



## Review Article

pISSN 2092-8335 • eISSN 2733-5380  
Keimyung Med J 2024;43(2):82-88  
<https://doi.org/10.46308/kmj.2024.00059>

**Received:** April 23, 2024  
**Revised:** May 13, 2024  
**Accepted:** May 21, 2024

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# Pediatric Inguinal Hernia Surgery: Recent Strategies and Techniques

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Pediatric inguinal hernia is the most prevalent surgical condition in children and accounts for nearly half of all pediatric surgical procedures performed. The primary cause of pediatric inguinal hernia is a patent processus vaginalis (PPV), which often requires surgery. Traditionally, the standard treatment involved high ligation of the PPV through a small incision combined with laparoscopic methods. These minimally invasive techniques offer improved cosmetic outcomes and are increasingly favored in clinical practice. This review aimed to present the current surgical techniques for pediatric inguinal hernia treatment, with a focus on various laparoscopic approaches. Additionally, it discusses the optimal timing for treating hernias in neonates and preterm infants as well as specialized surgical strategies for adolescent patients. This review highlights advancements in surgical methods that accommodate the specific needs of different age groups within the pediatric population.

**Keywords:** Herniorrhaphy, Infant, Inguinal hernia, Laparoscopy, Minimally invasive surgical procedures, Neonborn

## Introduction

Pediatric inguinal hernia is the most prevalent surgical condition in children and constitutes nearly half of all pediatric surgical procedures [1]. Nyhus categorized inguinal hernias into four types, a classification detailed in a surgical textbook (Table 1) [2]. Specifically, pediatric inguinal hernias are primarily classified as type 1, although they can sometimes present as type 2 with dilation of the internal ring. Unlike type 3 hernias in adults, which involve a posterior wall defect, pediatric cases are mostly type 1 and do not typically require the mesh reinforcement procedures used in adult hernias. The etiology of pediatric inguinal hernia is largely associated with a patent processus vaginalis (PPV), which can lead to the development of a communicating hydrocele or progress to an inguinal hernia with organ protrusion. Patency persists in approximately 60% of infants at 7 months and in 20% of adults without a history of hernia during autopsy studies [3,4]. Traditionally, the surgical response to pediatric inguinal hernias involves high ligation of the PPV at the proximal level. This standard procedure, typically conducted through a small incision, involves ligation of the hernial sac at the highest or most proximal point of the skin incision. However, the term "high ligation" from the perspective of open inguinal hernia repair is a misnomer when considering laparoscopic techniques, where it is more accurately described as internal ring ligation. The advent of laparoscopic surgery in children, pioneered by Montupet and Esposito [5] in 1994 and facilitated by the development of neonatal surgical instruments, has introduced various surgical options. Although classical high ligation has been effective, the principles of laparoscopic

**Table 1.** Nyhus classification of inguinal hernia

Type I	Indirect inguinal hernia Indirect inguinal ring normal (e.g., pediatric hernia)
Type II	Indirect inguinal hernia Indirect inguinal ring dilated but posterior inguinal wall intact: inferior deep epigastric vessels not displaced
Type III	Posterior wall defects A. Direct inguinal hernia B. Indirect inguinal hernia Internal inguinal ring dilated, medially encroaching on or destroying the transversalis fascia of the Hesselbach triangle (e.g., massive scrotal, sliding or pantaloon hernias) C. Femoral hernia
Type IV	Recurrent hernias

Modified from Nyhus LM, Klein MS, Rogers FB. Inguinal hernia. *Curr Probl Surg* 1992;28:407-50.

surgery have shown similar efficacy with better cosmetic results, leading to the diversification of surgical approaches. Furthermore, the emergence of novel surgical techniques has provided safe and varied options for extreme age groups (such as extremely low birth weight, very low birth weight, and premature infants) and patients with complicated medical conditions. This review aimed to comprehensively examine the current surgical techniques for pediatric inguinal hernia, timing of surgery, and related issues across various medical conditions.

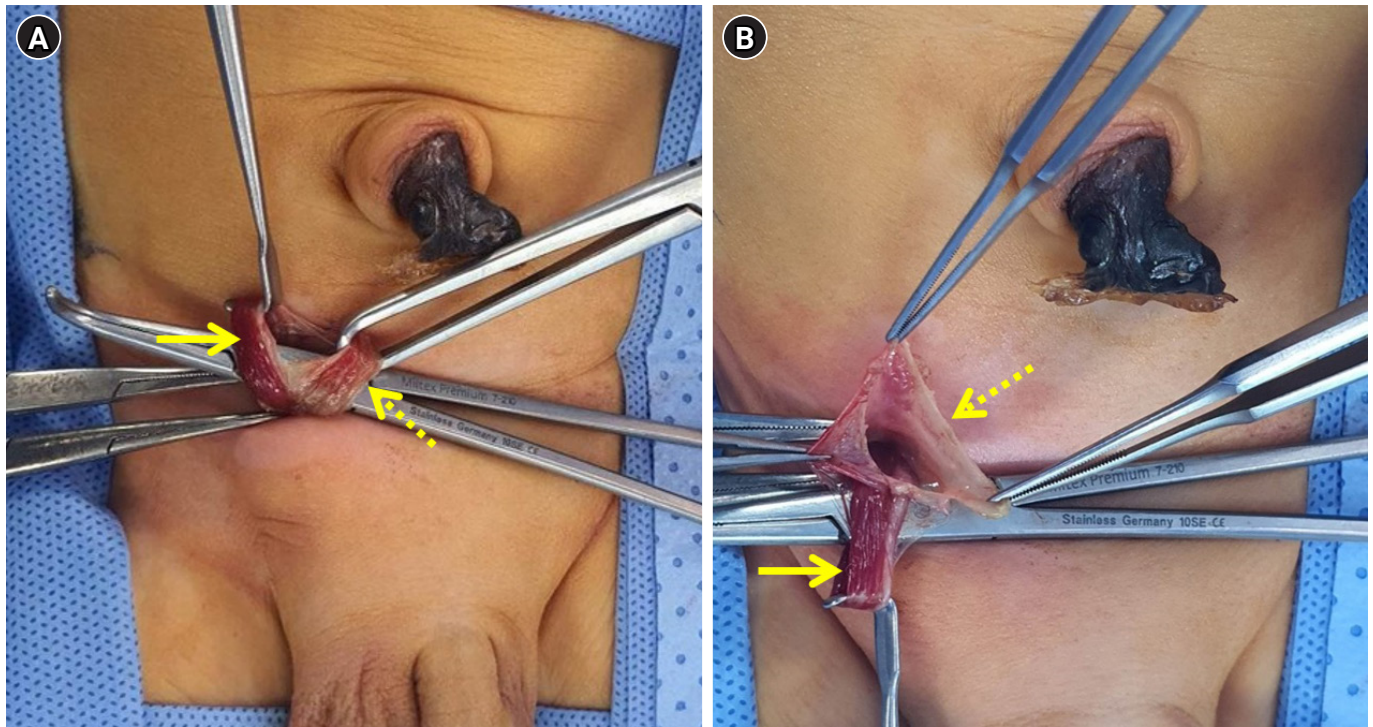
## Open inguinal hernia repair

Open inguinal hernia repair is well established as a fundamental procedure in pediatric surgery and continues to be extensively used, despite the advent of laparoscopic techniques. According to Schmedding et al. [6], it remains the predominant method for addressing pediatric inguinal hernias. The procedure typically begins with a transverse incision made along the inguinal crease, which strategically minimizes visible scarring and aligns well with the natural skin lines (Fig. 1). Following the incision, the fascia of Scarpa was carefully opened to expose the external oblique aponeurosis. This aponeurosis is then incised longitudinally along the direction of its fibers to facilitate access to deeper structures without causing unnecessary damage to the muscle layers. As the dissection progresses, attention is turned to the inguinal ligament, where cord structures are identified and isolated (Fig. 2). In male patients, the hernial sac is meticulously separated from the cord structures. During this phase, it is imperative to ensure that the vas deferens and the testicular vessels are not compro-



**Fig. 1.** Transverse skin crease incision after open repair of the right inguinal hernia.

mised. The sac is double clamped, divided, and followed proximally to the internal inguinal ring where it is securely ligated using absorbable sutures to prevent recurrence. In female patients, the hernial sac is mobilized up to the internal inguinal ring and a similar high ligation technique is applied. Some prefer transfixation to maintain the uterine support of the round ligament. A high ligation technique is critical to ensure that the hernia does not recur and is performed with precision to avoid any potential complications. One of the significant advantages of the open technique is its ability to be performed in an outpatient setting, which significantly reduces the healthcare burden. The procedure is characterized by a relatively quick recovery time, allowing it to be completed within a day of surgery. Furthermore, the use of locoregional anesthesia enhances its suitability for young patients by reducing the risks associated with general anesthesia [7,8]. Despite its widespread application and benefits, open inguinal hernia repair poses specific challenges in neonates, particularly small or premature infants. The procedure requires a delicate balance between



**Fig. 2.** Operative findings of open inguinal hernia. Hernia sac is located anteromedial side (dotted arrow). Spermatic vessel and vas deferens are separated (arrow). (A) Hernia sac is not opened. (B) Sac is opened.

making a sufficiently small incision to ensure cosmetic acceptability and avoiding damage to the fragile hernial sac, which can lead to severe complications.

### Laparoscopic inguinal hernia repair

Laparoscopic inguinal hernia repair is rapidly gaining popularity, with recent national surveys indicating a significant increase in its adoption by pediatric surgeons. Surveys conducted in Germany in 2019 showed that 35% to 50% of pediatric surgeons are now using laparoscopic techniques for inguinal hernia repair [6]. This is a stark increase compared to a 2012 survey among European pediatric surgeons, in which only 4% reported using this method [9]. Nevertheless, a German survey revealed distinct preferences and practices regarding inguinal hernia repair methodologies. According to the survey results, 47.1% of the respondents exclusively performed open surgeries, whereas only 5.9% used laparoscopic techniques alone. Interestingly, a significant proportion (47.1%) employed both laparoscopic and open approaches, indicating that approximately 53% of the surgeons integrated laparoscopic surgery into their practice. Despite this integration, laparoscopic procedures account for only 8.2% of all pediatric and adolescent hernia surgeries, underscoring the continued preference

for open inguinal hernia repair among these practitioners. These data suggest that although laparoscopic techniques are being adopted, open surgery remains the predominant method for pediatric inguinal hernia repair [6]. Changes in these trends may be observed in future surveys, but open repair techniques continue to dominate clinical practice.

The principle of laparoscopic inguinal hernia repair aligns with that of open repair, which primarily focuses on suture ligation of the internal ring. More than 20 different laparoscopic techniques exist, but they can be broadly categorized into three types according to the method of internal ring ligation: intracorporeal suturing, extracorporeal suturing, and total extraperitoneal ligation [10-12].

### Intracorporeal suturing

Intracorporeal suturing is typically the first laparoscopic technique performed in children [5]. This method involves the use of a 3 or 5 mm umbilical optic port and two additional 3 mm ports or a stab incision as the working ports. The camera instantly provided a clear view of the hernia location, and the internal ring was closed through the working ports using various suture techniques. This approach allows for the straightforward visualization and handling of lesions without exten-

sive dissection. However, in newborns, where the surgical field is limited, and the peritoneum is thin and friable, the procedure becomes more challenging and requires careful handling to avoid intra-abdominal organ damage. Direct suturing of the internal ring inlet is commonly performed (Fig. 3A) [5], sometimes following an incision of the periorificial peritoneum (herniotomy) to separate the sac before suturing the internal ring (Fig. 3B) [13]. Methods such as the purse-string or Z-suture [14] are used to ensure a water-tight seal, which is critical for preventing recurrence. The effectiveness of the ligation is tested by decompressing the inguinal hernia bulging site before and after suturing the internal ring to ensure that no bulging occurs, indicating secure closure.

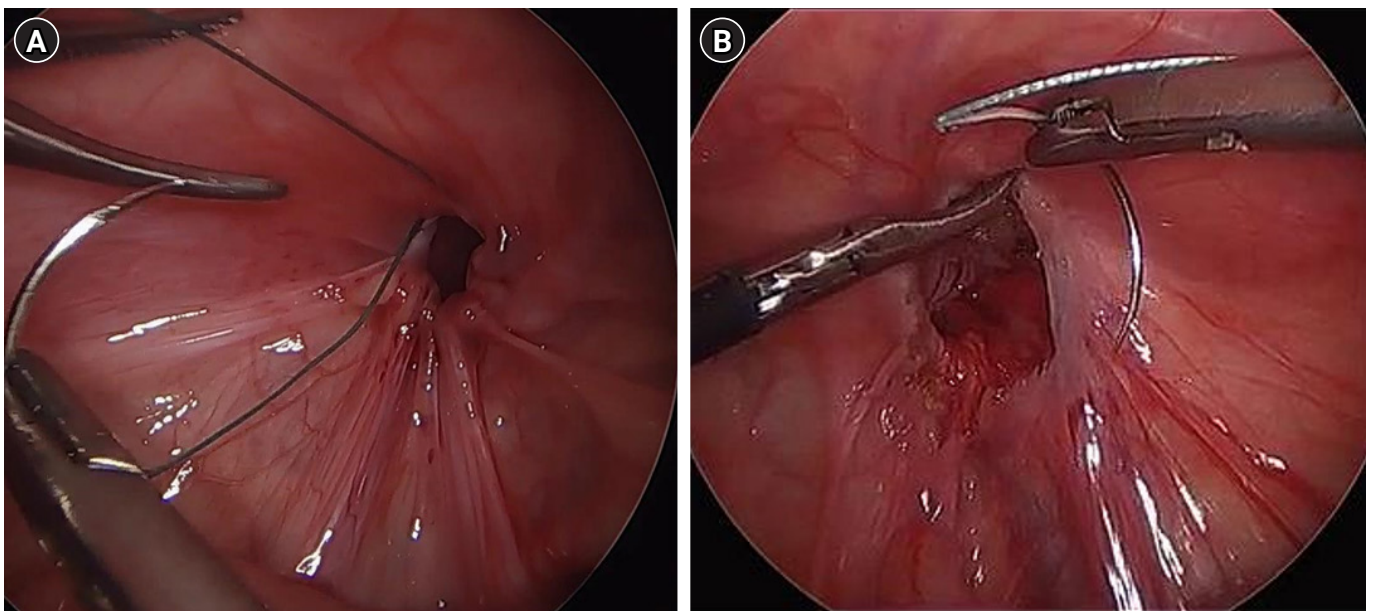
### Extracorporeal suturing

The extracorporeal suturing technique was first introduced by Masso Endo in 2001 and has since undergone various adaptations and improvements [15,16]. The process begins with the insertion of a 3 or 5 mm optic port through the umbilicus, which serves as the main visual guide to confirm the internal ring's location. Once the internal ring is visualized, the surgeons use their fingers to palpate the area externally to pinpoint the exact location for ligation. A needle is then inserted directly through the skin above the identified site on the internal ring. The needle is maneuvered to encircle the ring and the

suture is pulled back through the entry point and securely tied, thereby effectively ligating the internal ring. This method is particularly advantageous because it allows the hernial sac to be closed with minimal invasion and maximum precision. A recent meta-analysis demonstrated that extracorporeal suturing offers comparable results in terms of perioperative complications, recurrence rates, and cosmetic outcomes, making it a viable surgical option [11,17]. However, despite the efficacy and complete ligation of the internal ring, extracorporeal suturing involves penetration of the peritoneum to insert a camera port. Therefore, the technique cannot be classified as a completely extraperitoneal approach. This distinction is significant because it delineates the limitations of extracorporeal suturing compared with other laparoscopic methods that avoid peritoneal penetration.

### Totally extraperitoneal ligation

Introduced by Koo and Jung [12] in 2022, this method follows an extraperitoneal approach, resembling the process of open hernia repair; however, it is minimally invasive. A 5 mm port is inserted at the umbilicus to create an incision in the anterior rectal sheath, followed by dissection of the avascular plane of the extraperitoneal space as viewed through the camera. Two 3 mm working ports are located on the suprapubic skin and between the suprapubic skin and umbilicus (Fig. 4).



**Fig. 3.** Laparoscopic findings of intracorporeal suturing techniques. The peritoneum around the internal ring is closed as purse-string closure. (A) Without peritoneal incision (without herniotomy). (B) After peritoneal incision (with herniotomy).

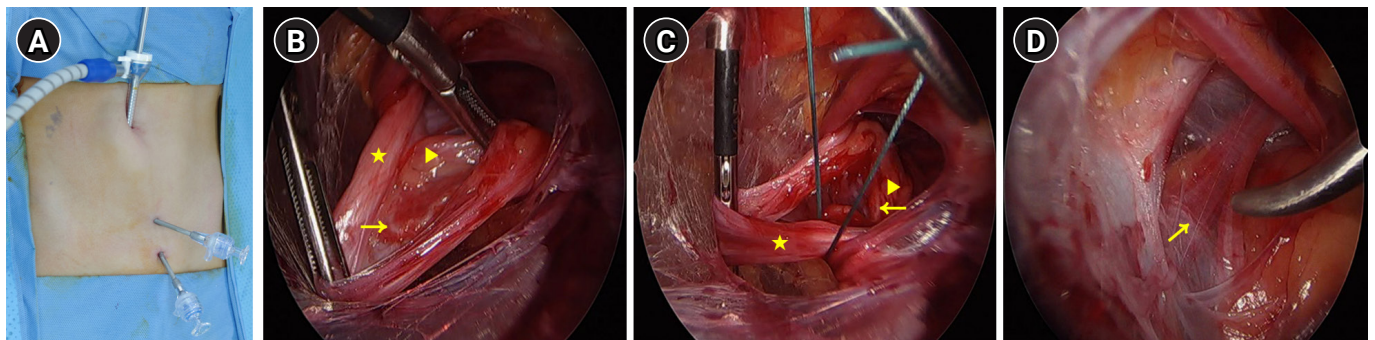
The hernia sac is then separated from the adjacent structures (Fig. 4B) and highly ligated using a knot pusher (Fig. 4C), achieving outcomes comparable to those of open surgery with better cosmesis and the additional advantage of addressing concurrent conditions such as hydrocele or cord lipoma. The contralateral PPV can be easily checked (Fig. 4D). Limitations include technical difficulties, especially for small infants, and a lack of long-term results.

These endoscopic techniques exemplify the diversity of approaches to pediatric inguinal hernia repair, reflecting a shift in surgical practice toward more minimally invasive methods without significant differences in recurrence rates or complications compared with traditional open techniques (Table 2). When multiple surgical approaches are available for a specific disease, patients are provided with better treatment options. For example, patients with intestinal problems who have undergone an ileostomy may develop incarcerated hernias requiring surgical intervention. Opting for open inguinal hernia repair in such cases could increase the risk of infection, owing

to the proximity to the stoma site. However, the laparoscopic approach allows surgery to be performed independently of the stoma location, significantly reducing the risk of infection, and offering a safer alternative (Fig. 5). This flexibility in surgical strategy enhances patient care by accommodating individual circumstances and comorbidities. The choice of technique ultimately depends not on the superiority of one method over another but on the precise execution of the selected surgical approach tailored to the patient's specific conditions.

### Pediatric inguinal hernia repair in extreme age

The timing of inguinal hernia repair in neonates and adolescents remains controversial and requires a tailored approach based on the patient's age and specific medical conditions. The optimal timing of inguinal hernia repair in neonates, including premature neonates, is a common practice for performing inguinal hernia repair before neonates are discharged from the



**Fig. 4.** Port location for the totally extraperitoneal ligation . (A) A 5-mm umbilical port for optic and two 3-mm ports located suprapubic and hypogastric area. (B) Separation of the sac (stars) from the vas deferens (arrows) and the spermatic vessels (arrowheads). (C) After separation, 3-0 nonabsorbable ligation of the sac at the level of internal ring. (D) Findings of the contralateral internal ring. Peritoneal lining (arrow) shows closed patent processus vaginalis.

**Table 2.** Comparison of the techniques of the pediatric inguinal hernia repair

	Open high ligation	Intracorporeal suturing	Extracorporeal suturing	Totally extraperitoneal ligation
Extraperitoneal approach	Yes	No	Suturing only <sup>a)</sup>	Yes
Double ligation	Yes	No	No	Yes
Dissection to expose internal ring	Yes	No	No	Yes
Operation wound	10–30 mm single <sup>b)</sup>	Two 3 mm, umbilicus <sup>c)</sup>	1–2 mm scar on suturing inlet ± single 3 mm, umbilicus <sup>c)</sup>	Two 3 mm, umbilicus <sup>c)</sup>
Body weight limitation	None	None	None	Over 10 kg <sup>d)</sup>

<sup>a)</sup>Umbilical port needs peritoneal puncture.

<sup>b)</sup>Low transverse skin crease incision for best cosmesis.

<sup>c)</sup>Umbilical 3/5-mm port, umbilical crease.

<sup>d)</sup>Only single article so far.



**Fig. 5.** A premature patient who underwent loop ileostomy for meconium related ileus diagnosed with incarcerated bilateral inguinal hernia. Intracorporeal suturing was performed instead of creating an incision besides stoma.

Neonatal Intensive Care Unit (NICU) [18]. However, recent research has raised concerns about postoperative complications such as apnea. A recent multicenter randomized clinical trial investigating the morbidity associated with the timing of inguinal hernia surgery in preterm infants reported that patients who underwent surgery before NICU discharge, particularly those with a post conceptual age of  $\geq 55$  weeks, had a higher risk of serious complications such as apnea, prolonged intubation, and bradycardia, compared to the patients who underwent surgery later [19]. Consequently, current recommendations suggest delaying surgery until after the infant's first year unless hernia-related complications require earlier intervention. Premature birth is associated with a high risk of incarceration. However, Ferrantella et al. [20] reported a large-scale database to analyze the readmission rates for complications related to untreated inguinal hernias in both preterm and full-term infants. Surprisingly, the study found a lower frequency of unplanned readmissions than that previously reported, suggesting that the risk of serious complications while awaiting elective hernia repair was low.

The approach to inguinal hernia surgery in adolescents varies significantly between pediatric surgeons and general surgeons. Pediatric surgeons traditionally opt for high ligation of the sac, a well-established technique in pediatric surgery that is considered the gold standard approach for both children and adolescents. This procedure involves surgical tie-off of the hernia sac at its base near the internal ring and has been re-

fined over the years to include both laparoscopic and robotic methods. Studies have shown that a high ligation of the sac in children does not increase the risk of developing an inguinal hernia in adulthood [21]. In contrast, general surgeons often prefer mesh repair for adolescent inguinal hernias, especially in minimally invasive procedures such as laparoscopic or robotic repairs [22]. Mesh repair is favored because of its durability and effectiveness in providing long-lasting solutions. Despite some concerns about the higher rate of complications associated with mesh repair, such as chronic pain or mesh rejection, it may be indicated in certain cases based on the surgeon's assessment and the specific characteristics of the hernia [21,22]. Hence, weighing the advantages and disadvantages of each surgical approach is crucial. The choice between high ligation and mesh insertion should be guided by individual patient factors, including the patient's age, size and type of hernia, potential risks, and the surgeon's experience and preference. A selective and individualized approach is recommended to optimize outcomes and minimize the risk of complications in patients undergoing inguinal hernia repair, particularly those of extreme ages.

## Summary

The primary etiology of pediatric inguinal hernia is a PPV, which is traditionally managed with high ligation. Recent advancements in surgical techniques, particularly the shift toward minimally invasive laparoscopic methods, have offered improved cosmetic outcomes and are increasingly favored in clinical practice. The timing of hernia repair in neonates and preterm infants and the adaptation of surgical strategies for adolescent patients are critical for optimizing treatment outcomes. Tailoring surgical strategies to meet the specific needs of different pediatric age groups is essential to minimize complications and enhance recovery. Integrating age-specific considerations with the latest evidence-based practices has enhanced the quality of care for pediatric patients undergoing inguinal hernia surgery. Ongoing research and collaboration within the medical community are vital for refining these approaches and ultimately ensuring better outcomes and patient satisfaction.

## Acknowledgements

None.

## Ethics approval

Not applicable.

## Conflict of interest

The authors have nothing to disclose.

## Funding

None.

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