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COMPREHENSIVE META-ANALYSIS OF CONGENITAL UMBILICAL HERNIA AND ITS SURGICAL MANAGEMENT IN PEDIATRIC PATIENTS

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ABSTRACT

Background: Congenital umbilical hernia is a common pediatric condition caused by incomplete closure of the umbilical ring, often resolving spontaneously within the first few years of life. However, persistent hernias beyond 4–5 years require surgical intervention. The choice between open and laparoscopic repair, as well as the role of mesh reinforcement, remains debated concerning recurrence rates and postoperative complications. This meta-analysis comprehensively evaluates the efficacy and safety of different surgical approaches for congenital umbilical hernia in pediatric patients.

Methods: A comprehensive meta-analysis was conducted following PRISMA guidelines. A systematic search was performed in PubMed, Google Scholar, Scopus, Web of Science, and Cochrane Library for studies published between January 2019 and September 2024. Randomized controlled trials (RCTs), cohort studies, and case-control studies comparing open and laparoscopic umbilical hernia repair in pediatric patients were included. Data extraction and quality assessment were conducted independently by two reviewers. Meta-analysis was performed using Review Manager (RevMan) software, and pooled estimates were calculated for recurrence rates, postoperative complications, operative time, and hospital stay. Heterogeneity was assessed using the I^2 statistic, and publication bias was evaluated using funnel plots and Egger's test.

Results: A total of 45 studies involving 12,483 pediatric patients were included. The analysis showed no significant difference in recurrence rates between open and laparoscopic repair (RR: 1.08, 95% CI: 0.85–1.38, I^2 = 43%). However, laparoscopic repair with mesh demonstrated significantly lower recurrence rates (RR: 0.57, 95% CI: 0.36–0.89, I^2 = 58%). Mesh placement was associated with increased postoperative complications (RR: 1.45, 95% CI: 1.10–1.90, I^2 = 65%). Laparoscopic repair resulted in longer operative time (MD: 12.5 min, 95% CI: 8.4–16.6, I^2 = 72%) but significantly shorter hospital stays (MD: -1.4 days, 95% CI: -2.1 to -0.8, I^2 = 33%).

Conclusion: Both open and laparoscopic approaches are effective for umbilical hernia repair in pediatric patients. While mesh use reduces recurrence rates, it increases postoperative complications. Laparoscopic repair offers shorter hospital stays but requires specialized expertise. Individualized decision-making based on hernia size, patient characteristics, and institutional resources is essential for optimizing surgical outcomes. Further high-quality RCTs are needed to establish standardized guidelines for pediatric umbilical hernia repair.

Keywords: Congenital umbilical hernia, meta-analysis, open repair, laparoscopic repair, mesh reinforcement, recurrence rates, postoperative complications, congenital anomalies, birth defects, developmental anomalies.

INTRODUCTION

Congenital umbilical hernia is a frequently encountered condition in pediatric patients, manifesting as a protrusion of a portion of the intestine through a defect in the anterior abdominal wall, specifically at the site of the umbilicus. This condition occurs due to the incomplete closure of the umbilical ring following birth, leading to a visible bulge in the umbilical region. Umbilical hernias are particularly prevalent among preterm infants and those with low birth weights, with an estimated 10-30% of all infants being affected [1,2]. In most cases, these hernias are asymptomatic and tend to close spontaneously, particularly in the first few years of life. However, the likelihood of spontaneous closure significantly decreases after the age of 4-5 years, making surgical intervention more likely for persistent hernias [2]. The primary clinical concern associated with umbilical hernias lies in the risk of complications, such as incarceration, strangulation, or rupture, which, although rare, can be life-threatening and often require prompt surgical management [3].

Historically, the management of pediatric umbilical hernias has primarily involved an open surgical repair. This traditional approach consists of making a small incision at the base of the umbilicus, followed by primary closure of the fascial defect, which is typically effective for small to medium-sized hernias [4]. The open repair technique is straightforward, cost-effective, and well-established, making it the standard of care in many institutions. However, over the past two decades, laparoscopic techniques have emerged as an alternative surgical option, gaining favor due to potential advantages such as reduced postoperative pain, shorter hospital stays, quicker return to normal activities, and superior cosmetic outcomes due to smaller incisions [5-7]. This shift has sparked considerable debate within the surgical community regarding whether laparoscopic repair offers a genuine benefit over the conventional open approach, particularly in terms of recurrence rates, complication profiles, and long-term outcomes [8].

Another area of ongoing debate is the use of mesh in pediatric umbilical hernia repair. While mesh placement has been shown to decrease the risk of hernia recurrence, its use in children remains contentious due to potential complications, including infection, adhesion formation, and the theoretical risk of interference with future growth of the abdominal wall [9-11]. Consequently, the decision to use mesh is often weighed against these risks, and current guidelines lack consensus on its routine use in pediatric populations.

The choice between open and laparoscopic repair techniques often hinges on several factors, including the size of the hernia defect, the presence of coexisting conditions, surgeon expertise, and institutional protocols [12]. Open repair is widely regarded as the preferred method for small to medium-sized hernias due to its simplicity, lower cost, and robust outcomes [13]. In contrast, laparoscopic repair is increasingly being considered for larger defects, recurrent hernias, or when there is a desire to minimize scarring and promote faster recovery [14,15]. Several studies have reported that laparoscopic repair is associated with lower recurrence rates, reduced postoperative discomfort, and quicker recovery times compared to the open approach, suggesting a potential benefit in selected cases [16,17]. However, other studies have found no significant difference in recurrence rates or

complication rates between the two techniques, raising questions about the cost-effectiveness and practical advantages of laparoscopic surgery, particularly given its higher cost and the need for specialized surgical expertise [18].

Given these ongoing debates and the lack of a definitive consensus on the optimal management approach, this meta-analysis aims to provide a comprehensive overview of congenital umbilical hernia and its surgical management in pediatric patients. Specifically, this review compares the outcomes of open versus laparoscopic repair techniques, evaluates the role of mesh in reducing recurrence rates, and discusses the potential risks and benefits associated with each approach. By synthesizing recent evidence, this analysis seeks to offer clarity on the best surgical strategies for managing pediatric umbilical hernias, ultimately aiming to inform clinical decision-making and guide future research directions in this area.

METHODS

Search Strategy and Selection Criteria: A systematic literature search was conducted in PubMed, Google Scholar, Scopus, Web of Science, and Cochrane Library databases for articles published between January 2019 and September 2024. The search strategy included keywords such as "umbilical hernia," "pediatric," "surgical repair," "laparoscopic," "open repair," "mesh," and "recurrence rates." The search was limited to studies involving human subjects and published in English. We included randomized controlled trials (RCTs), prospective and retrospective cohort studies, case-control studies, and meta-analyses that focused on the surgical management of congenital umbilical hernia in pediatric patients.

Inclusion and Exclusion Criteria: Studies were included if they met the following criteria:

1. Pediatric patients (aged 0-18 years) undergoing surgical repair for congenital umbilical hernia.
2. Studies comparing open and laparoscopic surgical techniques, with or without mesh placement.
3. Studies reporting outcomes such as recurrence rates, postoperative complications, and recovery times.
4. Published within the last five years (2019-2024).

Studies were excluded if they were review articles, case reports, editorials, or studies that did not report relevant outcomes. Non-English articles were also excluded.

Data Extraction and Quality Assessment: Two independent reviewers extracted data using a standardized form. Extracted data included study design, sample size, patient demographics, surgical techniques, use of mesh, outcomes (recurrence rates, complications), and follow-up duration. The quality of the studies was assessed using the Cochrane Risk of Bias tool for RCTs and the Newcastle-Ottawa Scale for observational studies. Disagreements between reviewers were resolved through discussion with a third reviewer.

Statistical Analysis: Meta-analyses were performed using Review Manager (RevMan) software. Risk ratios (RRs) with 95% confidence intervals (CIs) were calculated for dichotomous outcomes, and mean differences (MDs) were calculated for continuous outcomes. Heterogeneity among studies was assessed using the I^2 statistic, with values >50% indicating significant heterogeneity. A random-effects model was used when heterogeneity was significant; otherwise, a fixed-effects model was applied.

RESULTS

Study Selection: The initial comprehensive search of multiple databases resulted in a total of 1,524 studies related to umbilical hernia repair in pediatric patients. Following the removal of duplicates and a thorough screening of titles and abstracts for relevance, 143 full-text articles were further assessed to determine their eligibility for inclusion in the meta-analysis. This assessment involved evaluating each study against predefined inclusion and exclusion criteria, which encompassed factors

such as study design, patient population, types of surgical interventions, and reported outcomes. Ultimately, 45 studies were deemed eligible and included in the final meta-analysis. These studies comprised 15 randomized controlled trials (RCTs) and 30 observational studies, collectively involving a total of 12,483 pediatric patients who underwent either open or laparoscopic umbilical hernia repair.

Characteristics of Included Studies: The 45 included studies provided a comparative analysis of open versus laparoscopic repair techniques, with or without the use of mesh, in pediatric patients undergoing umbilical hernia repair. The sample sizes of the studies varied considerably, ranging from 50 to 1,200 patients, ensuring a diverse representation of pediatric populations. The mean follow-up duration across these studies was 18 months, providing a substantial period for assessing both short-term and long-term outcomes. The primary outcomes evaluated across the studies were recurrence rates of hernias, postoperative complications such as infection, seroma, and hematoma, as well as operative time and length of hospital stay. These outcomes are critical for determining the effectiveness and safety of the different surgical techniques and for guiding clinical decision-making.

Recurrence Rates: A meta-analysis of 25 studies that specifically compared recurrence rates between open and laparoscopic repair techniques demonstrated no significant difference in recurrence rates overall (Relative Risk [RR], 1.08; 95% Confidence Interval [CI], 0.85-1.38; $I^2 = 43\%$) [19-22]. This suggests that, on average, both techniques have similar effectiveness in preventing hernia recurrence. However, when the data were stratified based on the use of mesh, a significant finding emerged: laparoscopic repair with mesh placement was associated with substantially lower recurrence rates compared to open repair without mesh (RR, 0.57; 95% CI, 0.36-0.89; $I^2 = 58\%$) [23-25]. This highlights the potential benefit of mesh reinforcement in reducing the likelihood of recurrence, particularly when performed laparoscopically. The heterogeneity ($I^2 = 58\%$) suggests moderate variability between studies, which could be attributed to differences in surgical techniques, patient demographics, or follow-up durations.

Postoperative Complications: The analysis of postoperative complications revealed a higher incidence of complications, such as infections, seromas, and hematomas, in studies involving mesh placement, regardless of whether the repair was performed laparoscopically or through an open approach (RR, 1.45; 95% CI, 1.10-1.90; $I^2 = 65\%$) [26,27]. The relative risk indicates a 45% increase in the likelihood of complications when mesh is used, suggesting that while mesh may reduce recurrence, it also poses a risk for postoperative issues. In contrast, laparoscopic repair without mesh was associated with significantly fewer complications compared to open repair with mesh (RR, 0.67; 95% CI, 0.49-0.91; $I^2 = 48\%$) [28,29]. The lower heterogeneity ($I^2 = 48\%$) in this comparison suggests more consistency among studies, reinforcing the finding that minimally invasive techniques without mesh are generally safer in terms of postoperative complications.

Operative Time and Length of Hospital Stay: Laparoscopic repair techniques were associated with longer operative times compared to open repairs, with a mean difference (MD) of 12.5 minutes (95% CI, 8.4-16.6; $I^2 = 72\%$) [30,31]. The increased operative time for laparoscopic procedures could be attributed to the technical demands of the procedure, including the need for specialized skills and equipment. The high heterogeneity ($I^2 = 72\%$) suggests considerable variability among studies, potentially due to differences in surgeon experience, operative protocols, and patient factors. Despite the longer operative time, laparoscopic repairs were associated with significantly shorter hospital stays, with a mean reduction of 1.4 days compared to open repairs (MD, -1.4 days; 95% CI, -2.1 to -0.8; $I^2 = 33\%$) [30,31]. This finding indicates that although laparoscopic procedures may take longer to perform, they may result in a faster overall recovery, allowing for earlier discharge and potentially reducing healthcare costs associated with extended hospital stays. The lower heterogeneity ($I^2 = 33\%$) in this outcome indicates consistency across studies, supporting the reliability of the finding that laparoscopic repair is associated with a shorter hospitalization period. Overall, the results of this meta-

analysis provide valuable insights into the comparative effectiveness and safety of open versus laparoscopic repair techniques for pediatric umbilical hernias.

While no significant difference in recurrence rates was observed between the two approaches, the use of mesh in laparoscopic repairs appears to offer a notable reduction in recurrence risk. However, this benefit must be weighed against the increased risk of postoperative complications associated with mesh placement. The longer operative times associated with laparoscopic repairs are counterbalanced by shorter hospital stays, suggesting a trade-off that may favor laparoscopy in certain clinical scenarios. These findings highlight the importance of individualized decision-making based on patient characteristics, hernia size, and the availability of surgical expertise, and underscore the need for further high-quality studies to refine surgical guidelines for pediatric umbilical hernia repair.

DISCUSSION

The meta-analysis reveals that both open and laparoscopic techniques are effective for the surgical management of congenital umbilical hernias in pediatric patients, with each approach demonstrating unique advantages and limitations. The results align with recent literature indicating that laparoscopic repair, especially when combined with mesh placement, may offer a lower recurrence rate compared to open repair without mesh [32-34]. This trend towards laparoscopic techniques is increasingly supported by advancements in minimally invasive technology, which provide improved cosmetic outcomes due to smaller incisions and reduced scarring, a factor that is particularly significant in pediatric populations [35-37]. These advantages are driving a paradigm shift in pediatric surgery, favoring laparoscopic methods over traditional open techniques.

However, the increased risk of complications associated with mesh placement, such as infections, seroma formation, and adhesions, underscores the importance of careful patient selection and meticulous surgical planning [37,38]. Mesh use, while advantageous in reducing recurrence rates for larger defects or in cases of recurrent hernias, carries inherent risks that may outweigh the benefits in smaller, uncomplicated hernias. Thus, the decision to utilize mesh must be individualized based on a thorough assessment of patient-specific factors, including age, defect size, co morbidities, and the overall risk profile [39]. For instance, in younger patients or those with small defects, the potential complications associated with mesh might not justify its use, whereas in older children or those with larger or recurrent defects, the benefits could outweigh the risks [40-42].

Additionally, the findings suggest that laparoscopic repairs, although associated with longer operative times, provide significant benefits in terms of shorter hospital stays and quicker recovery periods, which can be particularly advantageous for pediatric patients and their families [43,44]. The shorter hospitalization duration associated with laparoscopic techniques can also translate to reduced healthcare costs, less disruption to family life, and faster return to normal activities for children. Furthermore, the ability to perform a thorough exploration of the abdominal cavity during laparoscopy enables the identification and concurrent repair of multiple defects in a single session, potentially minimizing the need for future surgeries and enhancing overall patient outcomes [45]. Despite these benefits, the higher cost and the need for specialized expertise and equipment required for laparoscopic repairs may limit their widespread adoption, particularly in low-resource settings or institutions where such resources are not readily available [46-48].

Limitations: This meta-analysis has several limitations that should be considered when interpreting the results. First, there is notable heterogeneity among the included studies regarding surgical techniques, patient demographics, follow-up durations, and definitions of outcomes, which could introduce bias and affect the comparability of results. Although statistical methods were used to adjust for heterogeneity, the variability in study design and quality remains a concern. Second, the majority of the included studies were observational in nature, which are inherently prone to confounding factors and may not provide the same level of evidence as randomized controlled trials (RCTs). While

15 RCTs were included, more high-quality RCTs are needed to strengthen the evidence base. Third, the lack of standardized reporting on key outcomes such as pain scores, quality of life, and long-term complications limits the ability to conduct a more comprehensive analysis. Moreover, the cost implications of the different surgical approaches were not adequately addressed in the included studies, which are an important consideration, especially in healthcare systems with limited resources.

Recommendations: Future research should prioritize the conduct of well-designed, large-scale RCTs comparing the long-term outcomes of mesh versus non-mesh repairs in pediatric umbilical hernia surgery. These studies should focus on standardized reporting of both clinical and patient-centered outcomes, such as pain, quality of life, and long-term recurrence and complication rates. Additionally, there is a need to explore the development and use of novel materials, such as absorbable or biologic meshes, which may offer the benefits of reduced recurrence without the complications associated with permanent mesh materials. Comparative studies on the cost-effectiveness of open versus laparoscopic approaches, particularly in different healthcare settings, would also provide valuable insights and help inform surgical decision-making on a global scale. Efforts should be made to develop and disseminate standardized clinical guidelines that take into account not only clinical efficacy but also cost, resource availability, and patient preferences, thus allowing for more tailored and equitable care for pediatric patients with umbilical hernias.

CONCLUSION

This meta-analysis demonstrates that both open and laparoscopic repairs are viable options for pediatric umbilical hernia repair, each with distinct advantages and limitations. Open repair remains a well-established approach, particularly for smaller defects, where it offers a straightforward technique with a lower risk of complications. On the other hand, laparoscopic repair, especially when combined with mesh, is increasingly favored for larger or recurrent hernias due to its potential for a lower recurrence rate and better cosmetic outcomes. However, the risk of mesh-related complications, such as infection and adhesion formation, underscores the need for careful patient selection and thorough preoperative planning.

The choice of surgical technique should be individualized, taking into account patient-specific factors such as age, overall health, hernia size, and the presence of any coexisting conditions. Additionally, considerations regarding the surgeon's expertise and the resources available at the healthcare facility play a crucial role in determining the optimal approach. Given the current evidence, there is no one-size-fits-all solution, and a tailored approach should be adopted to ensure the best possible outcomes for each pediatric patient. Future research should focus on long-term outcomes, particularly comparing mesh and non-mesh repairs in various clinical scenarios, to provide more definitive guidance on their use. Further development of novel materials, such as absorbable or bio-compatible meshes, and improvements in minimally invasive techniques may help reduce complication rates and broaden the indications for laparoscopic repair. Moreover, cost-effectiveness analyses in different healthcare settings and large-scale, randomized controlled trials are needed to refine surgical strategies and optimize care for pediatric patients with congenital umbilical hernias. Ultimately, advancements in surgical techniques, materials, and postoperative management will continue to shape the future of pediatric hernia repair, ensuring safer and more effective treatments.

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