

REVIEWS

Embryological Basis and Comparative Outcomes of Open versus Laparoscopic Repair in Pediatric Congenital Inguinal Hernia: A Narrative Review

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Congenital inguinal hernias, arising from failed processus vaginalis and canal of Nuck involution, are among the most common pediatric conditions, with an incidence of 160 per 1,000 in very low birth weight infants. While open herniotomy has long been the gold standard, laparoscopic repair has gained popularity in recent decades. This review discusses the embryological basis of congenital inguinal hernias and compares two surgical techniques, open hernia repair and laparoscopic hernia repair, weighing the risks and benefits of each to help determine which approach should be the standard for pediatric patients. The literature presents conflicting findings and the preferred surgical method remains controversial as surgeons must weigh several clinical considerations. Open hernia repair offers the clear benefits of lower same-side recurrence, less pain, and the option of using caudal anesthesia. On the other hand, laparoscopic repair provides a decrease in some postoperative complications, shorter hospital stays, and the ability to detect contralateral defects. While laparoscopy offers some advantages in complication rates and contralateral assessment, this review concludes that open herniotomy remains a dependable and often preferable standard. Ultimately, the choice between techniques requires an individualized approach, balancing the superior same-side recurrence profile of open repair against the diagnostic and minimally invasive benefits of the laparoscopic method. This review further examines clinical diagnostic markers, the role of ultrasonography, and future innovations like robotics and percutaneous closures, weighing their clinical benefits against emerging economic consideration.

Introduction

The annual incidence of congenital inguinal hernias in very-low-birth-weight preterm infants is high, with studies demonstrating rates of 160 per 1000 (16%) overall and as high as 260 per 1000 (26%) among male infants.¹ Unlike acquired hernias in adults, the pediatric form originates from a failure of the processus vaginalis (in males) or the canal of Nuck (in females) to obliterate following gonadal descent. These structures are embryological evaginations of the parietal peritoneum that, when they remain patent, create a direct pathway for herniation. This creates a persistent communication with the peritoneal cavity, providing the anatomical path for a congenital

hernia.² Anatomically, an inguinal hernia is a protrusion of intra-abdominal or extraperitoneal contents through an opening in the myofascial plane of the oblique and transversalis muscles. Indirect inguinal hernias are the near-universal type in the pediatric population and are situated lateral to the inferior epigastric vessels. These hernias typically present as a bulge in the groin that can change in size, especially with increases in intra-abdominal pressure. Herniation may lead to strangulation of the trapped contents, a serious complication that makes rapid recognition and treatment essential.³

The definitive treatment for an inguinal hernia is surgical repair. Symptomatic hernias are typically repaired to prevent incarceration and other acute complications, with open herniotomy and laparoscopic repair representing the two predominant surgical modalities. The open method is traditionally considered the gold standard, but laparoscopy has gained traction recently, increasing in estimated use by 5-fold, from 3% to 15%, in the United States from 2009-2018, though the reasons behind this trend, while likely multifactorial, are still unclear.⁴ A debate persists in the current literature regarding the optimal technique. Regardless of method, both are associated with favorable outcomes and are commonly performed in outpatient settings.³ The “ideal” management of pediatric inguinal hernias remains elusive because clinicians must navigate several anatomical, diagnostic, and technical trade-offs. There is a lack of synthesis regarding how embryological development factors, combined with modern diagnostic modalities and anesthetic concerns, should influence the choice of repair.

This review aims to elucidate the complex embryological pathogenesis of inguinal hernia and its potential role in clinical management. By narrowing our focus to the most critical surgical trade-offs, including recurrence profiles and anesthetic safety, and the role of emerging robotic devices, we provide a targeted comparative analysis. Our objective is to provide an evidence-based framework that helps clinicians navigate these variables to select the most appropriate surgical approach for each patient’s unique biological risk.

Embryological Pathogenesis of Inguinal Hernia

In males, the testes start out in a retroperitoneal position, near the developing kidneys. Between gestational weeks 28 and 36, they descend into the scrotum, guided by a fibrous cord called the gubernaculum. This descent is accompanied by the processus vaginalis, which appears around week 12 of gestation. The developmental sequence begins with the formation of the gubernaculum, a cord that anchors the retroperitoneal testes, located near the developing kidneys. The gubernaculum serves as a guide for the descent for their eventual migration. The processus vaginalis follows the gubernaculum’s path throughout the abdominal wall. It is widely accepted that testicular descent happens in two phases: an abdominal stage (from the abdomen to the

deep inguinal ring) and an inguinoscrotal stage (passing through the inguinal canal to the scrotum).^{5,6} The canal of Nuck, a small peritoneal pouch, is the female equivalent of the processus vaginalis.

Typically, the processus vaginalis/canal of Nuck closure allows the deep inguinal ring to seal while the distal part of the processus vaginalis remains as the tunica vaginalis around the testes. While this closure is often completed after birth, the processus vaginalis can remain patent, leaving a direct pathway for intra-abdominal organs to bulge out and form a hernia. This condition is more common in males because testicular descent is a longer and more complex process than the migration of the ovaries in females. Interestingly, because the left testis descends first, indirect hernias are more commonly found on the right side.⁶

In females, gonadal descent is similar but lacks the final external migration. The ovaries descend caudally, guided by the gubernaculum, which ultimately forms the ovarian ligament and the round ligament of the uterus. The canal of Nuck may accompany the round ligament through the inguinal canal. While the canal of Nuck normally closes in early childhood, a persistent, patent canal can predispose females to inguinal hernia.²

Histological and Molecular Drivers of Herniation

Although patent processus vaginalis is a necessary but not sufficient condition for a hernia, its presence does not guarantee a hernia will form, suggesting that other factors are at play. Studies have looked for these additional factors, with smooth muscle presence being a key finding. In 1999, Tanyel et al⁷ conducted a histological study comparing 41 tissue samples, including both male and female inguinal hernia sacs, with hydrocele and undescended testis controls. A hydrocele involves a pathway narrow enough to allow only peritoneal fluid to pass, and undescended testes involve a processus vaginalis that may be patent but rarely progresses to herniation. Using immunohistochemical staining, the study demonstrated that smooth muscle layers were present within the walls of hernia sacs in both males and females but were entirely absent in normal peritoneum and processus vaginalis samples. Furthermore, while hydrocele sacs contained only patchy bundles of smooth muscle, sacs from undescended testes rarely showed them. These findings suggest that the persistence of organized smooth muscle is a primary etiologic factor that prevents the natural obliteration of the inguinal pathway.⁷

A more recent study⁸ explored this further, looking at smooth muscle phenotype. It found that desmin and α -smooth muscle actin, markers for mature smooth muscle, were more common in inguinal hernia and hydrocele sacs than in tissue from undescended testes. The hernia specimens had a

higher density of myofibroblasts. This finding may represent a failed attempt at dedifferentiation from smooth muscle back to fibroblasts, a process that is critical for the processus vaginalis to close properly.⁸

Other factors have been proposed, including collagen subtypes and the gut microbiota. Type I collagen provides mature tensile strength, whereas type III is more distensible and associated with immature tissue. A study by Taniguchi et al⁹ investigated these ratios in the pediatric population and found no significant difference in collagen between infants with hernias and healthy controls ($P=.92$). This suggests that congenital inguinal hernias in infants are not caused by systemic collagen deficiency, unlike in adult populations where tissue weakness is a primary driver. Instead, these findings reinforce the conclusion that pediatric hernias are a developmental failure of processus vaginalis obliteration, rather than a structural tissue weakness, meaning that the closure of a persistent sac is an adequate and definitive treatment.⁹

The gut microbiota may be involved in the development of inguinal hernia. A Mendelian randomization analysis found a direct causative link between six groups of intestinal flora (like *Eubacterium brachygroup*) and inguinal hernia formation. Conversely, eight other groups (including *Lactobacillales*) seemed to offer protection. While more research is needed, the current literature suggests that this protective flora may reduce the occurrence of inguinal hernia by preserving the intestinal barrier and delaying skeletal muscle atrophy.¹⁰

In summary, while the basic mechanism of a failed processus vaginalis and canal of Nuck closure is well-understood, emerging evidence points to secondary factors. The presence of smooth muscle appears to be a key component in inguinal hernias, whereas collagen deficiency does not appear to contribute to the development of inguinal hernias in infants. The influence of the gut microbiome is a new and exciting finding that warrants further investigation.

Clinical Presentation and Diagnosis

Congenital inguinal hernias are far more common in males, who account for over 90% of all cases, likely due to the higher frequency of a patent processus vaginalis.¹¹ The classic signs are a noticeable swelling and, at times, pain in the groin. This bulge can fluctuate in size and severity based on activity or time of day for both males and females. For instance, coughing increases intra-abdominal pressure and can push the hernia contents farther out, making the bulge larger.³

Diagnosis rests on conducting a thorough patient history and physical examination. The examination begins with the patient standing, first with inspection for a visible bulge and then palpation of the groin and, in males, the scrotum. If no bulge is apparent, the patient can be asked to cough

or perform a Valsalva maneuver to increase intra-abdominal pressure and reveal the hernia.³ For infants, a clinician can elicit a cry (perhaps by gently restricting movement on the examination table) to achieve the same effect and make the bulge visible.⁶ It is critical to examine both sides and not just the symptomatic side, to assess for asymmetry.

If a patient's history suggests a hernia but one cannot be found on physical examination, imaging can be used to search for intestinal contents in the inguinal canal or the processus vaginalis/canal of Nuck. This also allows for the assessment of potential ischemic damage to the intestines, ovaries, or testes.¹² Ultrasonography, magnetic resonance imaging, or computed tomography are all options; however, either ultrasound or computed tomography is typically recommended due to their high sensitivity and cost-effectiveness in detecting inguinal hernias.³

Surgical Management Approaches

The definitive treatment for a congenital inguinal hernia is surgical repair. The two most common techniques are the traditional open repair and the more modern laparoscopic approach.

Traditional Open Herniotomy

Open repairs fall into two main categories: tissue repairs and prosthetic, mesh-based repairs. Tissue repairs, which use the patient's own native tissue to close the defect, are generally reserved for emergency cases or in a contaminated surgical field where the viability of the hernia contents is in question. In this procedure, the surgeon makes a small incision in a lower abdominal skin crease to access the hernia sac. The sac is then carefully dissected away from the spermatic cord (in males) or the round ligament (in females), taking great care not to damage these delicate structures. Finally, the base of the sac is tied off with a suture to close the communication with the abdominal cavity, and the incision is closed.¹³

Surgeons have adapted open pediatric hernia repairs based on a child's age, primarily relying on the Mitchell-Banks and Ferguson techniques. Infants have a short, straight inguinal canal, and the Mitchell-Banks method is often ideal as it allows for high ligation of the sac without needing to open the canal itself. The Ferguson method, involving opening and reinforcing the canal, is generally used in older children with a more developed anatomy.¹⁴ A large retrospective review¹⁵ of 4520 boys older than two years found that the Mitchell-Banks approach is safe even as children grow, with complication (2.9%) and recurrence (0.1%) rates nearly identical ($P>.05$) to those of the Ferguson technique (2.3% and 0.1%, respectively).

Laparoscopic Inguinal Hernia Repair

A laparoscopic repair is a minimally invasive surgery performed with the patient under general anesthesia. The surgeon uses a camera and small incisions to repair the hernia defect from the inside.¹⁶ In China, where laparoscopic repairs are more commonly performed than open repair, laparoscopic sac high ligation was the predominant method used in children younger than 13 years, ranging from 96.8% in children aged 0 to 3 years to 61.1% in children aged 10 to 12 years.¹⁷ In contrast, open and laparoscopic tension-free techniques are more commonly performed to repair inguinal hernias in adolescents and young adults older than 13 years (92.4%-100%, depending on age group).¹⁷ Laparoscopic procedures are associated with higher operative costs and a steep learning curve, requiring up to 250 repairs for some surgeons to master the technique. In a country like the United States, where open repair is still more commonly performed, the cost and training required for widespread adoption of laparoscopic repair present considerable challenges.³

Comparing Surgical Approaches

The debate over the optimal surgical approach for pediatric congenital inguinal hernias is ongoing, as both open and laparoscopic methods have advantages and disadvantages. While laparoscopic sac ligation is now frequently used in China for young children, open repair continues to dominate in the United States and Germany, possibly due to differences in surgical training and experience. Both methods are considered safe, and a large cohort study of adolescents in China (n=3249) found no significant differences between the two techniques in complication rates.¹⁷

A notable advantage of open surgery is its confirmed compatibility with regional techniques, such as caudal or spinal anesthesia. Unlike laparoscopy, which typically necessitates general anesthesia with airway protection, open repair relies only on localized somatic coverage of the groin.¹⁸ Robust randomized data from the general anesthesia or awake-regional anesthesia in infancy (GAS) trial¹⁹ involving 722 infants demonstrate equivalence in 5-year neurodevelopmental outcomes between patients receiving either awake-regional and short-duration general anesthesia for hernia repair. However, findings from a meta-analysis by Reighard et al²⁰ suggest associations between repeated or prolonged general anesthesia and worse outcomes across multiple neurodevelopmental domains. Specifically, childhood exposure to general anesthesia is linked to an increase in behavioral problems, deficits in executive and motor function, and a higher incidence of neurodevelopmental disorder diagnoses, including attention-deficit/hyperactivity disorder. Thus, the ability to use regional anesthesia in open procedures remains a valuable option for mitigating specific cumulative risks for infants who may have undergone multiple other surgical procedures requiring general anesthesia. While open

repair has been performed safely for decades, it is not without complications. A retrospective study of 1072 patients younger than 18 years found that 5 of 836 open herniotomy cases had surgical complications, including omentum necrosis, temporary femoral nerve dysfunction, and surgical site infection.²¹ This shows that, while rare, adverse outcomes can occur.

A key advantage of laparoscopy is the reduced tissue trauma to vital structures like the vas deferens or spermatic vessels.¹⁷ One retrospective study²² from China (n=495) assessing the adolescent population found that laparoscopic repair led to significantly shorter hospital stays, less blood loss, and fewer postoperative complications (like bleeding, hematoma, infection, and urinary retention) compared with open surgery. This study also noted lower rates of hernia recurrence and chronic pain.

The question of recurrence after open vs laparoscopic repair is complex. A large Chinese study (n=17,459) found the overall recurrence rate to be significantly lower ($P<.001$) in children younger than 16 years after laparoscopic surgery,²³ but other studies reveal a more nuanced reality involving a direct clinical trade-off between open vs laparoscopic approaches. Laparoscopy reduces the development of new hernias on the opposite side but has a higher risk of same-side recurrence. A Canadian retrospective study²⁴ (n=1952) that intentionally included surgeons with variable laparoscopic skill also found that laparoscopy reduced metachronous hernias (a new hernia on the opposite side, $P=.047$) but had a higher overall same-side recurrence rate ($P<.001$), even when adjusting for clinical confounders such as age, sex, prematurity, and emergency status. It also found no evidence of a learning curve effect over the multi-year study period. A large US study²⁵ of 53,287 children had similar findings and demonstrated that same-side recurrence was significantly higher after laparoscopy (1.5%) compared with open repair (0.4%) ($P<.001$). In another retrospective multicenter US study²⁶ comparing these techniques, researchers found that laparoscopic repair was associated with significantly shorter mean operative times (23 vs 522 minutes, $P<.01$). The study also noted a trend in recurrence for the laparoscopic vs open cohort (2.7% vs 0.65%), but this difference did not reach statistical significance ($P>.20$), suggesting that both methods offer similar safety and outcome profiles.

The US study by Carter et al²⁵ also highlighted a major benefit of the laparoscopic approach: the ability to identify and repair a contralateral patent processus vaginalis (CPPV) during the same operation, potentially preventing a future surgery. The routine closure of CPPVs is thought to be the reason for the reduced metachronous hernia rate; however, measuring the efficacy of this routine closure is limited by its high number needed to treat. Estimates suggest that 21 CPPVs must be closed to prevent one future metachronous hernia, indicating potential overtreatment.¹⁷

Postoperative pain is another crucial factor to compare. A 2024 single-center study²⁷ using the revised Face, Legs, Activity, Cry, and Consolability (FLACC) pain scale found that while overall pain scores for both surgical approaches were low (0.21 for open vs. 0.44 for laparoscopy), the difference in children younger than 2 years was more obvious: a score of 0.09 in the open group vs 0.62 in the laparoscopic group ($P<.05$). However, both scores were within the “relaxed” to “mild discomfort” range of the 10-point FLACC scale, and the study found no significant difference in the clinical need for additional postoperative painkillers. However, measures such as the FLACC scale have uncertain clinical significance. A recent study aimed to use a more objective physiologic measure of pain. Sakthivel et al²⁸ used the Newborn Infant Physical Examination monitor, which measures heart rate variability, and found that laparoscopy was associated with significantly higher intraoperative and postoperative pain in children younger than 2 years ($P<.001$ and $P=.002$, respectively). This difference was clinically important: The laparoscopic cohort frequently crossed the physiological threshold for “severe pain” and required higher doses of intraoperative and postoperative analgesia compared with the open repair group. Therefore, laparoscopy has a possible clinical disadvantage with respect to intraoperative and postoperative pain management in this vulnerable age group.

Overall, both open and laparoscopic methods are safe and effective options for repairing pediatric inguinal hernias, but they serve different clinical priorities. Open repair remains a reliable choice, favored for its low same-side recurrence rates, better pain profile in infants, and compatibility with regional anesthesia. Laparoscopy, meanwhile, reduces tissue trauma and allows for simultaneous evaluation of the contralateral side, though this comes with the caveat of potential overtreatment. Because neither approach is perfect for every scenario, the surgical decision should be tailored to the individual patient, weighing their age, anatomy, and cumulative anesthetic risk.

Special Considerations

Beyond the standard comparative metrics of recurrence and postoperative pain, several unique clinical and logistical factors influence the choice of surgical approach. Evaluating special populations alongside variables like surgeon experience and financial cost is essential for comprehensive, individualized decision-making.

Incarcerated Inguinal Hernias

Incarceration, where hernia contents become trapped, is one of the most frequent pediatric surgical emergencies, occurring in up to one in six cases of indirect inguinal hernias. It presents as a firm, painful mass and can be accompanied by nausea and vomiting. Given the high risk of complications, a comparison of techniques is crucial. An observational study²⁹ in China

Table 1. Comparison of Open vs Laparoscopic Surgical Repair of Pediatric Congenital Inguinal Hernia

Feature	Open Herniotomy (Gold Standard)	Laparoscopic Repair
Primary Approach	Inguinal incision, external dissection, and high ligation of the hernia sac. Often uses Lichtenstein repair principles.	Minimally invasive approach using internal visualization via a laparoscope to close the deep inguinal ring.
Anesthesia	Flexible; can be performed under regional techniques (eg, caudally) to limit general exposure.	Typically requires general anesthesia, which carries concerns regarding neurodevelopment in very young children.
Recurrence Risk	Associated with lower rates of same side recurrence.	Higher reported same-side recurrence, which may be influenced by surgeon experience with laparoscopy.
Contralateral Side	Requires a separate procedure if a hernia develops on the opposite side at a later date.	Allows for visualization and simultaneous repair of a contralateral patent processus vaginalis (CPPV), reducing metachronous hernia rates.
Postoperative Pain	Linked to lower acute physiological pain markers in infants younger than two years.	May involve paradoxically higher acute pain levels in infants despite the smaller incisions.
Complications	Low overall risk; the primary technical concern is injury to spermatic cord structures.	Often shows reduced wound infection rates; carries a rare risk of internal injury.
Resource Factors	Cost-effective approach with an established, shorter learning curve for surgeons.	Higher associated equipment costs and more demanding learning curve for proficiency.

found that laparoscopic repair in these emergency cases offered several advantages, including reduced trauma, quicker recovery, shorter hospital stays (1.64 vs. 8.39 hours), and fewer postoperative complications.

Preterm Infants

The vulnerable population of preterm infants presents unique challenges. A Korean study³⁰ of 149 preterm infants compared those undergoing repair in the neonatal intensive care unit (NICU) with those who had delayed surgery until after discharge. Early repair in the NICU is often necessary due to comorbidities such as bronchopulmonary dysplasia, neonatal respiratory distress syndrome, necrotizing enterocolitis, intraventricular hemorrhage, and sepsis. However, these early repairs were also associated with higher risks, including hernia recurrence and respiratory insufficiency. The specific surgical approach, whether open or laparoscopic, did not impact the likelihood of recurrence ($P=.32$). The study identified preoperative ventilator dependence and body weight less than 3000 g as the primary drivers of recurrence. Mechanically, ventilators increase intra-abdominal pressure, which puts constant physical stress on a fresh repair. From a technical standpoint, infants weighing less than 3,000 g have extremely “fragile” or “friable” tissues, making it more challenging for a surgeon to achieve a perfect high ligation of the sac.³⁰ These findings suggest that for these more fragile infants, the timing of the procedure and the patient’s physiological state (weight and respiratory status) appear more critical to a successful outcome than the choice of surgical technique itself.

Surgeon Experience

The laparoscopic approach emerged in the 1990s as an alternative surgical method for inguinal hernia repair, and the technique became more commonplace in the late 2000s and 2010s.⁴ A recent qualitative survey³¹ of pediatric surgeons in the eastern United States demonstrated a generational shift in preference: more than 90% of early-career surgeons (0-10 years' experience) prefer the laparoscopic approach, whereas less than 20% of late-career surgeons (>20 years' experience) prefer it ($P<.001$). Senior surgeons expressed a preference for the open technique because of its ability to excise the redundant hernia sac while avoiding entry into the abdominal cavity. In contrast, those preferring laparoscopy cite its technical ease to perform on infants, the ability to confirm the hernia before beginning the repair, and the ability to assess the contralateral side to prevent future metachronous hernias.³¹ As surgical training evolves, preferences will likely continue to shift toward laparoscopy, potentially redefining the standard of care. A study³² conducted at a national hospital in Tanzania found that laparoscopic repair for bilateral hernias significantly reduced operative time, postoperative recovery, and total hospitalization stay. Although parents of children who received laparoscopic repairs expressed higher satisfaction and rated cosmetic outcomes more favorably, the overall recurrence rate for laparoscopic repair was higher, at 22.7% compared with 4.5% for open repair ($P=.01$). The authors of this study noted that the steep learning curve in resource-limited settings might contribute to these early recurrence findings.³² Thus, open repair remains an effective and viable choice.

Future Surgical Techniques

Emerging studies are investigating additional alternatives to open and laparoscopic repair for congenital inguinal hernias. For example, a matched cohort pilot study²⁴ including 25 patients between the ages of 3 months and 8 years old found that the use of a robotic system to assist in inguinal hernia repairs was safe and feasible, with no significant differences observed in recurrence rate, postoperative complications, and net-surgical time when compared with laparoscopy. However, the overall operative time took longer for the robotic cohort when considering the time required to dock the robotic system.²⁴ Despite the small cohort size, which did not allow for any definitive conclusions about robotic surgeries in young age groups, the implications of this study are promising. A robot-assisted laparoscopy can facilitate the movement of working instruments beyond the normal range of the surgeon's arms and allows surgeons to sit in an ergonomic chair that optimizes posture, thus potentially reducing physical strain. The robotic surgery set up also facilitates minimizing tremors and can guide camera movement based on infrared eye tracking.³³

Another recent advancement in pediatric inguinal hernia repair involves utilizing double-modified hernia needles in single-port laparoscopic percutaneous extraperitoneal closure (SLPEC). This procedure uses only one 5-mm port near the umbilicus for the laparoscope while hernia needles are inserted through small skin punctures near the inner ring at the lower abdominal transverse line to help ligate the hernia sac and tie a knot with silk thread. Compared with the conventional two-port laparoscopic percutaneous extraperitoneal closure (TLPEC) in which two ports are created—one for the laparoscope and one for surgical instruments—the modified needles allow ligation of the hernia sac extraperitoneally without the need for a secondary port. A retrospective study³⁴ conducted at Fujian Children’s Hospital in China of 219 patients who underwent laparoscopic hernia repairs compared the effectiveness of SLPEC with the control TLPEC method. While the study found no statistically significant differences in the postoperative follow-up period, significant differences were observed in bleeding volume, pain levels, and postoperative recovery time between the two groups ($P<.001$). Due to the high risk of recurrence within 6 months after original inguinal hernia repairs, the patients in this study were followed for at least 12 months. Therefore, compared with conventional surgical techniques, SLPEC demonstrates competitive efficacy and impressive cosmetic results. Compared with patients in the SLPEC group, those in the TLPEC group had statistically longer operation times (31.35 vs 28.36 minutes, $P=0.048$). However, the three-minute difference is likely not clinically significant. Furthermore, there were no significant differences in hospital stay duration ($P=0.244$) or hospitalization costs ($P=0.073$).³⁴ Overall, SLPEC demonstrated some advantages, including minimal scarring, slightly shorter operation time, reduced bleeding, less pain, and quicker recovery.

Cost Considerations

With ongoing healthcare reform in the United States, economic cost continues to play an integral role in surgical decision-making. Health records in 32 hospitals across the United States demonstrated that robotic-assisted inguinal hernia repair was significantly more expensive than the laparoscopic procedure, with an average cost difference of \$2200 USD.³⁵ Another study³⁶ compared costs of various pediatric inguinal hernia repair techniques in a Dutch hospital, showing that the total operating room costs for robotic-assisted hernia repair are approximately \$1082 USD more than laparoscopic repair costs and \$1600 USD more than open repair costs. In addition, when taking into account personnel cost, which consisted of the salaries of all the team members involved in the case except the surgeon, the robotic-assisted method is difficult to justify given the high cost, especially in resource-limited settings.³⁵ However, as surgeon proficiency with robot-assisted procedures and technological refinements increase, additional research is needed to determine whether this option could be viable in hospitals that have the equipment.

Conclusion

Congenital inguinal hernias arise from a failure of the processus vaginalis or canal of Nuck to close during fetal development. This review highlights secondary factors like smooth muscle presence and gut microbiota composition as additional factors in the development of inguinal hernia.

Surgery remains the only curative treatment. The open herniotomy is the long-established standard, demonstrating strong efficacy and low recurrence rates. However, advances in minimally invasive techniques have made laparoscopy a viable, and often favored, alternative among a new generation of surgeons.

Each of the two techniques has advantages and disadvantages. Laparoscopy has fewer postoperative complications, like bleeding or infection, and can address an occult contralateral defect. However, it is also associated with higher same-side recurrence rates, greater postoperative pain in infants, and typically requires general anesthesia, which carries its own set of potential neurodevelopmental risks for young children. These risks include behavioral problems, neurodevelopmental disorders, and executive and motor function deficits. Open herniotomies, on the other hand, can typically be performed with regional anesthesia, without the need for general anesthesia, lowering the risk for neurodevelopmental adverse effects. The same-side recurrence rate and the severity of postoperative pain have also been shown to be significantly lower with open repair. Open repair usually requires lower analgesic doses intraoperatively and postoperatively compared with laparoscopic surgery but has been associated with longer hospital stays and more complications postsurgery. In addition, some studies show a higher overall recurrence rate compared with the laparoscopic method.

Future research should explore the potential secondary factors in the pathogenesis of congenital inguinal hernias, as this information could help tailor treatment. More research in special populations, such as preterm infants, would benefit further understanding of treatment differences compared with inguinal hernia repairs in other populations. Given the differences in recurrence rates between laparoscopic and open hernia repair, it would be helpful to continue studying the nuances in how these recurrences may differ, including same-side recurrence vs overall occurrence. As hospitals advance their technology, robot-assisted surgery may become more mainstream; however, this change will require further research into the costs, outcomes, and surgeon preferences.

Ultimately, the decision between open and laparoscopic repair in a child should be guided by a careful balance of recurrence risk, postoperative complications, surgeon preference, and family satisfaction. For special populations, such as preterm infants or those with incarcerated hernias, the open surgical approach may offer greater safety and precision. Open inguinal

hernia repair provides dependable, effective outcomes for both routine and complex pediatric cases. While laparoscopic inguinal hernia repair appears to have many benefits, it is not without risk and cannot be considered a better option than the gold standard open repair. As found in our review of the current literature, we believe that open inguinal hernia repair remains a valid option in the United States while laparoscopic repair continues to be refined and developed.

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REFERENCES

1. Rajput A, Gauderer MWL, Hack M. Inguinal hernias in very low birth weight infants: Incidence and timing of repair. *J Pediatr Surg.* 1992;27:1322-1324. doi:[10.1016/0022-3468\(92\)90287-H](https://doi.org/10.1016/0022-3468(92)90287-H)
2. Holley A. Pathologies of the canal of Nuck. *Sonography.* 2018;5:29-35. doi:[10.1002/sono.12137](https://doi.org/10.1002/sono.12137)
3. Hammoud M, Gerken J. Inguinal Hernia. In: *StatPearls.* StatPearls Publishing; 2025.
4. Shaughnessy MP, Maassel NL, Yung N, Solomon DG, Cowles RA. Laparoscopy is increasingly used for pediatric inguinal hernia repair. *J Pediatr Surg.* 2021;56(11):2016-2021. doi:[10.1016/j.jpedsurg.2021.01.032](https://doi.org/10.1016/j.jpedsurg.2021.01.032)
5. Benzi TSCG, Costa WS, Sampaio FJ, Favorito LA. Inguinoscrotal stage of testicular descent: analysis in 217 human fetuses. *J Pediatr Urol.* 2020;16:198-204. doi:[10.1016/j.jpuro.2020.01.016](https://doi.org/10.1016/j.jpuro.2020.01.016)
6. Brandt ML. Pediatric Hernias. *Surg Clin North Am.* 2008;88:27-43. doi:[10.1016/j.suc.2007.11.006](https://doi.org/10.1016/j.suc.2007.11.006)
7. Tanyel FC, Dağdeviren A, Müftüoğlu S, Gürsoy MH, Yürüker S, Büyükpamukçu N. Inguinal hernia revisited through comparative evaluation of peritoneum, processus vaginalis, and sacs obtained from children with hernia, hydrocele, and undescended testis. *J Pediatr Surg.* 1999;34:552-555. doi:[10.1016/S0022-3468\(99\)90071-4](https://doi.org/10.1016/S0022-3468(99)90071-4)
8. Krishnan N, Kakkar A, Nag TC, Agarwala S, Goel P, Dhua AK. A comparative study of smooth muscle cell characteristics and myofibroblasts in processus vaginalis of pediatric inguinal hernia, hydrocele and undescended testis. *BMC Urol.* 2024;24:115. doi:[10.1186/s12894-024-01449-0](https://doi.org/10.1186/s12894-024-01449-0)
9. Taniguchi S, Ueda K, Inoue T, Li TS, Kuga T, Hamano K. Impact of collagen subtype proportions in peritoneal tissues on inguinal hernia formation in adults and infants. *Pediatr Surg Int.* 2006;22:600-604. doi:[10.1007/s00383-006-1701-0](https://doi.org/10.1007/s00383-006-1701-0)
10. Wu C, Zhu Y, Xi H. Causation between the gut microbiota and inguinal hernia: a two-sample double-sided Mendelian randomization study. *Sci Rep.* 2024;14:20526. doi:[10.1038/s41598-024-71253-1](https://doi.org/10.1038/s41598-024-71253-1)
11. Grosfeld JL. Current concepts in inguinal hernia in infants and children. *World J Surg.* 1989;13(5):506-515. doi:[10.1007/BF01658863](https://doi.org/10.1007/BF01658863)
12. Saguintaah M, Eulliot J, Bertrand M, et al. Canal of Nuck abnormalities in pediatric female patients. *RadioGraphics.* 2022;42(2):541-558. doi:[10.1148/rg.210145](https://doi.org/10.1148/rg.210145)
13. Le Roux F, Lipsker A, Mesureur S, Haraux E. Inguinal hernia repair in children: surgical technique. *J Visc Surg.* 2016;153(2):121-125. doi:[10.1016/j.jviscsurg.2015.12.006](https://doi.org/10.1016/j.jviscsurg.2015.12.006)
14. Oliveros-Rivero J. From Liverpool to Chicago: The legacy of Mitchell-Banks and Ferguson in pediatric herniotomy. *J Pediatr Surg.* 2025;60(10):162488. doi:[10.1016/j.jpedsurg.2025.162488](https://doi.org/10.1016/j.jpedsurg.2025.162488)
15. Türk E, Memetoglu ME, Edirne Y, Karaca F, Saday C, Güven A. Inguinal herniotomy with the Mitchell-Banks' technique is safe in older children. *J Pediatr Surg.* 2014;49(7):1159-1160. doi:[10.1016/j.jpedsurg.2013.09.065](https://doi.org/10.1016/j.jpedsurg.2013.09.065)
16. Hewitt DB, Chojnacki K. Laparoscopic groin hernia repair. *JAMA.* 2017;318(13):1294. doi:[10.1001/jama.2017.11620](https://doi.org/10.1001/jama.2017.11620)
17. Ma Q, Liu X, Zou Z, et al. Surgical methods and outcomes of inguinal hernia repair in children, adolescents and young adults in a retrospective cohort study. *Sci Rep.* 2025;15:9220. doi:[10.1038/s41598-025-93841-5](https://doi.org/10.1038/s41598-025-93841-5)

18. Ceccanti S, Cervellone A, Pesce MV, Cozzi DA. Feasibility, safety and outcome of inguinal hernia repair under spinal versus general anesthesia in preterm and term infants. *J Pediatr Surg.* 2021;56(5):1057-1061. doi:[10.1016/j.jpedsurg.2020.09.064](https://doi.org/10.1016/j.jpedsurg.2020.09.064)
19. McCann ME, De Graaff JC, Dorris L, et al. Neurodevelopmental outcome at 5 years of age after general anaesthesia or awake-regional anaesthesia in infancy (GAS): an international, multicentre, randomised, controlled equivalence trial. *Lancet.* 2019;393(10172):664-677. doi:[10.1016/S0140-6736\(18\)32485-1](https://doi.org/10.1016/S0140-6736(18)32485-1)
20. Reighard C, Junaid S, Jackson WM, et al. Anesthetic exposure during childhood and neurodevelopmental outcomes: a systematic review and meta-analysis. *JAMA Netw Open.* 2022;5(6):e2217427. doi:[10.1001/jamanetworkopen.2022.17427](https://doi.org/10.1001/jamanetworkopen.2022.17427)
21. Tímár ÁE, Bénes D, Terebessy A, Fadgyas B. Inguinal hernioplasty in children—open or laparoscopic? a retrospective cohort study of 1,072 cases. *Pediatr Surg Int.* 2024;41:45. doi:[10.1007/s00383-024-05943-2](https://doi.org/10.1007/s00383-024-05943-2)
22. Wang H, Wang X. Laparoscopic versus open hernia repair for indirect inguinal hernia in adolescents: a retrospective cohort study. *J Invest Surg.* 2024;37:2427382. doi:[10.1080/08941939.2024.2427382](https://doi.org/10.1080/08941939.2024.2427382)
23. Zhang S, Cai D, Jin Y, et al. Exploration of laparoscopic day surgery mode for pediatric inguinal hernia: a large cohort study. *Updates Surg.* 2025;77:575-582. doi:[10.1007/s13304-025-02141-0](https://doi.org/10.1007/s13304-025-02141-0)
24. Safa N, Le-Nguyen A, Gaffar R, et al. Open and laparoscopic inguinal hernia repair in children: a regional experience. *J Pediatr Surg.* 2023;58:146-152. doi:[10.1016/j.jpedsurg.2022.09.023](https://doi.org/10.1016/j.jpedsurg.2022.09.023)
25. Carter M, Papastefan ST, Tian Y, et al. A retrospective nationwide comparison of laparoscopic vs open inguinal hernia repair in children. *J Pediatr Surg.* 2025;60:162056. doi:[10.1016/j.jpedsurg.2024.162056](https://doi.org/10.1016/j.jpedsurg.2024.162056)
26. Darmawan KF, Sinclair T, Dunn JCY. Comparison of laparoscopic and open pediatric inguinal hernia repairs at two institutions. *Pediatr Surg Int.* 2018;34(12):1293-1298. doi:[10.1007/s00383-018-4360-z](https://doi.org/10.1007/s00383-018-4360-z)
27. Sato H, Adachi S, Tominaga M, et al. Comparison of pain between laparoscopic percutaneous extraperitoneal closure (LPEC) and open procedure for inguinal hernias in children below 5 years of age. *Pediatr Surg Int.* 2024;40:294. doi:[10.1007/s00383-024-05875-x](https://doi.org/10.1007/s00383-024-05875-x)
28. Sakthivel M, Bapna T, Ivanic S, Lang C, Nataraja RM, Pacilli M. An objective evaluation of intraoperative and postoperative pain in infants undergoing open inguinal herniotomy and laparoscopic inguinal hernia repair using the newborn infant parasympathetic evaluation (NIPETM) monitor. *J Pediatr Surg.* 2025;60:161651. doi:[10.1016/j.jpedsurg.2024.07.036](https://doi.org/10.1016/j.jpedsurg.2024.07.036)
29. Zhang G, Ding H, Wang D, Guo F, Hu B. Pediatric incarcerated inguinal hernia: traditional open or laparoscopic-assisted approach? *Medicine.* 2024;103:e37810. doi:[10.1097/MD.00000000000037810](https://doi.org/10.1097/MD.00000000000037810)
30. Cho YJ, Kwon H, Ha S, et al. Optimal timing for inguinal hernia repair in premature infants: surgical issues for inguinal hernia in premature infants. *Ann Surg Treat Res.* 2023;104:296. doi:[10.4174/ast.2023.104.5.296](https://doi.org/10.4174/ast.2023.104.5.296)
31. Hellmann ZJ, Knod JL, Kulaylat AN, et al. Preferences for inguinal hernia repair in infants: a survey of the Eastern Pediatric Surgery Network. *J Surg Res.* 2025;306:188-196. doi:[10.1016/j.jss.2024.12.012](https://doi.org/10.1016/j.jss.2024.12.012)

32. Shirima S, Kitua D, Mwangi A, et al. Comparative analysis of surgical outcomes between open herniotomy and laparoscopic hernia repair among pediatric patients with inguinal hernias: a five-year retrospective review at Tanzania's National Hospital. *East Afr Health Res J.* 2025;9(1):144-151. doi:[10.24248/eahrj.v9i1.832](https://doi.org/10.24248/eahrj.v9i1.832)
33. Eurlings R, Killaars REM, Cakir H, et al. First results of pediatric robotic inguinal hernia repair with the Senhance® surgical system: a matched cohort study. *Healthcare.* 2024;12:1703. doi:[10.3390/healthcare12171703](https://doi.org/10.3390/healthcare12171703)
34. Xu LY, Cui X, Huang WH, Chen L, Zhou CM. A novel technique for the single-port laparoscopic percutaneous extraperitoneal closure (SLPEC) of paediatric isolated giant inguinal hernias using double-modified hernia needles. *Sci Rep.* 2024;14:15389. doi:[10.1038/s41598-024-60476-x](https://doi.org/10.1038/s41598-024-60476-x)
35. Abdelmoaty WF, Dunst CM, Neighorn C, Swanstrom LL, Hammill CW. Robotic-assisted versus laparoscopic unilateral inguinal hernia repair: a comprehensive cost analysis. *Surg Endosc.* 2019;33:3436-3443. doi:[10.1007/s00464-018-06606-9](https://doi.org/10.1007/s00464-018-06606-9)
36. Eurlings R, Kimman ML, Brandts L, Visschers RGJ, Van Gemert WG. Cost analysis of four surgical techniques for pediatric inguinal hernia repair in a Dutch hospital. *J Pediatr Surg Open.* 2025;11:100217. doi:[10.1016/j.yjps.2025.100217](https://doi.org/10.1016/j.yjps.2025.100217)