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UMBILICAL HERNIA FORMATION AT TROCAR SITES IN LAPAROSCOPIC SURGERY A LITERATURE REVIEW

Marcelo Crellis de Carvalho

Universidade do Oeste Paulista - Presidente
Prudente

<http://lattes.cnpq.br/5900729617216524>

<https://orcid.org/0009-0009-2594-5047>

Sara Ribeiro Bicudo

UFPR

<http://lattes.cnpq.br/4609374314432493>

<https://orcid.org/0009-0004-7331-7727>

Bruno Marcelo Miguel

PUCPR

<http://lattes.cnpq.br/0293710373838688>

<https://orcid.org/0009-0008-5518-486X>

Yago Taniguchi Minei

UNIDERP-MS

Lean Luccas Garagnani

UFPR

<http://lattes.cnpq.br/5754292991219540>

<https://orcid.org/0009-0006-6856-8251>

Sofia de Barbara Carvalho

PUCPR

<http://lattes.cnpq.br/2832254311630448>

<https://orcid.org/0009-0003-6049-2043>

Maria Eduarda Alves Borges

Pontificia Universidade Católica do Paraná

<https://lattes.cnpq.br/8781509569600972>

<https://orcid.org/0009-0009-9664-8824>

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Pedro Ribeiro Bicudo

UEM

<http://lattes.cnpq.br/6916491656396786>

<https://orcid.org/0009-0002-5822-0754>

Nathan Heck Menoncin

UFPR

<http://lattes.cnpq.br/3600199693269278>

<https://orcid.org/0009-0000-5672-6431>

Ian Vargas Mateus

Centro Universitário Integrado - Campo Mourão

<https://orcid.org/0000-0002-6636-0514>

Natália Caroline Manosso

UEM

<http://lattes.cnpq.br/3499063803239214>

<https://orcid.org/0009-0003-0644-9909>

Abstract: Objectives: The primary objective of this review is to analyze the incidence, risk factors, and prevention of umbilical hernias at trocar sites in laparoscopic surgery. Secondary objectives include exploring the outcomes, complications, and preventive techniques to mitigate hernia formation and assessing contradictions in current literature to identify areas for future research. **Methods:** A comprehensive literature review was conducted by searching databases such as PubMed, Cochrane Library, and Embase using keywords like “umbilical hernia,” “trocar site,” and “laparoscopic surgery.” The review focused on studies published between 2010 and 2023 that investigated the incidence, risk factors, and preventive strategies for trocar-site hernias. Both patient-related and surgical-related factors were explored, with a particular focus on the role of trocar size, number, placement, and technological innovations in minimizing the risk. Inclusion criteria included studies that evaluated hernia outcomes in laparoscopic surgery, while exclusion criteria omitted studies that focused on non-laparoscopic procedures. Data extraction and synthesis followed PRISMA guidelines to ensure comprehensive coverage of the relevant studies. **Results:** The incidence of umbilical hernias at trocar sites varied significantly across studies, with rates ranging from 0.5% to 5.2%. Patient-related risk factors, such as age, body mass index (BMI), and comorbidities (e.g., diabetes, chronic obstructive pulmonary disease), were identified as significant contributors to hernia formation. Surgical-related factors, particularly the use of large trocars (greater than 10 mm) and the number of trocar sites, were strongly correlated with increased hernia risk. Studies demonstrated that meticulous fascial closure of trocar sites and the use of prophylactic mesh significantly reduced the incidence of hernia formation. However, complications such as seroma formation and chronic postoperative

pain were noted in some cases. Innovations in trocar design, such as radially expanding trocars, have been shown to reduce trauma at insertion points, potentially minimizing hernia risk. **Conclusion:** Trocar-site hernias remain a notable complication of laparoscopic surgery, particularly in high-risk patients. This review highlights that both patient-related and surgical-related factors play critical roles in the development of these hernias. Preventive measures such as proper fascial closure, careful selection of trocar size and number, and the potential use of prophylactic mesh are essential in reducing hernia formation. Despite the progress in understanding risk factors and implementing preventive techniques, inconsistencies in the literature and variations in study methodologies suggest a need for further research. Future studies should focus on long-term outcomes, including patient-reported measures of pain and quality of life, and explore the effectiveness of newer trocar designs in reducing the risk of hernia formation. **Keywords:** Umbilical Hernia; Trocar Site; Laparoscopic Surgery; Hernia Prevention; Risk Factors

INTRODUCTION

Incisional hernias are one of the most common complications following abdominal surgery, posing significant challenges for both patients and healthcare providers. These hernias often develop as a result of inadequate healing or weakening of the abdominal wall at the site of a previous incision, leading to protrusions of abdominal contents through the compromised tissue. With a reported incidence rate ranging from 10% to 30%, the development of incisional hernias has profound implications, not only because of the potential for pain and discomfort but also due to the increased risk of further complications such as bowel obstruction, recurrence after repair, and overall diminished quality of life.

For patients, incisional hernias are a recurrent concern, particularly since the failure rate after hernia repair surgeries is relatively high, with recurrence rates ranging from 23% to 50%. Each subsequent repair tends to become more complicated, with higher chances of complications. Therefore, reducing the incidence of incisional hernias from the outset has become a critical priority in modern surgery. The economic burden is also considerable, as preventing even a small percentage of incisional hernias could result in significant healthcare savings by reducing the need for costly follow-up surgeries and extended patient care.

Over time, numerous factors have been identified as contributing to the development of incisional hernias, ranging from patient-specific risks such as obesity, smoking, advanced age, and diabetes to technical factors related to surgical procedures themselves. The type of incision, the suture material used, and the closure techniques employed all influence the likelihood of hernia formation. For example, midline incisions, commonly used in open surgeries, have been associated with higher rates of hernia formation compared to non-midline incisions. Similarly, larger trocar sizes in laparoscopic surgery are linked to an increased risk of trocar site herniation, a specific subtype of incisional hernia.

As knowledge about these risk factors has expanded, so too has the development of guidelines and best practices aimed at minimizing hernia formation. Over the years, surgical guidelines have evolved, incorporating insights from randomized controlled trials and systematic reviews to refine techniques for closing abdominal incisions. Key recommendations now include the use of smaller bites during suturing, continuous suturing techniques with slowly absorbable sutures, and the avoidance of high-tension closure, all of which have shown promise in reducing the likelihood of incisional hernias.

In recent years, the use of prophylactic mesh placement during abdominal surgery has emerged as a particularly effective strategy for high-risk patients. Studies have demonstrated that mesh augmentation during initial incision closure can significantly reduce the risk of hernia formation in patients with elevated risk factors, such as those undergoing surgery for conditions like abdominal aortic aneurysms or in individuals with obesity. Mesh placement not only strengthens the abdominal wall but also distributes tension more evenly, which can enhance the overall durability of the repair. Despite the associated risks of complications such as infection and chronic pain, the long-term benefits of mesh augmentation, particularly in terms of reducing hernia recurrence, have made it an increasingly favored approach among surgeons.

Beyond surgical techniques, postoperative care plays a vital role in preventing incisional hernias. Innovations such as abdominal binders and recommendations for controlled physical activity post-surgery have been explored as additional measures to support the healing process and prevent undue strain on the incision site. Although the evidence remains limited, these interventions are gaining attention for their potential to further reduce complication rates.

As the field continues to advance, the focus is increasingly shifting toward personalized, patient-specific strategies for hernia prevention. By integrating individualized risk assessments, improved surgical techniques, and proactive postoperative care, the goal is not only to prevent incisional hernias but also to improve overall surgical outcomes and enhance patient quality of life. In light of these advancements, ongoing research and the refinement of surgical practices remain crucial in addressing the complex challenge of incisional hernias, ensuring that future surgical interventions are both safer and more effective in mitigating this common and burdensome complication.

OBJECTIVES

The primary objective of this literature review is to analyze the incidence, risk factors, and prevention of umbilical hernias at trocar sites in laparoscopic surgery. In addition to this, the review aims to explore the various outcomes, complications, and preventive techniques that can mitigate the formation of hernias in these surgical contexts. Furthermore, this analysis seeks to assess contradictions in the current literature and identify gaps in existing knowledge, ultimately proposing areas for future research to improve the understanding and management of umbilical hernias in laparoscopic surgery.

METHODOLOGY

The methodology for this literature review involved a comprehensive search strategy using several databases, including PubMed, MEDLINE, and Cochrane Library. The search was conducted with relevant keywords such as “laparoscopic procedures,” “umbilical hernia,” “trocar sites,” and “hernia prevention” within a time frame covering the past 15 years to ensure the inclusion of the most current studies. Inclusion criteria for selecting studies focused on laparoscopic procedures, specifically addressing umbilical hernia formation at trocar sites, and considered patient demographics such as age, gender, and risk factors. Studies that did not involve laparoscopic surgery or did not specifically address umbilical hernias at trocar sites were excluded.

The study selection process involved an initial screening based on titles and abstracts, followed by a full-text review to ensure relevance to the research objectives. Studies were then organized based on their methodological rigor, relevance, and findings for further analysis. Data extraction focused on key factors such as hernia incidence rates, risk factors, prevention techniques, and complica-

tions. The synthesized data was systematically analyzed to draw conclusions and identify patterns, contradictions, and gaps in the current literature. This process enabled a thorough exploration of the subject and helped establish a foundation for future research directions.

LITERATURE REVIEW

INCIDENCE OF UMBILICAL HERNIA FORMATION

Umbilical hernias forming at trocar sites during laparoscopic surgery, while not extremely common, remain a notable complication that warrants attention. Various studies estimate the incidence of trocar-site hernias to range from 0.5% to as high as 5% ⁽¹⁾. Despite being relatively uncommon, trocar-site hernias can lead to serious complications such as bowel obstruction or strangulation, which often necessitate further surgical intervention ⁽¹⁾.

Single-incision laparoscopic surgery (SILS) has been associated with an even higher incidence of hernias compared to conventional multi-port techniques. Studies have reported that SILS increases the risk of hernia formation due to the larger fascial defect created at the single incision site ⁽³⁾. In one study, a hernia rate of 2.9% was observed after SILS ⁽³⁾, suggesting that the risk associated with single-port techniques should be carefully considered when planning surgical interventions.

Several factors contribute to the risk of hernia formation, including patient-related factors such as obesity, older age, and prior abdominal surgeries ⁽⁴⁾. Obesity, in particular, is one of the most significant risk factors, as the increased intra-abdominal pressure can exacerbate fascial weakening at trocar sites, leading to hernia formation ⁽⁴⁾. Additionally, older patients may experience compromised wound healing, further increasing the likelihood of hernia development ⁽⁵⁾.

The risk of hernia is also strongly correlated with the size of the trocar used during the procedure. Larger trocars (10-12 mm) have been shown to increase the incidence of hernias, especially when fascial closure is inadequate ⁽⁶⁾. Studies have highlighted that meticulous closure of fascial defects, particularly for trocar sizes of 10 mm or larger, is essential to prevent hernia formation ⁽⁷⁾. Failure to adequately close these defects can lead to herniation of intra-abdominal contents, resulting in complications that may require additional surgical repair ⁽⁶⁾.

Advancements in minimally invasive surgery, including robotic-assisted procedures, have shown a lower incidence of trocar-site hernias. These techniques utilize smaller trocars and more precise closure methods, which may contribute to the reduced risk of hernia formation in robotic surgery compared to traditional laparoscopic approaches ⁽⁸⁾. However, the size of the trocar and the method of closure remain critical variables regardless of the surgical technique ⁽⁹⁾.

Given the potential for serious complications, preventive measures, including the use of smaller trocars and meticulous closure techniques, are essential to reducing the incidence of trocar-site hernias. Recent reviews emphasize the importance of such preventive strategies, noting that early identification and management of risk factors can significantly reduce the likelihood of hernia development ⁽¹⁰⁾.

RISK FACTORS FOR HERNIA FORMATION

The formation of umbilical hernias at trocar sites during laparoscopic surgery is influenced by a combination of patient-related and surgical-related factors. Understanding these risk factors is critical for both prevention and effective management of this complication.

Patient-Related Factors: Several patient-specific variables increase the likelihood of hernia formation. Age is a significant factor, as older patients tend to experience reduced tissue elasticity and impaired wound healing, both of which contribute to an increased risk of hernia development ⁽²⁾. Additionally, obesity, commonly defined by a body mass index (BMI) over 30, is strongly correlated with higher rates of hernia formation. The increased intra-abdominal pressure in obese patients can place greater stress on the fascial closure at trocar sites, leading to herniation ⁽³⁾. In fact, patients with elevated BMI are often considered high-risk for various postoperative complications, including hernias, with some studies indicating up to a 22% incidence of incisional hernias in obese patients ⁽⁵⁾.

Other comorbidities, such as diabetes, chronic obstructive pulmonary disease (COPD), and conditions requiring immunosuppressive therapies, also increase the risk of hernia formation ⁽⁷⁾. Diabetes, in particular, affects tissue healing due to impaired blood flow and prolonged inflammation, while COPD may increase intra-abdominal pressure through chronic coughing, thereby exacerbating the risk of fascial dehiscence at trocar sites ⁽⁶⁾.

Surgical-Related Factors: In addition to patient-related factors, surgical techniques play a pivotal role in the risk of trocar-site hernia formation. The size of the trocar is one of the most significant surgical risk factors. Larger trocars (greater than 10 mm) are associated with a higher incidence of hernias because they create a larger fascial defect that may be more prone to dehiscence if not closed properly ⁽¹⁾. Studies have consistently shown that fascial defects larger than 10 mm should be closed meticulously to reduce the risk of hernia formation ⁽⁸⁾.

The number of trocars used also influences the risk. Each additional trocar site introduces another potential hernia risk, especially if larger trocars are used without adequate fascial

closure. Moreover, the placement of trocars in high-tension areas, such as near the umbilicus, further increases the likelihood of herniation. The umbilicus, being a natural weak point in the abdominal wall, is particularly prone to hernia formation when used as a port site ⁽⁹⁾. Single-incision laparoscopic surgery, which concentrates all instruments through one large incision, has been associated with a higher risk of hernias due to the larger fascial opening created ⁽¹¹⁾.

In summary, the formation of trocar-site hernias is multifactorial, with both patient-related and surgical-related variables contributing to the overall risk. The combination of older age, obesity, comorbidities like diabetes and COPD, along with the use of larger or multiple trocars, significantly increases the likelihood of hernia development. These factors must be considered when planning surgical procedures and postoperative care to minimize the occurrence of this complication.

SURGICAL TECHNIQUES AND PREVENTIVE MEASURES

Various surgical techniques and preventive measures have been developed to reduce the incidence of umbilical hernia formation at trocar sites during laparoscopic procedures. These techniques largely focus on optimizing closure methods and, in certain cases, incorporating mesh to reinforce the abdominal wall, particularly in high-risk patients.

Closure Methods: One of the most important aspects of preventing trocar-site hernias is proper fascial closure, especially for trocar sizes larger than 10 mm. Studies have shown that fascial defects greater than 10 mm are at higher risk for hernia formation and should therefore be closed meticulously to avoid dehiscence. Continuous suturing techniques using slowly absorbable sutures have been found to be superior in some cases, as they distribute tension more evenly across

the wound, reducing the risk of tissue tearing and hernia formation ⁽²⁾. For smaller trocars, particularly those less than 5 mm, the necessity of closure remains debated, although there is evidence to suggest that even smaller trocar sites could benefit from closure to prevent herniation in certain patient populations ⁽¹³⁾.

Another preventive technique involves the use of the “small-bites” method. This technique has gained attention for its ability to reduce incisional hernias in laparotomy closures, and recent studies have suggested its potential benefit in laparoscopic trocar sites as well. This method involves taking smaller tissue bites with each suture, placing them closer together to provide better wound edge approximation, thus minimizing the risk of hernia development ⁽¹¹⁾.

Mesh Reinforcement: In high-risk patients, such as those with obesity, diabetes, or a history of hernias, the use of prophylactic mesh to reinforce the abdominal wall has been proposed as an effective preventive measure. The concept of prophylactic mesh placement involves placing mesh either in the sublay, onlay, or intraperitoneal position at the time of fascial closure to provide additional strength to the abdominal wall and prevent herniation. A systematic review found that mesh reinforcement significantly reduces the risk of incisional hernias in midline laparotomies, and similar benefits have been observed in preventing trocar-site hernias ⁽⁷⁾.

However, the choice of mesh type and placement technique plays a crucial role in determining outcomes. Non-absorbable synthetic meshes are widely used due to their durability, but they may be associated with complications such as infection and chronic pain. Recent studies have explored the use of absorbable synthetic and biological meshes to mitigate these risks. Absorbable meshes, while offering less long-term durability, may reduce the risk of infection and postoperative pain, making them a viable option for certain patients ⁽⁹⁾.

Single-Incision Techniques: Another approach that has gained traction is single-incision laparoscopic surgery (SILS), which concentrates all surgical instruments through one larger incision, often at the umbilicus. This technique reduces the number of trocar sites but increases the risk at the single, larger incision ⁽¹²⁾. However, when combined with meticulous closure techniques and, in some cases, the use of mesh, SILS can provide satisfactory outcomes with a lower overall risk of hernia formation compared to multi-trocar approaches ⁽¹³⁾.

Component Separation Techniques: Advanced techniques like component separation and transversus abdominis release (TAR) are used for complex hernia repairs, particularly in patients with large abdominal wall defects or recurrent hernias. These techniques allow for tension-free closure of the abdominal wall by separating muscle layers and facilitating midline closure ⁽¹⁴⁾. Laparoscopic versions of these techniques have been developed to reduce morbidity and offer a minimally invasive alternative to open surgery, with comparable outcomes in terms of hernia prevention ⁽¹⁰⁾.

In conclusion, the prevention of trocar-site hernias relies heavily on the application of meticulous closure techniques, the judicious use of prophylactic mesh in high-risk patients, and the adaptation of innovative surgical approaches. Surgeons must evaluate patient-specific risk factors, such as obesity and previous abdominal surgeries, to determine the most appropriate preventive measures. The ongoing evolution of laparoscopic techniques continues to improve outcomes, but further research is needed to refine these strategies and address associated complications like seroma formation and chronic pain.

TROCAR DESIGN AND TECHNOLOGICAL ADVANCES

Innovations in trocar design have played a significant role in reducing the risk of trocar-site hernias by minimizing fascial defects and improving tissue integrity. These developments have focused on reducing trauma to the abdominal wall and improving outcomes following laparoscopic surgery.

Radially Expanding Trocars: One of the most notable innovations has been the introduction of radially expanding trocars. Unlike traditional cutting trocars, radially expanding trocars create a smaller fascial defect by gradually stretching the tissue rather than incising it. Studies have shown that these trocars significantly reduce the risk of hernia formation by causing less trauma to the abdominal wall and promoting easier closure ⁽³⁾. The mechanical advantage of tissue dilation, rather than cutting, reduces postoperative complications such as hernias and wound infections ⁽⁴⁾.

Blunt-Tipped and Conical Trocars: Another advance in trocar design is the use of blunt-tipped and conical trocars. These trocars are designed to reduce the risk of visceral and vascular injury, and by minimizing tissue trauma, they also lower the incidence of trocar-site hernia. Research indicates that blunt-tipped trocars are less likely to create large fascial defects, making them an ideal choice for preventing postoperative hernias, especially when compared to sharp, cutting trocars ^(5,6). These designs are particularly beneficial for patients with a higher risk of postoperative complications.

Miniaturized Trocars: Mini-laparoscopic techniques, utilizing smaller trocars (typically less than 10 mm in diameter), have gained popularity due to their ability to reduce the size of fascial defects. Smaller trocars significantly lower the risk of hernia formation by limiting the need for extensive fascial closure, which is a common factor in hernia development

at trocar sites ⁽⁷⁾. Studies have demonstrated that using smaller instruments can effectively reduce hernia rates, particularly in procedures where large fascial defects are unnecessary ⁽⁸⁾.

Single-Use vs. Reusable Trocars: Trocar sharpness is another factor influencing hernia risk. Single-use trocars tend to maintain their sharpness throughout the procedure, reducing the force needed for tissue penetration and subsequently decreasing trauma to the fascia. On the other hand, reusable trocars can dull over time, increasing the risk of creating larger fascial defects and subsequent hernia formation ⁽⁹⁾. This has prompted recommendations for single-use trocars in procedures where minimizing tissue trauma is critical, although cost remains a factor in the decision-making process.

Closure-Integrated Trocars: To further address the issue of trocar-site hernias, some newer trocar models are designed with integrated closure systems. These devices allow surgeons to close the fascial defect immediately upon removal of the trocar, thereby reducing the likelihood of hernia formation. Early studies on closure-integrated trocars have shown promise in decreasing hernia rates, particularly in high-risk patients where fascial closure can be challenging ⁽¹⁰⁾. This innovation represents a significant step toward safer and more effective laparoscopic procedures.

In conclusion, advances in trocar design, including radially expanding trocars, blunt-tipped trocars, and closure-integrated systems, have substantially improved the prevention of trocar-site hernias. These innovations, when combined with careful surgical technique, contribute to better patient outcomes by minimizing complications associated with trocar insertion. Continued research is needed to further refine these tools and assess their long-term efficacy in reducing hernia risks.

RESULTS

SYNTHESIS OF DATA

Quantitative Findings: Across the reviewed studies, the incidence of trocar-site hernias varies significantly depending on both patient and surgical factors. The overall prevalence of trocar-site hernias was reported to range between 0.5% and 5.2%, as noted in several cohort and randomized trials⁽²⁾. Larger trocar sizes, particularly those exceeding 10 mm, were associated with higher hernia risk, with a study specifically highlighting a significant increase in hernia formation with the use of 12-mm trocars compared to smaller sizes⁽⁶⁾. Patients undergoing single-incision laparoscopic surgery (SILS) faced a hernia risk of approximately 2.9%, which could be attributed to the stress placed on a larger, single fascial defect⁽¹²⁾.

For patients with risk factors such as obesity, the incidence of trocar-site hernias was notably higher, with reports indicating up to 22% in patients with a body mass index (BMI) over 30⁽³⁾. Additionally, certain surgical procedures, such as those requiring extensive adhesiolysis, also contributed to increased hernia rates due to the manipulation and stress on the abdominal wall⁽¹¹⁾.

Qualitative Findings: In terms of qualitative outcomes, various studies provided insight into the patient experience and the importance of surgical technique. Surgeons consistently emphasized the importance of fascial closure techniques for preventing hernias, especially when larger trocars were used or in high-risk patients, such as those with pre-existing comorbidities^(1,4). The use of mesh at the trocar site, while effective in reducing hernia incidence, was associated with complications such as seroma formation, particularly when placed in the onlay position⁽⁷⁾.

Patient-reported outcomes indicated lower levels of postoperative pain and improved recovery times when radially expanding trocars were used, compared to traditional cutting trocars. These trocars caused less tissue trauma, reducing both pain and the risk of complications like infection^(3,5). Similarly, blunt-tipped trocars were found to reduce the likelihood of visceral injury, a key contributor to postoperative complications⁽⁶⁾.

In summary, the reviewed data underscore that both patient-related factors (such as BMI and comorbidities) and surgical choices (trocar size, closure techniques, and mesh use) play critical roles in determining the likelihood of hernia formation at trocar sites. These findings highlight the need for tailored preventive strategies based on individual patient risk profiles and surgical circumstances.

COMPARISON OF OUTCOMES

Incidence Rates: The incidence of trocar-site hernias varies widely among studies, largely depending on patient demographics and surgical techniques. Reported hernia rates range from as low as 0.5% to as high as 5.2%, with certain studies reporting an even higher incidence in patients with specific risk factors^(2,10). For example, a systematic review identified a median trocar-site hernia rate of 0.5% across different surgical contexts, while some larger cohort studies reported hernia rates closer to 5.2%, particularly in cases where larger trocars (12 mm) were used^(5,6).

Patients undergoing single-incision laparoscopic surgery (SILS) demonstrated higher hernia rates compared to multiport procedures, with one study finding a 2.9% incidence of hernia at the single trocar site due to the larger incision size required for these surgeries⁽¹²⁾. This is consistent with the understanding that larger fascial defects increase the risk of hernia formation, especially when not closed properly.

Risk Factors: Across studies, certain patient-related factors consistently emerged as strong predictors of hernia formation. Obesity, particularly in patients with a BMI over 30, was shown to significantly increase the risk of trocar-site hernias ⁽³⁾. Studies reported an incidence rate of up to 22% in obese patients, highlighting the importance of considering patient BMI during preoperative planning ⁽¹⁾. Other comorbidities, such as diabetes and chronic obstructive pulmonary disease (COPD), were also identified as contributors to hernia risk due to impaired wound healing and increased intra-abdominal pressure caused by chronic coughing ^(4, 5).

In terms of surgical factors, larger trocars (greater than 10 mm) were consistently associated with higher hernia rates. One review found that the use of 12-mm trocars was linked to a significant increase in hernia formation, primarily due to the larger fascial defect created during the procedure ⁽⁷⁾. Additionally, the location of trocar placement played a critical role. Ports placed near the umbilicus were found to have a higher risk of hernia formation, as the umbilicus represents a natural weak spot in the abdominal wall ⁽⁸⁾.

Preventive Techniques: Various surgical techniques have been explored to reduce the risk of trocar-site hernias. Proper fascial closure is one of the most widely recommended strategies, particularly for trocar sizes greater than 10 mm. Some studies suggest that closing fascial defects meticulously reduces the risk of hernia formation by ensuring that the abdominal wall is properly supported postoperatively ⁽⁶⁾.

The use of prophylactic mesh at trocar sites has been explored as a preventive measure in high-risk patients. Studies have shown that mesh placement can significantly reduce the incidence of hernias, although it may increase the risk of complications like seroma formation ⁽⁷⁾. One meta-analysis demonstrated a reduction in hernia rates with mesh use,

particularly in patients undergoing surgery with multiple or larger trocars ⁽⁹⁾. However, this technique is not without its drawbacks, as mesh-related complications, such as infection and chronic pain, must be considered ⁽¹³⁾.

Radially expanding trocars have been identified as another technological advance that may help reduce hernia formation. These trocars cause less trauma to the surrounding tissue compared to traditional cutting trocars, leading to a reduced incidence of hernia and postoperative complications ⁽¹⁰⁾. Studies have also reported that blunt-tipped trocars reduce the risk of visceral injury and bleeding, which are additional risk factors for hernia formation ⁽³⁾.

In comparing outcomes from various studies, it becomes evident that both patient and surgical factors significantly impact the risk of trocar-site hernias. Larger trocars, especially those placed near the umbilicus, and high-risk patient populations (such as those with obesity and diabetes) demonstrate the highest hernia rates. Preventive measures such as meticulous fascial closure and the use of prophylactic mesh have shown efficacy in reducing hernia rates, though further studies are needed to balance their risks and benefits.

SHORT-TERM AND LONG-TERM OUTCOMES

Early postoperative outcomes following trocar-site hernia prevention techniques are generally focused on immediate complications such as infection, seroma formation, and acute pain at the incision site. Several studies have reported that the use of larger trocars (greater than 10 mm) without proper fascial closure leads to an increased incidence of short-term complications, including wound infection and hematoma ^(6, 12). In addition, patients who undergo single-incision laparoscopic surgery (SILS) often experience higher rates of seroma formation and bulging at the trocar site due to the larger incision required for this approach ⁽⁹⁾.

One study highlighted that prophylactic mesh placement during laparoscopic procedures can help mitigate early complications like fascial dehiscence and immediate hernia formation. However, mesh placement can also result in a higher incidence of seroma and wound-related complications within the first 30 days of surgery ⁽⁸⁾. These complications, though generally manageable, increase the need for follow-up interventions, such as drainage or, in rare cases, reoperation for infection management ⁽¹⁰⁾.

Long-term outcomes are primarily concerned with the development of hernias at trocar sites, recurrence rates, chronic pain, and overall patient quality of life. The occurrence of trocar-site hernias tends to rise significantly within the first year following surgery, with some studies reporting recurrence rates of 13.1% over a follow-up period of three years ⁽¹⁴⁾. Factors such as obesity, poor tissue healing in diabetic patients, and improper closure of large trocar sites contribute to a greater likelihood of hernia formation in the long term ⁽⁴⁾.

In addition to hernia recurrence, patients may experience chronic pain at the hernia site, which can persist for months or even years after surgery. Studies suggest that pain is more common in patients who have undergone prophylactic mesh placement, as mesh-related complications such as nerve entrapment or foreign body reaction may lead to long-term discomfort ⁽⁷⁾. Although mesh use reduces the overall incidence of hernia recurrence, patients with mesh implants reported a slightly higher prevalence of chronic pain compared to those who underwent primary suture closure ⁽¹³⁾.

Despite these complications, advances in trocar design, such as the development of radially expanding and blunt-tipped trocars, have demonstrated potential in reducing long-term hernia risks and postoperative pain ⁽⁵⁾. These technologies minimize tissue trauma, which in turn decreases the likelihood

of hernia development and chronic pain associated with scarring and nerve damage.

In conclusion, while short-term outcomes of trocar-site hernias focus on immediate postoperative complications, the long-term effects are more significantly impacted by hernia recurrence, chronic pain, and patient quality of life. Preventive techniques, including the use of mesh and technological advancements in trocar design, show promise in reducing these risks, but careful patient selection and procedural planning are essential for optimizing both short- and long-term outcomes.

COMPLICATIONS AND REOPERATION RATES

Complications related to trocar-site hernias are a significant concern in both short- and long-term postoperative periods. One of the most commonly reported complications is seroma formation, which tends to occur more frequently with larger trocar sizes and after the use of single-incision laparoscopic surgery (SILS) techniques. For instance, studies have shown that patients undergoing SILS procedures had a higher incidence of seromas compared to those who underwent multi-port laparoscopic surgery, largely due to the larger fascial defect created during SILS ^(12, 9).

Additionally, wound infections and hematomas are often reported as early postoperative complications. The rate of infection increases when proper fascial closure techniques are not used, especially with larger trocar sizes ⁽⁶⁾. In particular, larger trocars (greater than 10 mm) have been associated with a significantly higher risk of wound complications, which can lead to delayed healing and prolonged hospital stays ⁽⁶⁾. These complications sometimes necessitate reoperation to address issues such as persistent infections or the need for more comprehensive wound management ⁽⁸⁾.

Reoperation rates following trocar-site hernia development are another critical factor in assessing surgical outcomes. Studies indicate that patients who develop trocar-site hernias often require follow-up surgeries to repair the hernias. The recurrence rates of these hernias are particularly high when they are not repaired correctly in the initial procedure. One study noted that up to 5% of patients with larger fascial defects required reoperation due to persistent herniation or complications related to mesh placement⁽¹¹⁾. Mesh infections, although rare, can also necessitate reoperation for mesh removal or revision⁽¹⁰⁾.

Moreover, the decision to use mesh prophylactically has been linked to a slight increase in the likelihood of follow-up surgeries due to complications like chronic pain or mesh-related infections. While mesh significantly reduces the risk of hernia recurrence, patients with complications such as mesh infection may require partial or full mesh explantation, increasing the need for reoperations⁽⁸⁾. In a comparative study, patients who had undergone prophylactic mesh placement showed a reoperation rate of 3.7% due to complications related to the mesh, while the control group without mesh showed lower reoperation rates, albeit with higher hernia recurrence⁽⁸⁾.

In conclusion, while complications such as seromas, infections, and hematomas are relatively common after laparoscopic procedures, proper fascial closure techniques and careful consideration of mesh use can help reduce the overall risk of complications. However, when complications do occur, reoperation is often necessary to manage them effectively, particularly in cases of mesh-related issues or recurrent hernias.

DISCUSSION

INTERPRETATION OF FINDINGS

The findings from the literature review reveal that trocar-site hernia formation is a multifactorial issue influenced by a range of patient-specific and surgical factors. Several studies consistently indicate that patient-related risk factors, such as age, obesity, and comorbidities like diabetes and COPD, play a significant role in increasing the likelihood of hernia development at trocar sites. For instance, the study by Bosanquet et al. (2015) identified that the incidence of incisional hernias following midline abdominal incisions is strongly correlated with these factors, with obesity and older age standing out as critical contributors (Bosanquet et al., 2015). This aligns with the findings of Ahonen-Siirtola et al. (2019), who emphasized that patients with higher BMI exhibit significantly elevated intra-abdominal pressure, which can stress fascial closures at trocar sites, leading to herniation (Ahonen-Siirtola et al., 2019).

Surgical-related factors, particularly the size and placement of trocars, have been equally well-documented as major contributors to hernia formation. Larger trocars (greater than 10 mm), as explored by Swank et al. (2012), are associated with an increased risk of herniation due to the larger fascial defect created, which may be prone to dehiscence if not closed properly (Swank et al., 2012). This notion was further supported by Kohler et al. (2019), whose findings suggested that meticulous closure of fascial defects larger than 10 mm is essential for reducing hernia risk, a point underscored by studies that specifically recommend fascial closure for all trocar sites exceeding this threshold (Kohler et al., 2019).

Additionally, trocar placement in high-tension areas, such as near the umbilicus, has been shown to further elevate the risk of hernia formation, particularly in procedures like

single-incision laparoscopic surgery (SILS), where all instruments pass through a single, larger incision. Clark et al. (2013) demonstrated that this concentrated use of one site, particularly around the umbilicus, increases the likelihood of hernias developing at this natural weak point in the abdominal wall (Clark et al., 2013). This finding echoes concerns raised by studies like that of Deerenberg et al. (2022), which recommend that surgeons avoid the umbilical site whenever possible, or at least ensure careful closure if it must be used (Deerenberg et al., 2022).

Preventive strategies, such as the use of prophylactic mesh, are gaining attention due to their effectiveness in reducing the incidence of trocar-site hernias. Kohler et al. (2019) and Borab et al. (2017) both found that using mesh prophylactically during elective laparotomies, particularly in patients at high risk for hernia formation, significantly reduces the likelihood of postoperative hernias (Kohler et al., 2019; Borab et al., 2017). However, these strategies are not without drawbacks. Complications like mesh infections or chronic postoperative pain, as observed in the study by Borab et al., can sometimes necessitate reoperation or mesh removal (Borab et al., 2017). Therefore, the decision to use mesh must balance the benefits of reducing hernia risk with the potential for complications, as highlighted in these findings.

In summary, the reviewed data suggests that hernia formation at trocar sites is the result of an interplay between patient and surgical factors. High-risk patients—particularly those who are older, obese, or have comorbid conditions—combined with the use of larger trocars or poor site selection, are most susceptible to hernia development. Preventive measures, such as meticulous fascial closure and prophylactic mesh placement, can mitigate these risks but come with their own set of challenges that must be carefully managed. The literature supports a tailored approach

that accounts for both patient risk factors and surgical techniques to minimize the occurrence of trocar-site hernias.

CONTRADICTIONS AND INCONSISTENCIES IN THE LITERATURE

A review of the literature reveals several contradictions and inconsistencies regarding the risk factors and preventive techniques for trocar-site hernia formation. One notable area of discrepancy is the role of trocar size in hernia development. While multiple studies agree that larger trocars (greater than 10 mm) significantly increase the risk of hernia formation, there is inconsistency in how different studies report the threshold size and its impact. For example, the study by Clark et al. (2013) found that trocar-site hernias predominantly occurred at 12-mm trocar sites, particularly when used near the umbilicus, suggesting that these larger incisions should be avoided or closed meticulously (Clark et al., 2013). In contrast, Swank et al. (2012) observed no significant difference in hernia incidence between 10-mm and smaller trocar sizes in certain procedures, suggesting that factors such as patient comorbidities might play a larger role than previously thought (Swank et al., 2012).

Another area of inconsistency is the use of prophylactic mesh to prevent hernias. Kohler et al. (2019) and Borab et al. (2017) both reported significant reductions in hernia formation with the use of mesh, particularly in high-risk patients. However, conflicting data emerges when considering complications associated with mesh, such as infection and chronic pain. Borab et al. (2017) reported an increased incidence of postoperative seromas and chronic pain in patients who received mesh, raising concerns about its widespread use (Borab et al., 2017). On the other hand, Kohler et al. (2019) found that these complications were minimal in their study, particularly

with the use of newer, dual-layered meshes, suggesting that mesh-related complications may be linked to the type of mesh used and its positioning during surgery (Kohler et al., 2019).

There are also inconsistencies in the reporting of patient-related risk factors. Most studies agree that obesity and older age are significant risk factors for hernia development, yet there is less consensus on the impact of comorbidities such as diabetes or COPD. For instance, Deerenberg et al. (2022) emphasized diabetes as a major risk factor for poor wound healing and subsequent hernia formation (Deerenberg et al., 2022), while Swank et al. (2012) found that diabetes had less of an impact than other factors, such as pre-existing hernias or multiple previous surgeries, which they argued were more predictive of hernia formation in their patient cohort (Swank et al., 2012).

Lastly, the efficacy of certain surgical techniques, such as fascial closure methods, remains a point of contention. Ahonen-Siirtola et al. (2019) advocated for meticulous closure of fascial defects, particularly in larger trocar sites, as a critical step in preventing hernia formation (Ahonen-Siirtola et al., 2019). However, Swank et al. (2012) noted that even with proper fascial closure, certain patients—especially those with high intra-abdominal pressure—continued to develop hernias, suggesting that closure technique alone may not be sufficient and should be combined with other preventive measures (Swank et al., 2012).

In conclusion, the literature on trocar-site hernia formation presents several contradictions, particularly regarding the impact of trocar size, the efficacy of prophylactic mesh, and the role of patient comorbidities. These inconsistencies may stem from differences in study design, patient populations, and the surgical techniques employed. Further research is needed to resolve these discrepancies and to bet-

ter understand the most effective preventive strategies for different patient groups.

CLINICAL IMPLICATIONS

The findings from the literature review suggest several important clinical applications for minimizing hernia formation in laparoscopic surgery. One key takeaway is the importance of preoperative risk assessment, particularly in patients with known risk factors such as obesity, advanced age, and comorbid conditions like diabetes and chronic obstructive pulmonary disease (COPD). The study by Deerenberg et al. (2022) emphasizes that patient-related factors should guide the choice of trocar size and placement, as larger trocars and those placed in high-tension areas like the umbilicus carry a higher risk of hernia formation.

Incorporating preventive strategies into surgical practice is essential. For example, Swank et al. (2012) demonstrated the importance of closing trocar sites greater than 10 mm to prevent fascial dehiscence and subsequent hernia formation. Similarly, Clark et al. (2013) highlighted the importance of using smaller trocars or advanced trocar designs that reduce trauma to the abdominal wall, particularly in high-risk patients.

Furthermore, advancements in trocar technology, such as radially expanding trocars, have shown promise in reducing the incidence of port-site hernias, as discussed by Chapelle et al. (2015). These trocars minimize the size of the fascial defect and can reduce postoperative complications when used appropriately.

Finally, incorporating mesh in high-risk patients or using advanced closure techniques, as suggested by Borab et al. (2017), can significantly reduce the incidence of incisional hernias following laparoscopic procedures. However, careful patient selection and a clear understanding of the potential risks and benefits are necessary to optimize outcomes in clinical practice.

LIMITATIONS OF THE STUDIES

The reviewed literature presents several limitations that could affect the validity and generalizability of the findings. One key limitation across multiple studies is the heterogeneity of study designs, patient populations, and outcome measures. For instance, Swank et al. (2012) noted that many studies included in their systematic review varied widely in terms of patient demographics and surgical techniques, which makes it challenging to draw definitive conclusions about the most effective preventive measures for hernia formation at trocar sites.

Similarly, Chapelle et al. (2015) pointed out the limited power of randomized controlled trials (RCTs) included in their review to detect significant differences in trocar-related complications. Many of the studies focused on short-term outcomes, such as postoperative pain and infection, rather than long-term hernia formation, which limits the ability to evaluate the true risk of hernia development over time.

Another common limitation is the underreporting of asymptomatic hernias. For example, the study by Agaba et al. (2014) highlighted that many patients with trocar-site hernias are asymptomatic and, as a result, do not seek medical attention. This underreporting can lead to an underestimation of the true incidence of hernia formation and may skew the data in favor of lower complication rates.

In addition, the lack of standardization in the definition of hernia formation and the use of different diagnostic tools (e.g., clinical examination versus imaging) complicates the interpretation of results. Borab et al. (2017) raised concerns about the inconsistency in the follow-up periods across studies, which ranged from months to several years, making it difficult to compare long-term outcomes reliably.

Finally, the study by Clark et al. (2013) identified another limitation related to the small sample sizes in many studies, which may limit the statistical significance of their findings. Small sample sizes can also result in a lack of generalizability to broader populations, particularly in patients with multiple risk factors for hernia formation.

In conclusion, while the reviewed studies provide valuable insights into the risk factors and preventive measures for trocar-site hernia formation, their limitations must be acknowledged. Future research should focus on larger, well-designed RCTs with standardized outcome measures and longer follow-up periods to provide more definitive evidence on the best practices for preventing hernia formation in laparoscopic surgery.

CONCLUSION

SUMMARY OF FINDINGS

This comprehensive literature review sheds light on the multifactorial nature of umbilical hernia formation at trocar sites during laparoscopic surgeries. The studies reviewed highlight both patient-related and surgical-related risk factors that contribute significantly to the incidence of trocar-site hernias. Hernia formation at trocar sites remains a significant complication, particularly in patients with certain predispositions. The overall incidence rates, though varying slightly across studies, are concerning enough to warrant focused attention on prevention strategies. In terms of patient-specific factors, advanced age, obesity (particularly a body mass index over 30), and comorbidities such as diabetes and chronic obstructive pulmonary disease (COPD) stand out as major contributors. These factors impair tissue healing and increase intra-abdominal pressure, thereby escalating the risk of hernia formation at weak points like trocar sites.

From a surgical perspective, the size of the trocar is a pivotal determinant, with trocars greater than 10 mm being more likely to result in hernias due to the larger fascial defect they create. Additionally, the number and placement of trocars also play a crucial role. Multiple trocar insertions, particularly in high-tension areas like the umbilicus, which is naturally weak, further elevate the risk of hernia formation. Single-incision laparoscopic surgery, while innovative, poses a higher risk due to the larger fascial opening required, which contributes to the overall increase in hernia incidence.

Preventive measures, such as meticulous fascial closure, the use of smaller trocars where possible, and advancements in trocar design, have shown promise in reducing hernia risk. Moreover, the use of prophylactic mesh in high-risk patients has been discussed across several studies as a viable strategy to prevent hernia formation. However, these interventions are not without their own complications, such as an increased risk of postoperative pain and infection.

The synthesis of these findings suggests that trocar-site hernia formation is influenced by a delicate interplay of multiple factors. Both patient demographics and surgical decisions contribute to the incidence and severity of this complication. As such, the responsibility of reducing hernia occurrence falls on both clinicians and surgeons, requiring a proactive and preventive approach to surgical planning and execution.

RECOMMENDATIONS FOR SURGEONS AND CLINICIANS

Based on the reviewed literature, several key recommendations can be made for surgeons and clinicians seeking to minimize the occurrence of umbilical hernias at trocar sites during laparoscopic surgery. First, patient risk stratification should be an integral part of preoperative planning. Identifying patients at high risk—those with obesity, advanced age, or underlying comorbidities—enables surgeons to take extra precautions. For instance, in high-risk patients, consideration of prophylactic mesh placement, as highlighted by Borab et al. (2017), may be warranted to reduce the likelihood of hernia formation. Although mesh placement is not without risks, such as infection or chronic pain, the benefits in high-risk populations often outweigh these concerns.

Second, careful selection of trocar size and placement is essential. Where feasible, surgeons should opt for smaller trocars, particularly those less than 10 mm, to minimize the fascial defect and thus reduce the chance of hernia formation. Additionally, the umbilicus, while convenient as a trocar insertion site, should be approached with caution due to its inherent weakness as a natural opening in the abdominal wall. Alternative sites may offer a more robust fascial closure and, consequently, a reduced risk of postoperative hernia.

Third, meticulous attention should be paid to the closure of trocar sites. In cases where trocars larger than 10 mm are used, or where multiple trocars are inserted, proper closure of the fascial defect is paramount. This includes not only ensuring that the fascial layers are properly aligned but also using suturing techniques that distribute tension evenly across the wound. Techniques such as the “small-bite” closure, which minimizes tissue strangulation and promotes better healing, should be considered as part of routine surgical practice.

Technological advancements in trocar design also offer promising avenues for reducing the risk of hernia formation. Radially expanding trocars, which minimize fascial damage by creating a smaller entry hole, have shown potential in reducing postoperative complications, including hernia formation. Surgeons should stay updated on these advancements and consider incorporating new technologies that have demonstrated efficacy in reducing complications.

Lastly, postoperative care and monitoring should not be overlooked. Patients with known risk factors for hernia formation should be monitored more closely during the postoperative period. Early detection of asymptomatic hernias, through routine clinical examinations or imaging, can allow for timely intervention before complications arise. Additionally, educating patients about the importance of limiting physical activity post-surgery to avoid excessive strain on the abdominal wall can contribute to better long-term outcomes.

SUGGESTIONS FOR FUTURE RESEARCH

While significant strides have been made in understanding trocar-site hernia formation, several gaps in the literature remain. Future research should focus on large-scale, randomized controlled trials with standardized protocols to better quantify the risk factors and effectiveness of preventive measures. The heterogeneity in study designs, patient populations, and follow-up periods across the current literature makes it difficult to draw firm conclusions on the best practices for hernia prevention. Standardized trials with uniform criteria for measuring outcomes, such as hernia incidence, postoperative pain, and long-term complications, are needed to provide more definitive guidance.

Another critical area for future research is the long-term outcomes associated with

different trocar designs and closure techniques. While the immediate postoperative benefits of certain techniques, such as small-bite closure or radially expanding trocars, have been established, there is a lack of long-term data on the recurrence rates of hernias and other complications associated with these innovations. Longitudinal studies that follow patients for several years post-surgery will be essential in determining the sustainability of these preventive measures.

The role of prophylactic mesh in hernia prevention also warrants further investigation. While several studies have demonstrated its efficacy in high-risk populations, there remains a need for more data on the optimal types of mesh and placement techniques. Research should explore whether bioabsorbable or biologic meshes offer better outcomes in terms of reducing hernia recurrence without increasing the risk of infection or chronic pain.

Finally, patient-centered outcomes, such as quality of life and long-term functional outcomes, should be incorporated into future studies. While reducing hernia incidence is a critical goal, the overall well-being of the patient, including their ability to return to normal activities and their experience of postoperative pain, should also be considered when evaluating the success of different surgical techniques.

In conclusion, the prevention of trocar-site hernias in laparoscopic surgery is a complex challenge that requires a multifaceted approach. Surgeons must carefully weigh the risks and benefits of different techniques, while future research must continue to explore innovative strategies and provide clearer guidelines for clinical practice. By addressing the current gaps in the literature and focusing on both short-term and long-term outcomes, the surgical community can move closer to reducing the incidence of this significant postoperative complication.

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