due to bowel ischemia or perforation [22]. In contrast, for asymptomatic or minimally symptomatic patients, a watchful waiting strategy may be appropriate, particularly in older patients or those with significant comorbidities, as long as no signs of incarceration or rapid enlargement are present [23].

2.3.2 Open techniques

The most commonly used open technique for inguinal hernia repair is the Lichtenstein technique and is considered the gold standard due to its low recurrence rates and tension-free approach. The procedure involves placing a synthetic mesh over the defect in the inguinal canal and securing it to the surrounding structures with sutures or fibrin glue [24]. Elective Lichtenstein repair using glue for mesh fixation, compared to sutures, has been shown to be faster and associated with less postoperative pain, while maintaining comparable hernia recurrence rates [25]. This reinforces the weakened abdominal wall without creating tension, which is a key factor in reducing recurrence. The widespread adoption of mesh-based repairs

has largely replaced traditional non-mesh techniques such as the Bassini and Shouldice repairs, which rely on suturing native tissues together, often under tension, leading to higher recurrence rates [26, 27].

Studies have demonstrated that mesh-based hernia repairs significantly reduce recurrence rates compared to non-mesh techniques. However, in cases where there is a high risk of infection, such as in strangulated hernias with bowel resection or contaminated surgical fields, a non-mesh repair may be used to reduce the likelihood of mesh-related infections and complications [28].

2.3.3 Endoscopy techniques

Minimally invasive techniques, including laparoscopic and robotic-assisted approaches, have become widely used alternatives to open inguinal hernia repair and are considered the gold standard for bilateral hernias [29]. Laparoscopic repair is also recommended in women, as they have a higher risk of hernia recurrence, and in cases of sportsman's hernia, where faster recovery and reduced postoperative pain are critical [30]. This approach offers several advantages, including shorter recovery time, less postoperative pain, reduced blood loss, and a lower risk of chronic groin pain compared to open repair [31, 32]. Additionally, mesh placement in the preperitoneal space reduces the risk of nerve entrapment, further decreasing the likelihood of chronic pain. However, laparoscopic techniques have some drawbacks, including higher costs, longer operative times, and the need for general anaesthesia. Surgeon expertise and specialized training are essential, as laparoscopic and robotic procedures require advanced skills and show noticeable "learning curve" [32].

The two primary laparoscopic techniques are Transabdominal Preperitoneal (TAPP) repair and Totally Extraperitoneal (TEP) repair. In TAPP, the surgeon accesses the peritoneal cavity, makes an incision in the peritoneum, and places a mesh in the preperitoneal space before closing the peritoneal layer. In contrast, TEP avoids entering the peritoneal cavity, with mesh placement occurring entirely within the preperitoneal space via a balloon dissection. Both techniques provide tension-free repair [33]. However, TAPP carries a higher risk of intra-abdominal organ injury and adhesion formation due to peritoneal entry, while TEP is more technically demanding and requires greater expertise in preperitoneal dissection. TAPP also has a longer operative time compared to TEP. Both techniques are effective options for laparoscopic inguinal hernia repair, with studies showing similar clinical outcomes. TAPP, though equally effective, has been associated with slightly longer hospitalization times compared to TEP [30, 34].

Robotic-assisted inguinal hernia repair follows the same principles as laparoscopic techniques, offering enhanced visualization, improved instrument dexterity, and better ergonomics, which may reduce surgeon fatigue and increase precision [35]. However, studies have shown no significant clinical benefit of the robotic approach over conventional laparoscopy for straightforward inguinal hernia repair, while incurring higher costs and longer operative times . In a systematic review analyzing 64,426 patients, the operative time for robotic unilateral hernia repair was significantly longer, although bilateral repairs had comparable durations [36]. Despite the increased operative time, robotic surgery was associated with less postoperative pain and shorter recovery room stays, suggesting potential benefits for patient comfort [37] . Cost remains a major drawback, with robotic repair consistently showing higher expenses compared to laparoscopic techniques. However, robotic hernia repair has been safely performed in outpatient settings, and further studies are needed to evaluate its cost-effectiveness and long-term benefits in an era of constrained healthcare resources [38].

2.4 Complications

Surgical repair of inguinal hernias is generally safe, but complications can arise, ranging from early postoperative issues to long-term effects. Mortality rates for elective repairs are low, with studies reporting 0.02% in patients under 60 years and 0.48% in those over 60, whereas emergency repairs have a significantly higher mortality rate of up to 7%, particularly in elderly patients with comorbidities. [39, 40] Wound-related complications such as bruising, hematoma, and surgical site infections occur in about 3% of cases, though prophylactic antibiotics have not been conclusively shown to reduce infection rates [41].

Hernia recurrence remains a concern, with mesh-based repairs demonstrating lower recurrence rates compared to traditional sutured techniques. However, improper mesh placement, inadequate fixation, or small mesh size can increase recurrence risk [42]. Chronic pain, defined as pain persisting beyond three months postoperatively, is one of the most significant long-term complications, affecting up to 30% of patients, with 3% experiencing severe pain that interferes with daily activities [43]. Risk factors include preoperative pain, anterior surgical approaches, nerve irritation, and postoperative complications [44]. Infertility is another potential complication, with vas deferens injury occurring in 0.3% of adult cases and 0.8-2.0% in children [45].

Laparoscopic and robotic approaches carry specific risks, with sero-hematoma formation being the most frequent complication [46]. Bladder and bowel perforation, particularly in TAPP procedures, trocar hernia, and mesh erosion into the bladder have been reported, along with

urinary retention due to general anaesthesia [47]. Other potential complications include ischemic orchitis, testicular atrophy, sexual dysfunction, and infertility, which may result from vascular or nerve damage during the procedure.

3. Summary

Surgical repair remains the gold standard of inguinal hernia treatment, with the choice of technique depending on patient symptoms, hernia characteristics, and surgeon expertise. Lichtenstein repair remains the gold standard for open surgery, offering low recurrence rates and widespread accessibility, while laparoscopic approaches (TAPP and TEP) are preferred for bilateral and recurrent cases. Robotic-assisted techniques, though promising, currently show no significant advantage over laparoscopy in terms of clinical outcomes, with higher costs and longer operative times being major drawbacks. In cases of strangulation or infection risk, non-mesh repair may be necessary. While watchful waiting is an option for asymptomatic patients, most hernias eventually require surgery to prevent complications, emphasizing the importance of individualized patient management.

Disclosures

Author's contribution

Conceptualization - Jakub Skiba and Zuzanna Skiba; methodology - Kinga Tylczyńska; software ,- Natalia Tylczyńska and Ignacy Maciejewski; check - Szymon Szypulski, Maria Michalska and Sebastian Iwaniuk; formal analysis - Ignacy Maciejewski and Kinga Kowalik; investigation - Aleksandra Zielińska; resources - Zuzanna Skiba; data curation - Kinga Tylczyńska and Maria Michalska; writing - rough preparation - Kinga Kowalik and Szymon Szypulski; writing - review and editing, Kinga Kowalik and Aleksnadra Zielińska; visualization, Natalia Tylczyńska; supervision - Jakub Skiba; project administration – Jakub Skiba; receiving funding not applicable, All authors have read and agreed with the published version of the manuscript.

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