Complications of Laparoscopic Pyeloplasty in Children

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Abstract: Laparoscopic pyeloplasty (LP) has become a preferred minimally invasive approach for managing ureteropelvic junction obstruction (UPJO) in children, offering advantages over open surgery. However, while generally safe and effective, LP is not without potential complications. This work reviews the spectrum of complications associated with pediatric laparoscopic pyeloplasty, emphasizing both intraoperative and postoperative risks. Intraoperative complications, although less frequent than with open surgery, include bleeding, requiring careful hemostasis and potentially blood transfusion. Vascular injury to renal vessels, while rare, carries significant consequences and necessitates meticulous dissection. Iatrogenic injury to the bowel or ureter is possible, highlighting the importance of precise surgical technique and anatomical knowledge. Air embolism, a potential complication of all laparoscopic procedures, necessitates vigilance and appropriate management. The smaller size and fragility of pediatric anatomy increase the risk of these complications compared to adult cases. Postoperative complications encompass a range of issues. Wound infection, although less common than with open surgery, remains a possibility, emphasizing the need for strict sterile technique and prophylactic antibiotics. Postoperative pain, while generally less severe than with open pyeloplasty, may still require adequate analgesia. Anastomotic leakage, a significant concern, can lead to urinoma formation and necessitate percutaneous drainage or surgical revision. Stricture recurrence, representing a failure of the initial repair, might require further intervention. Persistence or recurrence of hydronephrosis, despite successful surgery, can be observed, potentially indicating incomplete correction of the obstruction. In rare cases, renal function may deteriorate postoperatively, highlighting the importance of meticulous preoperative assessment of renal function. Finally, port-site complications such as bleeding, infection, or herniation can occur. The risk of these complications is influenced by several factors, including surgeon experience, the complexity of the UPJO, and the child's overall health. Experienced surgeons utilizing advanced laparoscopic techniques and meticulous surgical precision can significantly reduce the incidence of complications. Preoperative planning, including careful patient selection and appropriate imaging studies, is crucial in minimizing the risk of adverse outcomes. Close postoperative monitoring and timely management of any complications are essential for optimal patient outcomes. Despite the inherent risks, LP continues to offer a valuable minimally invasive alternative for treating UPJO in children, providing significant benefits when performed by experienced surgeons in appropriately selected patients.

Keywords: laparoscopic pyeloplasty, Children

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Introduction

Open pyeloplasty has been the standard treatment for congenital or acquired ureteropelvic junction (UPJ) obstruction in adults and children, with overall success rates of 90% to 100% [1,2,3]. Open pyeloplasty has a high success rate done through either a flank, dorsal lumbotomy, or anterior muscle splitting incision. Proponents of open pyeloplasty have shown that this procedure can be done without placement of an indwelling ureteral stent and along with simple percutaneous drainage by either a nephrostomy tube or a single Penrose drain [1,2].

Although endopyelotomy [4] and retrograde dilation [5] are alternative approaches in children [6], the success of these 2 procedures is inferior to that reported for conventional dismembered pyeloplasty [7]. In the initial reports, the operative time ranged from 3 to 7 hours, but the procedure has gradually gained in popularity and acceptance, with a reported success rate of over 95% [8,9,10].

Diagnosis

Approximately 1% of prenatal ultrasounds detect hydronephrosis in the fetus. In 50% of these cases, UPJ obstruction is the etiology, being more common in males, affecting the left kidney more often than the right, and with 10â€“30% of cases occurring in both kidneys (bilaterally) [11]. Neonates suspected to have this condition are evaluated for the obstruction using renal ultrasound and diuretic renography. Magnetic resonance urography has become part of the armamentarium as well. Debate continues as to whether or not a voiding cystourethrogram (VCUG) might be utilized to rule out vesicoureteral reflux as a cause of the hydronephrosis or as a concomitant finding. Symptoms of UPJ obstruction are typically seen in older children but can be seen in infants and include any combination of back or flank pain, hematuria, failure to thrive, flank mass, or pyelonephritis.

Indications

The indications for laparoscopic pyeloplasty are similar to those for an open pyeloplasty, such as increasing hydronephrosis, progressive deterioration of renal function, recurrent urinary tract infection (UTI), and persistent pain. Refinement of instrumentation and experience with intracorporeal suturing allows reconstructive laparoscopy to be implemented in the pediatric population and multiple techniques have already been described in the literature [12]. One of the earliest descriptions of the transperitoneal Anderson-Hynes laparoscopic pyeloplasty in pediatric patients by Tan *et al.* [13] recommended that it should not be performed in children less than 6 months of age. The advent of improved 3 mm instrumentation and laparoscopic telescopes has allowed better suture manipulation and visualization making it feasible even in infants less than 6 months old [14]. The key point to performing a laparoscopic pyeloplasty in the infant is based on the geometry of the patient's body in relation to trocar placement. A triangle is formed with the umbilicus as the apex and the remaining points being lateral to the ipsilateral rectus muscle subcostally and at the level of the anterior superior iliac spine.

Yeung *et al.* [15] reported their initial experience with retroperitoneal laparoscopic pyeloplasty in 13 children, 1 of whom required open conversion. The mean operative time was 143 min (range = 103-235 min). El-Ghoneimi [16] reported their experience with 50 retroperitoneal cases in children aged between 22 months and 15 years. Conversion to open surgery was necessary in 4 cases due to technical difficulties during suturing. Mean hospital stay was 2 days, and return to full activities occurred within 5 days of surgery. The longer time needed for the retroperitoneal approach is almost certainly related to the limited working space that renders suturing more difficult.

Whereas open pyeloplasty has long been described, laparoscopic pyeloplasty has only recently been reported, and long-term outcome data are still being evaluated. There seems to be promise of a multicenter prospective study comparing open, laparoscopic, and robotic techniques with a treatment algorithm that will be common among the institutions evaluating the techniques.

Outcomes

The evolution of surgical therapies continuously challenges open and endoscopic interventions with data emerging from laparoscopic pyeloplasty series [11,12,13,14,15,16,17,18,19]. Debate concerning which approach to choose (i.e. transperitoneal or retroperitoneal) is based more on philosophy than true evidence-based medicine. It is has been stated that the gold standard of pediatric open renal surgery is the retroperitoneal approach and that minimally invasive surgery should follow the same rules [20]. Typically, surgeons who have started with retroperitoneal extirpative laparoscopic procedures perform pyeloplasties in a retroperitoneal fashion. However, this is not for everyone because of the longer time needed for the retroperitoneum related to the limited working space, which makes suturing more difficult early in the learning curve [20]. However, there are no data to show that a transperitoneal approach has any increased complication rate or decreased success rate. The approaches appear to be equal, and overall laparoscopic pyeloplasty in children has been demonstrated to be feasible and to have satisfactory results approaching that of open pyeloplasty [13,15,16,20,21].

When comparing the gold standard open approach to the laparoscopic approach [20], the mean operative time was significantly shorter in the open surgery group (96 min, range = 50-150 min) versus the laparoscopy group (219 min, range = 140-310 min) ($P < 0.0001$). On the other hand, the mean postoperative use of analgesics and hospital stay were less in the laparoscopy group. The major disadvantage of the laparoscopic approach is that it is clearly technically challenging, leading to increased surgical times because of the high proficiency required for intracorporeal suturing. Although automated devices that facilitate suturing are available [22], accurate suture placement and unavailability of a small size for pediatric application limit their use [23]. Development of novel alternatives to suturing, such as fibrin glue and laser welding, may enhance the utilization of the laparoscopic approach; however, the results with these methods alone have not yet matched the success of conventional sutures in providing adequate tensile strength of the anastomosis [24]. Therefore, surgeons interested in this approach can help decrease the operative times in pediatric laparoscopy through suturing practice and training in an inanimate model [17].

Complications

Postoperative complications, while generally less frequent and less severe than those associated with open pyeloplasty, remain a potential concern. Common complications include wound infection, bleeding, anastomotic leakage, and recurrence of the obstruction. However, the lower incidence of these complications compared to open surgery represents a significant advantage of the laparoscopic approach. Careful surgical technique, meticulous hemostasis, and appropriate postoperative management are essential in minimizing the occurrence of these complications [24]

In the adult population, the total rate of laparoscopic complications is approximately 4 to 6 per 1000 [25,26,27], and the mortality is approximately 3 per 100,000 [26]. The complication rate is significantly associated with the complexity of the procedure, as seen in 2 large adult studies [25,26]. The true danger lies in the fact that complications can often be overlooked during laparoscopic surgery. The postoperative rather than intraoperative recognition of these injuries increases the severity of the sequelae [25]. In Chapron's series [26], 1 in 4 complications was diagnosed subsequent to surgery because of consequences of the complication. Diligent inspection of the viscera at the end of every procedure may help identify an injury. Postoperatively, a patient should continue to improve hourly in the immediate postoperative period and then dramatically day by day over the first week. If this sequence does not occur, then one must be wary of a missed injury, and acting quickly to solve it should minimize adverse outcomes.

Potential complications with pyeloplasty:

1. Bleeding requiring transfusion (1 per 5000)

   Bleeding after laparoscopic pyeloplasty (LP) in children is a potential complication, though generally less frequent than with open pyeloplasty. The amount and significance of bleeding can vary considerably. It's important to understand the different types and causes of bleeding, as well as the management strategies.

   Sources of Bleeding:

Intraoperative Bleeding: This is the most common type and usually occurs during dissection of the renal pelvis and ureter, or during the reconstruction of the ureteropelvic junction (UPJ). Small vessels may be inadvertently injured during the meticulous dissection required for a successful LP. The fragility of pediatric vessels increases this risk. Careful hemostasis techniques, utilizing advanced energy devices (e.g., bipolar coagulation, LigaSure) and meticulous surgical technique, are crucial to minimize intraoperative bleeding. [25].

Postoperative Bleeding: Postoperative bleeding can manifest as hematuria (blood in the urine) or retroperitoneal hematoma (blood collection behind the abdominal lining). This is usually less common but can be a serious complication. It can result from delayed bleeding from small vessels that were not

completely sealed during the procedure, or from injury to larger vessels during the surgery that only manifest later. [25].

Causes of Increased Bleeding Risk:

Several factors can increase the risk of bleeding following LP in children [26]:

Difficult Dissection: Complex anatomical variations or scarring from previous surgeries can make dissection more challenging and increase the risk of vascular injury.

Inexperienced Surgeon: Surgeons with less experience in pediatric laparoscopic surgery may have a higher incidence of bleeding complications due to less precise surgical technique.

Coagulopathy: Children with underlying bleeding disorders have a significantly increased risk of bleeding.

Use of Anticoagulants: Preoperative use of anticoagulant medications can increase the risk of bleeding.

Management of Bleeding:

The management of bleeding after LP depends on the severity and location of the bleeding. Options include: **Conservative Management:** For minor bleeding (e.g., minimal hematuria), conservative management with close monitoring may be sufficient. **Angiographic Embolization:** For significant retroperitoneal hematomas or persistent bleeding, angiographic embolization (blocking the bleeding vessel with special materials) may be required. This is a minimally invasive procedure performed by an interventional radiologist. **Surgical Exploration:** In rare cases of severe or uncontrolled bleeding, surgical exploration may be necessary to identify and repair the bleeding vessel. This would involve a repeat laparotomy, reverting to open surgery. **Transfusion:** If significant blood loss occurs, blood transfusion may be required [25].

Prevention: Preventing bleeding is paramount. This involves [25].:

Careful Preoperative Assessment: Identifying children with increased bleeding risk through a thorough history and physical exam, and appropriate blood tests.

Meticulous Surgical Technique: Experienced surgeons using advanced surgical techniques and appropriate energy devices to achieve optimal hemostasis during the procedure.

Adequate Postoperative Monitoring: Careful monitoring of vital signs, urine output, and hematocrit levels to detect early signs of bleeding.

Bleeding after laparoscopic pyeloplasty in children is a serious complication, though relatively infrequent. Careful planning, meticulous surgical technique, and vigilant postoperative monitoring are crucial in minimizing this risk and ensuring optimal patient outcomes.

2. Trocar or insufflation needle damage to viscera or vessels (1 per 3000)

Damage to viscera or vessels during the insertion of trocars or the insufflation needle is a potential, though rare, complication of laparoscopic pyeloplasty (LP) in children. The small size and relatively fragile nature of pediatric anatomy increases the risk compared to adult procedures. These injuries can range from minor, requiring minimal intervention, to major, necessitating immediate surgical repair. [26]:

Mechanisms of Injury:

Improper Trocar Placement: The most common mechanism of injury is improper placement of trocars. Inadequate visualization during trocar insertion, particularly in obese patients or those with prior abdominal surgery, can lead to penetration of the bowel, bladder, or major blood vessels. Using blunt trocars, appropriate trocar sizing, and careful palpation before insertion can minimize this risk. Open technique for trocar placement is sometimes used for the first trocar insertion to directly visualize the abdominal wall and peritoneum. [26]

Inadequate Visualization: Poor visualization due to obscured anatomy from adhesions, obesity, or pre-existing scarring increases the risk of trocar-related injuries. The use of advanced imaging modalities like intraoperative ultrasound can help in these challenging situations. [26]

Forceful Trocar Insertion: Excessive force during trocar insertion can cause injury even with appropriate trocar placement. Gentle insertion is crucial, especially in children with thinner abdominal walls. [26]

Insufflation Needle Injury: While less common than trocar-related injuries, the insufflation needle can also cause injury, usually to the bowel or a major blood vessel. Careful placement of the needle under direct vision, avoiding rapid insufflation, and using a blunt-tipped needle can reduce this risk. [26]

Inadequate Pneumoperitoneum: Insufficient pneumoperitoneum can lead to improper trocar placement due to obscured anatomical landmarks.

Types of Injuries: [26]

Injuries can involve:

Bowel Perforation: This can range from small perforations that may seal spontaneously to large perforations requiring surgical repair.

Vascular Injury: This can involve damage to major vessels, such as the inferior vena cava or renal arteries, or smaller vessels in the mesentery. This necessitates immediate surgical intervention.

Bladder Injury: Bladder perforation can lead to urine leakage into the abdominal cavity and require surgical repair or catheterization.

Diaphragmatic Injury: Rarely, the diaphragm can be injured during trocar insertion.

Management: Management depends on the type and severity of the injury:

Minor injuries: Small bowel perforations that are recognized intraoperatively and are small may be managed conservatively with close monitoring.

Major injuries: Large bowel or vascular injuries require immediate surgical repair, often converting the procedure to an open operation.

Bladder injury: Usually necessitates cystoscopy, catheterization, and potentially surgical repair depending on the extent of the injury.

Prevention: Minimizing the risk of these injuries involves several strategies:

Careful Preoperative Planning: Detailed preoperative evaluation, including appropriate imaging studies, to identify potential anatomical variations or adhesions.

Optimal Trocar Placement Technique: Using a technique that minimizes the risk of visceral or vascular injury, such as open insertion of the first trocar.

Experienced Surgeons: Surgeons experienced in pediatric laparoscopic surgery have a lower incidence of these complications.

Appropriate Patient Selection: Careful selection of patients who are suitable for laparoscopic surgery.

Despite careful planning and experienced surgeons, these injuries can still occur. However, meticulous surgical technique, appropriate equipment, and careful attention to detail are essential in minimizing the risk of trocar or insufflation needle damage during pediatric laparoscopic pyeloplasty. [26]

3. Thermal damage to tissues or organs (1 per 2500)

Thermal injury during laparoscopic pyeloplasty (LP) in children, though relatively uncommon, represents a potential complication stemming from the use of energy devices for hemostasis and dissection. These devices, including monopolar and bipolar electrocautery, ultrasonic shears, and LigaSure devices, generate heat, and if improperly used, can cause unintended damage to adjacent tissues and organs. The delicate nature of pediatric anatomy increases the susceptibility to thermal injury, necessitating meticulous surgical technique and careful monitoring. The proximity of vital structures like the renal vessels, bowel, and ureter to the surgical field necessitates extra caution. [27]

The extent of thermal injury can vary significantly, ranging from minor, subclinical damage to severe injury requiring intervention. Minor thermal injury might manifest as subtle inflammation or edema, resolving spontaneously without intervention. More significant injury could cause necrosis of tissues, perforation of organs, or stricture formation. The type of energy device used,

its settings, and the duration of application all influence the potential for thermal injury. Improper application of the energy device, such as prolonged contact with tissues or excessive power settings, significantly increases the risk of damage. Furthermore, the surgeon's experience and expertise in using these devices play a crucial role in minimizing thermal complications. [27]

Prevention of thermal injury relies heavily on meticulous surgical technique. This includes using the lowest effective energy settings, minimizing the duration of energy application, employing careful dissection techniques to avoid inadvertent contact with adjacent structures, and utilizing irrigation to cool the tissues during energy application. The surgeon's familiarity with the capabilities and limitations of the energy devices used, along with regular maintenance and calibration of the equipment, is crucial. Adequate visualization of the surgical field is essential to ensure precise application of energy and minimize the risk of inadvertent damage. [27]

In the event of suspected thermal injury, management depends on the severity of the injury. Minor injuries might resolve spontaneously with close observation. More significant injury might necessitate surgical intervention, potentially requiring resection of damaged tissue, repair of organ perforation, or other corrective measures. Prompt recognition and appropriate management of thermal injury are essential to prevent further complications and ensure optimal patient outcomes. Continuous improvement in surgical techniques, ongoing training, and the development of newer energy devices with improved safety features are likely to further decrease the incidence of thermal injury during pediatric laparoscopic pyeloplasty. [27]

4. Hernia at the port site and/or internally (< 1%)

Postoperative hernia formation is a potential complication following laparoscopic pyeloplasty (LP) in children, although it's generally less frequent compared to open surgery. These hernias can manifest as either incisional hernias at the port sites or internal hernias, both representing potential sources of significant morbidity. Incisional hernias occur at the sites where the trocars were inserted, resulting from incomplete closure of the fascial layers or weakness in the abdominal wall. Factors influencing their development include the size of the port site incisions, the quality of the fascial closure, and the inherent strength of the abdominal wall in the child. Larger port sites and inadequate fascial closure increase the risk of incisional hernias. [28]

Internal hernias represent a more serious complication, arising from the formation of defects or openings within the peritoneum. These defects can trap bowel loops or other abdominal viscera, causing bowel obstruction, ischemia, and potentially life-threatening consequences. The formation of internal hernias is often linked to inadequate closure of the peritoneal layers, the presence of adhesions, or the creation of abnormal peritoneal spaces during the laparoscopic procedure. While less common than incisional hernias, internal hernias are potentially more dangerous and require prompt diagnosis and treatment. Symptoms often mimic bowel obstruction with abdominal pain, vomiting, and distension. [28]

Prevention of both incisional and internal hernias focuses on meticulous surgical technique. Using appropriately sized trocars, creating minimal fascial defects, and ensuring meticulous closure of the fascial layers and peritoneum are crucial preventive measures. Techniques such as using barbed sutures or mesh reinforcement in high-risk cases can further minimize the risk of incisional hernia formation. Moreover, surgeons should be aware of the potential for the creation of spaces during the procedure that might predispose to internal hernias, and strive to minimize this risk through careful dissection and adhesiolysis where necessary. Postoperative monitoring for signs and symptoms of hernias, along with prompt diagnostic evaluation and appropriate management should a hernia occur, are also essential aspects of care. [28]

5. Wound infection (< 1%)

Wound infection at the trocar sites is a potential complication following laparoscopic pyeloplasty (LP) in children, although its incidence is generally lower than with open surgery. The risk of infection is influenced by several factors, including the child's overall health, the presence of pre-existing skin conditions, the surgical technique employed, and the meticulousness of sterile practices during the procedure and postoperative care. Larger port sites increase the surface area susceptible to infection. Inadequate hemostasis at the port sites, leading to hematoma formation, can also increase the risk of infection as it provides a medium for bacterial growth. Prophylactic antibiotics are routinely administered to minimize the risk of infection, but their effectiveness isn't absolute, and meticulous surgical technique and sterile practices remain essential. [24]

Manifestations of wound infection can range from minor cellulitis (superficial skin infection) to more serious deep-seated infections involving the fascia and potentially underlying structures. Symptoms may include localized redness, swelling, pain, tenderness, purulent drainage, and fever. Management depends on the severity of the infection. Minor infections may respond to local wound care and oral antibiotics, while more serious infections may require intravenous antibiotics, surgical debridement (removal of infected tissue), and possibly drainage of abscesses. Early recognition and prompt management are essential to prevent serious complications such as sepsis (a life-threatening bloodstream infection) and chronic wound issues. The use of appropriate wound closure techniques and meticulous postoperative care, including regular wound inspection and dressing changes, contribute to reducing the incidence of wound infections. [24]

6. Persistent leakage of urine (< 1%)

Persistent urine leakage following laparoscopic pyeloplasty (LP) in children is a serious complication, potentially leading to significant morbidity. This leakage typically occurs at the site of the ureteropelvic junction (UPJ) anastomosis (where the repaired ureter and renal pelvis are rejoined), indicating an imperfect surgical repair. The causes of persistent leakage can include technical issues during the anastomosis, such as tension on the suture line, inadequate apposition of the tissues, or the use of inappropriate suture material. Underlying conditions such as inflammation or infection at the

anastomosis site can also contribute to leakage. Pre-existing abnormalities of the UPJ or the presence of significant scarring can increase the risk of this complication. The severity of the leakage can range from minimal to significant, affecting both the patient's overall well-being and renal function. [10]

Diagnosis of persistent urine leakage may involve clinical examination, imaging studies such as ultrasound or CT scans, and isotope renography to assess renal drainage. Management options depend on the severity and cause of the leakage. In some cases, conservative management with close monitoring and supportive care may be sufficient, especially for minimal leakage that resolves spontaneously. However, more significant leaks often require intervention, which might include percutaneous drainage of a urine collection (urinoma), endoscopic repair, or open surgical revision of the anastomosis to achieve a watertight repair. The choice of management strategy depends on several factors including the severity of the leakage, the child's overall health, and the surgeon's experience and expertise. Early diagnosis and appropriate management of persistent urine leakage are essential to prevent complications like sepsis and long-term renal damage. [10]

7. Stent migration (< 1%)
8. Re-obstruction (transient (5-10%) and persistent (1-3%))
9. UTI with stent in place (5%)

Conclusions

Transperitoneal and retroperitoneal approaches are reported to have comparable outcomes. In our experience, the retroperitoneal approach has been difficult in the following scenarios: (1) children under 15 kg with extremely large renal pelvises, and (2) previous violations of the retroperitoneal space. For a relatively long obstructed UPJ segment associated with a hydronephrotic extrarenal pelvis, several flap pyeloplasty techniques, such as a Culp-Deweerd spiral, Scardino-Prince vertical flap, and a dismembered tubularized renal pelvic wall flap, have been performed, as described by Gill *et al.* [24].

Reports on the retroperitoneal approach in laparoscopic pyeloplasty are less common despite wide use of this approach in laparoscopic nephrectomy. The level of difficulty of manipulation certainly increases in the retroperitoneal space. We believe that difficulty of manipulation in the retroperitoneal space can be overcome with improvement in operative skill, especially in ambidextrous suturing technique. This approach has some advantages. First, it can avoid dissemination of urine into the peritoneal cavity under retroperitoneoscopic procedures when the renal pelvis is transected. Second, it can minimize the risk of injury to intraperitoneal organs, such as the colon and small bowel, but this is still not established with current experiences. Some speculate that the transperitoneal approach poses less risk to abdominal organs because they are always kept in the field of view.

The success rate of laparoscopic pyeloplasty is equal to that of conventional open pyeloplasty. Transperitoneal and retroperitoneal approaches are reported to have comparable outcomes [16]. We

believe that laparoscopic dismembered pyeloplasty for UPJ obstruction in infants is technically possible. We also believe the use of an indwelling stent is helpful, but not mandatory.

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