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Just a Simple Hernia? Brief Insights into a Complex Topic

Ralf-Bodo Tröbs

Department of General, Visceral and Pediatric Surgery, St. Vincenz Hospitals, Paderborn, Germany
Email: pedsurgtroe@gmail.com

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Abstract

Inguinal hernias affect between 1 and 6 out of 100 children. They are treated surgically. The aim of this review is to present the most relevant aspects of pediatric inguinal hernia. Special emphasis is placed on the differences between boys and girls and the special features of small infants. Classical works, studies on anatomy and developmental human biology as well as new aspects of the last decade have been evaluated. Infantile inguinal hernias are almost invariably the result of a failure of spontaneous closure of the vaginal peritoneal process. As a general rule, the younger the child, the more frequent the hernia. There is a wide range of anatomical variants. The most important complication of a hernia is incarceration with the risk of gonadal damage or hemorrhagic bowel infarction. The urgency for surgical correction of a hernia or hydrocele depends on the likelihood of incarceration. The principle of inguinal herniotomy is to close the hernia sac at the inner inguinal ring and, if possible, to cut through it. There are some important gender-associated differences. Childhood inguinal hernias are much more common in boys than in girls. Ovarian prolapse is an important special form in girls. For open surgery the spermatic cord (round ligament) with hernia sac can be exposed via opening of the external oblique aponeurosis (Ferguson/Gross, Grob, Rehbein, and others) or peripherally of the intact external ring (Czerny, Potts, Mitchell-Banks). Simple sac ligation and dissection seem appropriate for most hernias. The following rule of thumb applies in clinical practice: the smaller the infant and the smaller the hernial orifice, the greater the risk of incarceration. The risk of bilateral or contralateral inguinal hernia differs significantly between girls and boys. The main advantage of the laparoscopic procedure is the possibility of assessing the opposite side. Laparoscopic repair provides similar outcomes to open but may shorten the operative time in bilateral cases. For hydroceles, the laparoscopic approach provides some substantial new insights into anatomy. The timing of surgery in premature babies is the subject of controversial debate. There is currently a trend to delay hernia repairs in premature babies

until after discharge to reduce the risk of respiratory distress and recurrence. Operations under regional anesthesia are associated with faster postoperative recovery and improved patient comfort.

Keywords

Inguinal Hernia, Hydrocele, Patent Processus Vaginalis, Gender Differences, Surgery

1. Introduction

There is nothing as interesting as an inguinal hernia.
Robert W. Gross, formerly Ladd-Professor at the Havard Medical School

Inguinal hernia repair is the most common surgery in infants and toddlers. Most pediatric surgical units. It forms more than one-quarter of surgeries in a pediatric surgical unit [1].

Inguinal hernias occur in 1% to 6.6% of all children in the USA, Africa and Asia. In premature babies, the rate is between 9% and 35%. In an Asian study, inguinal hernias occurred in 6.6% of boys and 0.7% of girls (9.4 to 1). In a recent nationwide study from Germany, however, the gender ratio was only 3.9 to 1 [2]. Overall, the number of hernia operations in children is declining in the USA, England and Germany, although the reasons for this development are unclear [2]. Regardless of gender or ethnicity, the younger the child, the more likely they are to have a hernia.

The presented paper first provides an overview of the development, anatomy and the different variants of infantile inguinal hernia. In the following section, the fundamental elements of the clinical appearance and diagnosis are elucidated. In particular, the special features of the female hernia are described. It is imperative to acknowledge the heightened challenges associated with risk management and surgical planning in premature infants who are considered to be vulnerable. Finally, the results of open surgical and laparoscopic hernia repair are discussed. The review is founded predominately upon an analysis of current English-language specialist literature. The articles were selected according to clinical relevance and evidence. Moreover, the review encompasses a number of papers that are considered to be of seminal importance. Eponyms were retained in instances where they had been introduced into clinical practice. The author acknowledges that these eponyms may not be attributable to a singular first description or individual achievement.

2. Pediatric Inguinal Hernia—A Heterogenic Entity

Diagnostics, indications for surgery and surgical procedures are among the basic skills of a pediatric surgeon. Inguinal hernia repair in infants is safe and effective. It is usually considered to be a "quick" but subtle and atraumatic operation. On the other hand, procedures for large hernias in small infants can be very difficult. Due to the vulnerability of premature infants, procedures in this age group should

be classified as major surgery [3] [4].

Despite significant similarities, there are significant differences between inguinal hernias in boys and girls. There is a strong gender predisposition to inguinal hernias. Only 1 in 5 to 8 hernias affects female children. This concerns not only the prevalence, but also pathogenesis, clinical presentation, diagnosis and treatment, as well as some details of management and surgery. In this context, it is surprising that a large proportion of clinical trials do not differentiate between boys and girls. One of the main aims of this review is to highlight some of the sex-specific differences (Table 1 and Figure 1).

Table 1. Overview of anatomy, embryology and types of pediatric inguinal hernia.

	Female	Male
Embryology	Ovarian descensus, lig. rotundum Overwhelming descensus (?)	Testicular descensus, gubernaculum
Anatomical predisposition	Lack of obliteration of the processus vaginalis peritonei Short inguinal canal in infants and young children	
Acquired predisposition	Prematurity, coughing and straining with chronic lung disease (bronchopulmonary dysplasia, cystic fibrosis), history of ventilation, constipation	
Hernia sac contents	Ovary, uterine tube, rare uterus, omentum, intestine, urinary bladder	Intestine, omentum, testicles, urinary bladder
Hydrocele	Nuck's cyst	Hydrocele funiculi, hydrocele testis, abdomino-scrotal hydrocele
Rare forms	• Direct inguinal hernia • Hernia en pantaloon (indirect + direct Hernia)	
Differential diagnosis	Hydrocele funiculi, et testis Hydrocele/Nuck's cyst of the girl Cryptorchidism Testicular torsion Meconium periorchitis Peritonitis with pus in the sac (Chyl-)ascites with ascites or chylus in the sac	

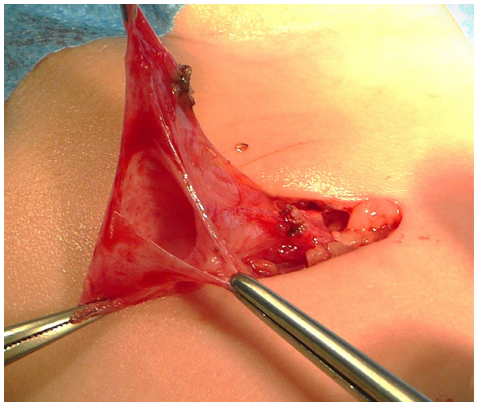

Figure 1. Hernia sac in a girl exposed via groin incision.

3. Pathogenesis

3.1. Inheritance and Developmental Basics

Maternal inguinal hernias can be inherited. Daughters of mothers with inguinal hernias have a fivefold increased risk of inguinal hernia. On the other hand, boys whose mothers have a connective tissue disorder have an increased risk of developing a hernia [5].

There is also evidence that a maternal birth weight of less than 2500 g is associated with an increased incidence of inguinal hernia in the offspring [6].

Contrary to popular belief, pediatric inguinal hernias should not be considered to be congenital in nature. Hernias in newborns immediately after birth are very rare. However, the open processus vaginalis peritonei is considered to be congenital and is identified as an essential prerequisite for the development of an inguinal hernia. However, the term "congenital" is commonly used to indicate the difference to predominately acquired form in the adult.

In boys, the protrusion of the peritoneal process is closely associated with testicular descensus. In girls (**Figure 1**), it remains unclear whether the presence of the Fallopian tube and ovary in the hernia sac is the result of excessive gonadal descensus or a secondary phenomenon [7] [8]. Failure of the processus vaginalis to obliterate in conjunction with an increase in intra-abdominal pressure predisposes to the formation of an inguinal hernia.

3.2. Anatomical Substrate

The processus vaginalis is a fetal peritoneal diverticulum, which, together with muscular fibers (the cremaster) and the deferential duct epididymis (formerly the mesonephric duct) accompany the descending testis. An abdominal wall hernia is characterized by the presence of a hernial orifice, hernial sac and hernial sac contents. In a pediatric inguinal hernia, the open deep inguinal ring and canal represent the hernial orifice. The persistently open processus vaginalis peritonei represents the hernial sac. The internal organs of the caudal part of abdominal cavity form the contents of the hernia sac. Indirect or lateral inguinal hernias based on a persistent open vaginal process occur in 99% of cases in pediatric cases. The wide variety of forms of persistent processus includes a spectrum of different malformations, such as "empty" persistent filiform processus, funiculocele, hydrocele testis, classic inguinal hernia and combined forms [9]. A right-sided inguinal hernia occurs in approximately 60% of cases, a left-sided inguinal hernia in 25%, and a bilateral inguinal hernia in 15%. However, there are differences between boys and girls. The predominance of right-sided hernias is explained by the fact that the left-sided closure of the deep inguinal ring precedes that of the right side. The wide variety of forms of persistent processus includes a spectrum of different malformations, such as "empty" persistent filiform processus, funiculocele, hydrocele testis, classic inguinal hernia and combined forms [9].

Premature infants develop a much higher incidence of inguinal hernia than term infants (30% vs. 3% - 5%) [3] [10].

The predisposition of premature infants to develop an inguinal hernia can be explained by anatomy. In contrast to older individuals, infants have a short, almost vertical passage of the inguinal canal. The deep and the superficial internal rings are nearly superimposed. This means that the stabilizing blind mechanism of the later oblique course of the inguinal canal is absent [11].

Predisposing factors for an inguinal hernia can also be disorders of sexual differentiation (DSD), disorders of the anatomy of the abdominal wall (exstrophy-epispadias complex, prune belly syndrome) and rare connective tissue diseases (Ehlers-Danlos syndrome, Marfan syndrome) [10] [12].

4. Clinical Appearance and Diagnostics

The cardinal symptom of inguinal hernia is the protrusion in the suprainguinal region, in boys possibly the prolapse of the bowel into the ipsilateral scrotum (scrotal hernia). The child is examined while lying down, and older children are also examined while standing or during voluntary pushing.

The so-called hernia sac crackling on digital palpation transverse to the course of the funicular cord or the uterine teres ligament (silk glove or silk purse sign) is due to the displacement of the hernia sac below the external inguinal ring in relation to the tissue below it. In one large series, the silk glove sign was specified at 97.3% [13].

Ultrasound examination has proven to be a diagnostically accurate procedure for assessing the hernial sac and its contents [10] [13]. In the diagnosis of hydroceles, diaphanoscopy is still a relevant examination method for the additional assessment of the testicular position and the contents of the hydrocele sac, in a darkened examination room. The light source is placed on the scrotum and causes the fluid in the scrotum to glow. The testicles or bowels are outlined as a darkened contour. More detailed information is, of course, provided by ultrasound examination (**Table 2**).

Table 2. Incidence, side distribution and derived surgical aspects.

	Girls	Boys
Incidence	10% - 20% of pediatric hernias	80% - 90% of pediatric hernias
Laterality	Right side more common, bilateral in 10% - 15%	Bilateral hernias more common in 20% - 30%
Contralateral risk	Contralateral risk up to 30% - 40%	10% - 15% (higher in preterm)
Surgical urgency	Early repair of ovarian hernias to avoid ovarian torsion	Within weeks. Urgently in the case of incarceration
Contralateral exploration	Prophylactical bilateral repair seems appropriate	Not recommended for open surgery

4.1. Hydrocele

Hydrocele is a special form of regression disorder of the vaginal process. Hydro-

celes and Hernias represent an embryological and clinical continuum [14].

They are filled with a serous fluid that resembles peritoneal fluid. Three main types of hydroceles can be distinguished: communicating hydrocele, hydrocele of the spermatic cord (**Figure 2**), and scrotal hydrocele.

Hydroceles often disappear within the first 18 to 24 months of life [15]. Small and flaccid postnatal hydroceles can be classified as a variant of normal and do not require further intervention. However, very dense hydroceles and hydroceles with signs of communication with the peritoneal cavities (increase in volume on standing or during the day) are quite disturbing and may interfere with testicular circulation. The indication for surgery must then be determined on an individual basis. The principle consists of cutting and ligating the vaginal process and partial resection of the hydrocele wall. Access is via the classical inguinal incision [16]. Laparoscopic management of pediatric hydrocele has been reported and seems to be beneficial. The laparoscopic view on the deep inguinal ring allows to differentiate between three types of hydroceles:

Type I hydrocele—closed ring and no communication to the peritoneal cavity.

Type II hydrocele—patent ring, hydrocele communicates to the peritoneal cavity (wide opening, opening covered by peritoneal seal, pin hole-like opening).

Type III hydrocele—patent ring, hydrocele does not communicate to the peritoneal cavity (solitary or multiple cysts) [17].

The female hydrocele is called Nuck's cyst (according to the famous anatomist from Holland) (**Figure 3**).

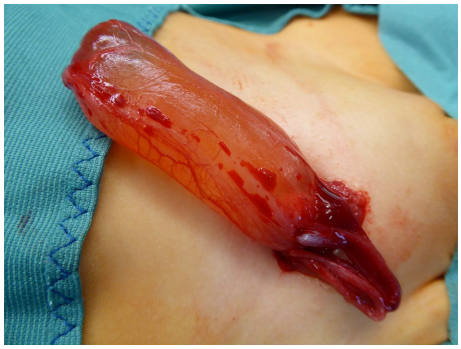

Figure 2. Male funiculocele. The tiny connection to the peritoneal cavity is ligated and essential structures of the spermatic cord are separated.

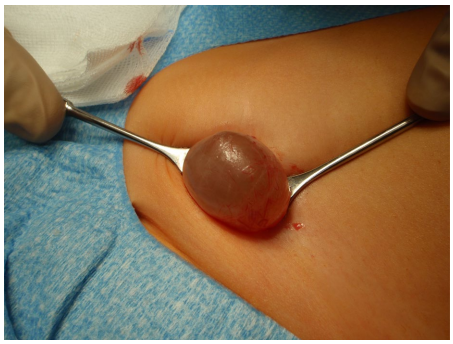

Figure 3. Nuck's cyst cyst in a preschool girl.

4.2. Ovarian Hernia

In the case of ovarian prolapse (predominately in the infant girl) an almond-shaped resistance above the vulva indicates a prolapsed ovary. As ovarian prolapse in girls usually involves a sliding hernia in which the ovary and adnexa are fixed in the hernia sac, reduction is often associated with immediate re-prolapse. In other cases, the less compressible ovary is enlarged edematously, and a kinking of the stalk can make reduction impossible. Forced attempts of reduction are not allowed. There is especially an increased risk of organ loss due to ovarian torsion. Color-coded Doppler sonography is very helpful in assessing the perfusion of the ovary (differentiation of uncomplicated sliding hernia or ovarian prolapse from incarceration or torsion). In addition, uterine prolapse can be identified with preoperative ultrasound. Operation urgency in the case of uncomplicated ovarian prolapse is not well defined [18]. In our institution, patients were admitted and we performed this surgery within 24 hours.

Uterine prolapse in an infant girl is very rare and should always raise suspicion for an underlying syndrome or anatomical anomaly (spina bifida, caudal regression syndrome, myopathy, connective tissue disorder) (**Figure 4** & **Figure 5**).

Figure 4. Presentation of an ovarian hernia in an infant.

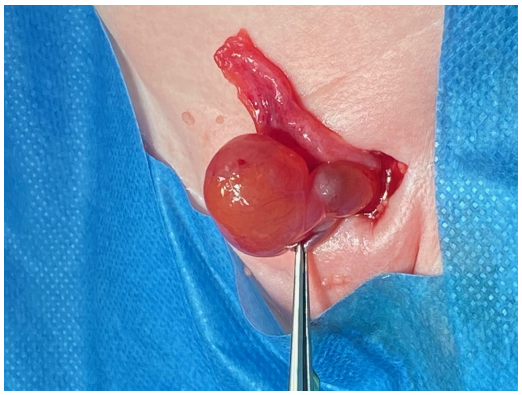

Figure 5. "Ovarian hernia" with prolapsed adnexa and paraovarian cyst in a newborn infant.

4.3. Red Flags, Incarceration

Red flags, *i.e.*, emergency symptoms that usually require surgical revision of the

inguinal canal within hours, arise in the case of a restless, painful infant (facies!) with a leaking inguinal hernia and refusal to feed, as well as in the case of repeated vomiting. An attempt to reduce the content of the hernia under analgesia and sedation can bring immediate relief. The operation is then carried out the following day with delayed urgency.

In boys, the position and size of the testicles must always be taken into account. Testicular torsion should be considered in any case suspicious for acute scrotum. In newborns with an enlarged scrotum and a bumpy color, pre- or perinatal testicular torsion can be assumed. In older boys, the torsion is flanked by severe accompanying symptoms (pain, vomiting, inability to walk). Incarcerated hernias are typically associated with a more protracted operation time, an extended hospital stay and increased hospital costs [15]. Depending on socioeconomic status and resource availability, emergency surgery due to incarceration can be a high priority in pediatric surgical care [19]. In Western countries, however, emergency operations for incarceration are rare.

5. Timing

Once a pediatric inguinal hernia is diagnosed, surgery should not be delayed unnecessarily. Timely elective repair is recommended—within weeks if stable, and urgently if incarcerated. In the case of incarceration gentle manual reduction should be attempted. For this purpose, the use of muscle-relaxing sedation or analgosedation (e.g., midazolam and possibly ketamine) is recommended. If the reduction is successful, surgery should be done within 24 - 48 hours. Otherwise, urgent operative reduction is required.

The timing of inguinal hernia repair in premature infants requires careful consideration. In general, a herniotomy in a small premature baby is a major operation. For decision making the risk of hernia incarceration has to be balanced with the safety of anesthesia and surgery. In clinical practice, repair is often scheduled 1 - 2 weeks before planned discharge. It has been shown that performing hernia repair during the initial neonatal admission was associated with lower cost, but higher recurrence rate, when compared to later repair [20].

A randomized clinical trial has shown that among preterm, the late repair strategy resulted in fewer infants having at least one serious adverse event. These findings support delaying inguinal hernia repair until after initial discharge from the neonatal intensive care unit [21] [22] (**Figure 6** and **Table 3**).

Table 3. Timing of hernia repair.

Situation	Recommendation
Preterm, unstable newborn	Delay until stable, but plan early repair
Asymptomatic hernia in a term neonate	Repair within 1 - 2 weeks
Toddlers, preschool children	Early elective repair
Incarcerated hernia	Immediate reduction or urgent surgery
Ovarian hernia	Surgery within days

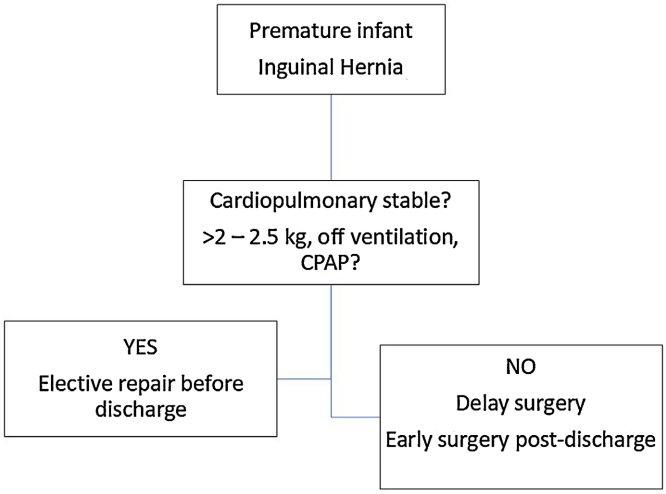

Figure 6. Decision support for the timing of herniotomy in premature infants in the NICU.

6. Surgery

Definitions: *Herniotomy* is defined as the surgical intervention involving the ligation and removal of the hernia sac. This approach is regarded as the prevailing method for the treatment of indirect lateral hernia in children. Conversely, *herniorrhaphy* entails the augmentation of the inguinal muscle channel through the utilization of muscles, sutures or mesh. The latter is neither pathophysiologically justified nor age-appropriate in children. Exceptions to this rule are infrequent.

It is generally accepted that the diagnosis of an inguinal hernia constitutes a mandatory indication for surgical intervention. Spontaneous regression of a symptomatic hernia does not occur.

Both open inguinal herniotomy and laparoscopic surgery are currently surgical options of roughly equal status. Both methods have advantages and disadvantages, which are briefly compared in Table 4. Figure 7 shows different surgical approaches for hernia repair.

Table 4. Comparison of the advantages and disadvantages of open and laparoscopic hernia repair. However, there is conflicting information in the literature on some aspects.

Criteria	Open	Laparoscopic
Access*	One incision Girls 10 - 20 mm Boys 10 - 30 mm	Umbilical incision 5 mm and one or two 3 mm Incisions
Cosmetic	Visible scar, later hidden by pubic hair	Scarcely visible scars
Duration of Surgery	Usually short, straightforward	Longer for beginners. Shorter for bilateral repair
View on the opposite deep ring	No possible, later operation if necessary	Direct inspection and closure
Risk of complications	Very low, standardized	Greater with an inexperienced team

Continued

Anesthetic exposure, Capnoperitoneum	Lower, no capnoperitoneum	Higher, especially for small babies
Recovery	Fast recovery	Rather quickly but delayed if capnoperitoneum is incompletely relieved
Costs	Less expensive	Higher

*Estimated age-, constitution- and technology-dependent values.

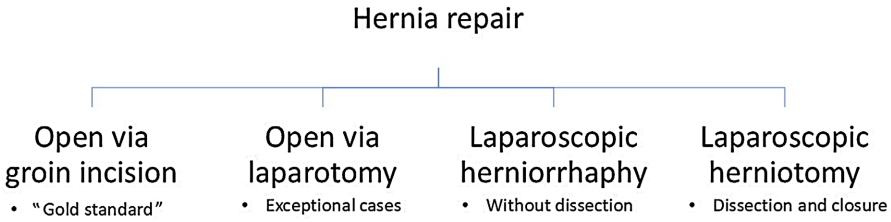

Figure 7. Different surgical approaches for hernia repair.

As an inguinal herniotomy is a complete aseptic procedure with a low risk of infection (<1%), routine antibiotic prophylaxis is not required. In premature babies, immunosuppressed children or in the presence of concomitant infections prophylaxis should be given [23].

The surgical principle of inguinal herniotomy in children is to close the hernia sac at the level of the deep inguinal ring. It is commonly not necessary to employ complex surgical techniques involving reconstruction of the muscular elements of the inguinal canal, as is the case in adults and children [24].

6.1. Open Hernia Repair

Basically, there are two open surgical procedures.

1) By opening the anterior wall of the inguinal canal (operation according to Ferguson/Gross, Grob, Rehbein and others). The main steps are to open the external inguinal ring or the external aponeurosis, close the neck of the hernia sac, remove the hernia sac and reconstruct the inguinal canal.

2) With the preservation of the intact external inguinal ring and the inguinal canal, a procedure (operation according to Czerny, Mitchell-Banks, etc.) has an unchanged success rate, especially in infants and small children with normal-sized hernias.

Even pioneer pediatric surgeons propagated ways to minimize access and tissue-sparing dissection [25].

Originally, hernia sac ligation alone without opening the inguinal canal was propagated for younger children. However, it was also shown to be safe for use in children over 2 years of age and school-age children [26].

Some analyses compared the results after opening herniotomy using the Mitchell-Banks or Gross-Ferguson technique.

In a retrospective study of herniotomized children over 2 years of age who un-

derwent surgery with or without opening of the external aponeurosis, no significant differences were found in the incidence of early or late complications. These included the recurrence rate (1.6% vs. 1.8%), the rate of postoperative undescended testicles (2.1% vs. 0.7%), testicular atrophy (1.5% vs. 0.4%) and postoperative hydroceles (1.9% vs. 1.8%) [27]. The second percentages in this series reflect a trend towards lower complication rates for the technique without opening the aponeurosis. Ahmad, *et al.* (2021) came to the conclusion that the simple herniotomy without opening the inguinal canal has less postoperative scrotal edema and recurrences (0.8% vs. 6.2%) with significantly reduced operating time [28].

Whether the inguinal canal is opened or not, posterior fixation of the sac closed at the neck of the hernia sac in the inguinal canal may provide additional stability (Ferguson method according to Ladd and Gross, 1941). In most cases, however, this additional surgical step is probably unnecessary [29].

The open technique also allows the minimization of skin incisions without increasing the recurrence rate. Suzuki *et al.* (2014) used a selective sac extraction method using a two-forceps technique to separate the hernia sac. They achieved their goal with skin incisions between 4 and 12.5 mm in length [30].

Ultimately, inguinal hernias can be closed in exceptional situations as part of a laparotomy or specifically by means of a minilaparotomy.

Finally, inguinal hernias can be closed in exceptional situations as part of a laparotomy or specifically by means of a minilaparotomy [31].

There is some disagreement as to whether the contralateral side should also be examined in the case of open repair and unilateral inguinal hernia. The possibility of iatrogenic injury to the vas deferens, the testicular vessels and the genitofemoral nerve with the genital ramus are strong arguments against such an approach [9] [7].

The high incidence of metachronous hernias in former preterm infants, the left-sided hernia and the early presentation argue for a "routine" exploration of the asymptomatic contralateral side. Laparoscopic herniorrhaphy was a game-changer in this field, as it allowed for the assessment of the opposite side to be carried out routinely and without any additional measures. However, the question of which asymptomatic open processes required closure still required further consideration.

6.2. Laparoscopic Hernia Repair

The use of laparoscopic techniques in children has opened up fundamental new perspectives.

Using thin-caliber instruments and a careful surgical technique, laparoscopy enables atraumatic and later scarless surgery. These favorable cosmetics naturally have a positive effect on self-experience and quality of life.

Pioneers of this approach were Montupet and Esposito in 1999 and Schier in 2000 [32]-[35].

However, the range of respective modifications is now almost becoming con-

fusing. In laparoscopic herniorrhaphy, a distinction can be made between external and internal suturing techniques. In addition to the closure of the inner inguinal ring, there are technical variants that favor a dissection of the hernia sac at the level of the deep inguinal ring [36]. Other methods aim to invert the sac. A large number of studies have confirmed that the open and laparoscopic methods have nearly the same value in terms of surgical outcomes.

Laparoscopic herniorrhaphy, laughed at the time, has now become more widely accepted and is the standard procedure in many departments. Despite some benefits of the laparoscopic procedure, it seems that a majority of pediatric surgeons prefer the open approach [37] [38]. In the years 2015 to 2017, open inguinal herniotomy was predominantly performed in Germany. Due to gender-related anatomy, predominantly girls over the age of one year underwent laparoscopic surgery in the present study [2].

With laparoscopy, the former dogma of hernia treatment limited to the symptomatic side, which was valid in many places, was shaken. As laparoscopic surgery allows visualization of both inguinal rings (**Figure 8**) without additional tissue traumatization, the surgeon is faced with the question of simultaneous treatment of a contralaterally open vaginal process. The bubble sign is a simple sign of the persistence of a vaginal process. When external pressure is applied to the inguinal canal, bubble formation can be observed laparoscopically at the deep inguinal ring (**Figure 9**). With the introduction of laparoscopy, it has become possible to reliably identify and specifically treat rare types of inguinal hernia in children.

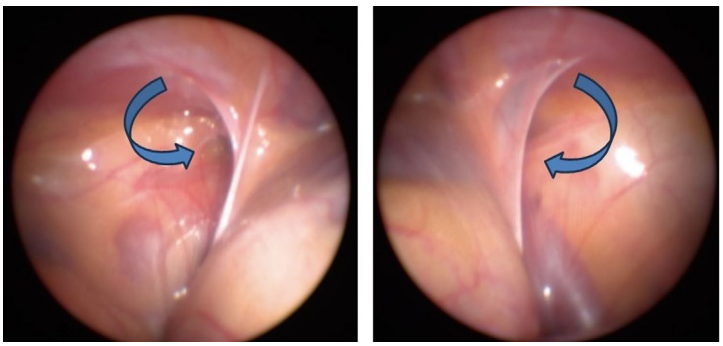

Figure 8. Laparoscopic view on the open deep inguinal rings.

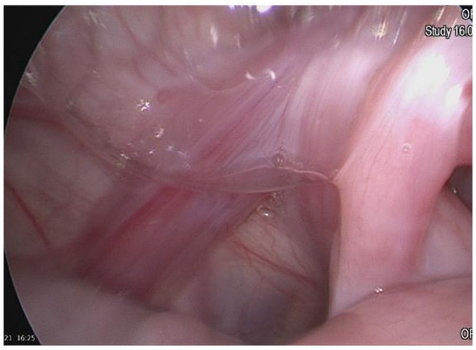

Figure 9. The bubble sign. View of the left deep inguinal ring in a case of adnexal prolapse.

Laparoscopy allows reliable differentiation between indirect and direct hernias or the rare simultaneous occurrence of indirect and direct inguinal hernias (en pantaloon) on one side [39].

Laparoscopic methods are based on selective closure of the deep inguinal ring. The possible consequences of closing an asymptomatically open process must be weighed against the risk of a metachronous contralateral inguinal hernia. No clear recommendation can be derived from the literature [22].

The probability of the subsequent development of an inguinal hernia from an open vaginal process has been estimated as high as 25% - 50% [15]. Another study found a lower recurrence rate of 13% [40]. This rate of developing symptomatic metachronous hernias is highest in premature and newborn babies, while it decreases with increasing age.

In boys, laparoscopic closures may be associated with an increased rate of testicular retraction [41]. It seems that herniorrhaphy without transection of the hernia sac, in particular, predisposes to an increased rate of secondary ascended testicles. However, this plausible conclusion is controversially debated in literature.

In girls, closure of the internal inguinal ring is not associated with the potential risk of damage to gonadal function. In the author's opinion, this favors the female sex for laparoscopic surgery. In boys, the retroperitoneal testicular vessels and the ductus deferens, in particular, are fragile structures that must be particularly protected.

A recently compiled meta-analysis even came to the conclusion that laparoscopic extraperitoneal hernia closure is associated with lower MCIH incidence and shorter operation times, with no increase in hernia recurrence, surgical site infection, or length of hospitalization [32].

6.3. Surgical Complications and Long-Term Outcome

Particularly in preterms, postoperative apnoea, desaturation and bradycardia with the need for immediate intervention or even (re-)intubation pose a real risk. From this point of view regional anesthesia procedures close to the spinal cord ("neuroaxial") have particular advantages. The consideration of regional anesthesia may reduce post-operative apnoea and pain, but there is no difference in neurodevelopment outcomes [22].

Postoperative respiratory monitoring of preterm infants is recommended in particular up to a corrected, *i.e.*, post-conceptual age of 60 weeks [4] [33]. For an infant with a gestational age of 30 weeks, for example, this vulnerable phase would extend to a postnatal age of 4.5 months.

Common minor complications after inguinal hernia repair in children are suture granulomas and almost always a superficial wound infection. In up to 10% of cases, a temporary hydrocele may develop in the residual hernia sac. Testicular atrophy, which can be expected in about 1% of boys, can have several causes. In particular, repeated incarceration of the hernia sac with impaired testicular circulation favors ischemic damage to the testis. The recurrence rate after surgery for a pediatric in-

guinal hernia is between 1% and 6%. Predisposing factors include prematurity, large hernial orifice, increased intra-abdominal pressure (peritoneal dialysis, ventriculoperitoneal shunt) and anatomical predisposition Bladder exstrophy).

Indicative data on complication rates [24]:

- Retraction of the testis 0.8% bis 2.8%
- Testicular atrophy 1% bis 20%
- Cutting of the ductus < 1%
- Hydrocele up to 10% (conservative management)
- Vary rare, injury of the urinary bladder, bowel or adnexa
- Nerve trapping or damage (ilioinguinal, iliohypogastric, genitofemoral nerve)

The risk of chronic pain syndrome occurring after an inguinal herniotomy must be taken into account, particularly in older children and adolescents. In a study of 176 children and adolescents, 6 children (3.4%) complained of local pain after 3 months. Half of these disappeared in the subsequent period. For prevention, the authors recommend a caudal epidural block, short operating times and adequate postoperative analgesic treatment [42]. The same rate of patients with chronic pain was found in a study of 213 patients after an amazing 49 years of follow-up. There was a 3% pain rate and a 5% infertility rate. The authors also found that in 8.4% of cases, another hernia operation was necessary after a hernia operation in childhood. It should be noted that chronic pain is only mild and does not usually limit daily activities [43].

Potentially, laparoscopic procedures have their own complication potential because most manipulations take place inside the abdomen. Particularly in the case of percutaneous puncture techniques for laparoscopic herniotomy, the possibility of difficulty controlling bleeding due to injury to the inferior epigastric artery/vein, and more rarely the testicular vessels or iliac vessels, must be taken into account. By injecting the retroperitoneum with a physiological saline solution, the risk of unintentional injury to the testicular vessels or the ductus deferens at the deep inguinal ring can be minimized [44].

The use of a synthetic mesh for hernia repair is also not necessary in adolescents. Of particular concern is the potential development of chronic pain syndrome [**Reistrup**].

6.4. Hernia Recurrence

Recurrencies of pediatric hernia are generally rare. Ford and Hutson (2014) found the following percentages for the development of hernia recurrence:

- Generally, 1%*
  - Following incarceration 3%
  - Preterms up to 17%*
  - Rarely, direct hernia on the same side (ipsilateral) [24].
- Footnote *The potential recurrence rate for infant hernias is particularly dependent on the immaturity of the child. It is highest in babies with birthweight < 1500 to 1000 g.

However, in the case of ipsilateral recurrency, first and foremost, of course, iatrogenic causes should be thought of: for example, incomplete closure of the hernia sac or the use of unsuitable suture material. For open surgery, synthetic sutures that are resorbable at medium time are considered adequate. One study found that the use of absorbable or braided sutures in laparoscopic inguinal hernia repair was associated with an increased rate of recurrence in adolescents [45].

There are also a number of intrinsic causes for recurrence. Affected patients may have conditions with chronically increased intra-abdominal pressure, such as ventriculoperitoneal shunt for hydrocephalus, posterior urethral valves, bladder exstrophy, seizure disorder, asthma, using continuous positive airway pressure for respiratory distress syndrome, and gastroesophageal reflux disease. Another group that is predisposed had diseases with weakness of the anterior abdominal wall, specifically mucopolysaccharidosis, omphalocele, connective-tissue disorders, or spinal dystrophy [46].

After unilateral treatment, contralateral metachronous hernias remain, which must be closed in a second operation.

A meta-analysis from 2015 estimated the rate of a metachronous hernia on the opposite side to be 6% overall [47]. In particular, left-sided hernias and a persistent vaginal process were risk factors for a metachronous hernia. There was also an increased risk for girls and infants [48].

7. Conclusion

Inguinal hernias represent a broad spectrum of different forms of obstruction of the fetal processus vaginalis peritonei. Based on developmental differences, there are different diagnostic and therapeutic approaches for boys and girls. Surgical planning is particularly important in vulnerable premature and newborn babies. It is vital that treatment be tailored to the specific needs of the patient, taking into consideration their age, overall risk and the nature of the underlying pathology.

Author's Contributions

RBT conceptualised the study and was responsible for the publication. The illustrations presented are derived from the author's clinical experience.

Data Availability

All data generated or analyzed for this review are included in this published article.

Ethical Approval

In this particular instance, the requirement for an ethics vote must be denied. The absence of any patient data in this article, and the concomitant inability to attribute it to any specific patients, renders the necessity for an ethics vote inapplicable.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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