Pediatric Urology for the General Surgeon

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KEYWORDS

• Pediatric urology • Inguinal hernia • Hydrocele • Cryptorchidism • Circumcision • Genitourinary trauma

KEY POINTS

- The decision to perform pediatric inguinal herniorrhaphy depends on accurately distinguishing between a true inguinal hernia, communicating hydrocele, and simple hydrocele.
- Timely orchiopexy for the undescended testis best preserves fertility and endocrine function, while protecting against trauma and minimizing malignancy potential.
- The benefits of neonatal circumcision modestly outweigh the risks of the procedure, thus justifying access to fully informed families.
- Trauma to the genitourinary tract can typically be managed conservatively, recognizing key indications for surgical intervention.

INTRODUCTION

There are several common pediatric urologic conditions that could potentially impact the general surgeon. Particularly in rural areas, access to pediatric urology expertise may be limited. A working knowledge of a few common problems may obviate patient referrals or help the surgeon determine what care can be safely delivered without urology subspecialty. This article reviews the pathophysiology of several problems commonly encountered by pediatric urologists and describes a practical approach for the general surgeon, including the pediatric inguinal hernia or hydrocele, the cryptorchid testis, and circumcision. Additional focus is devoted to genitourinary trauma to help guide management in acute, emergent situations that lack on-site subspecialty expertise.

HERNIA/HYDROCELE

Background

The pediatric inguinal hernia may be most familiar to the general surgeon because of the similar anatomy encountered during indirect inguinal hernias in adults. In utero, the

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processus vaginalis allows the testes to pass through the inguinal canal between 20 to 28 weeks gestation[1] and typically obliterates after testis passage. Persistent patency of the processus may result in a symptomatic hernia or hydrocele. The term "hernia" suggests the passage of abdominal contents, such as bowel or omentum, through the inguinal canal. The term "communicating hydrocele" suggests a smaller opening that allows passage of fluid alone. The incidence of patent processus vaginalis in the pediatric population is between 1% and 5% and occurs more commonly in males.[2,3] Significant risk factors for inguinal hernia include cryptorchidism, prematurity, and low birth weight.[2–4] There is also an increased familial risk and in a variety of syndromes.[2,5] These conditions are distinct from the simple hydrocele, meaning that fluid is present within the scrotum, but does not communicate.

Diagnosis

The typical presentation of pediatric inguinal hernia or hydrocele is scrotal or inguinoscrotal swelling. Pain or nausea symptoms are rare, even with tense distention of the scrotum, and testis viability is not compromised. Diurnal size variation of the scrotum is a key diagnostic feature of a communicating hydrocele, classically enlarging after physical activity or toward the end of the day and diminishing by the morning. Swelling that extends into the inguinal canal is more likely to indicate a hernia. Occasionally, abdominal contents can be palpated and manually reduced. Other notable physical examination findings include the "silk glove" sign, which entails palpating the layers of the patent processus vaginalis slipping over each other, and transillumination of the scrotum with a penlight (**Fig. 1**). If the physical examination is normal and the family cannot give a clear history of diurnal size fluctuation, it is reasonable to repeat the examination in follow-up and ask the family to further observe the scrotal size in the mornings and evenings.

It may be challenging to differentiate between a communicating hydrocele and a true inguinal hernia; however, the difference is important. The primary concern with hernia is the risk of bowel incarceration. The signs and symptoms of an incarcerated hernia include erythema, a firm bulge, and pain over the inguinal canal. This condition is an emergency because of the risk of strangulation and peritonitis. This risk should be absent with communicating hydroceles because the patent processus vaginalis is so narrow.

If the ipsilateral testis is not palpable because of a tense, distended scrotum, ultrasonography can confirm the presence of the testis and rule out secondary hydrocele

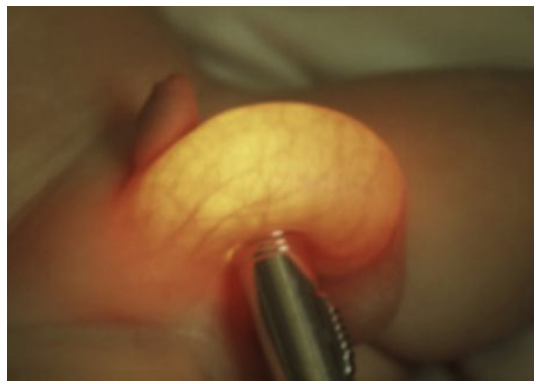


Fig. 1. Transillumination of a left hydrocele with a pen light.

from a testis tumor. If the testis is palpably normal, imaging is not necessary. Simple hydroceles (noncommunicating) that are not associated with hernia should be considered differently. Simple hydrocele is common in male neonates, presumably from delayed closure of the processus that traps fluid within the scrotum.[6] The natural history of the simple hydrocele in the perinatal period is for the fluid to slowly resorb over time. Similarly, simple hydroceles presenting in the postpubertal period can be observed in hopes of spontaneous resolution.

Management

Surgical repair has been the historic mainstay of treatment of pediatric inguinal hernias and communicating hydroceles, although there may be a role for observation in the latter. Hernia repair is normally performed promptly following the diagnosis and can be performed as an outpatient procedure as long as the adjusted gestational age is great enough (typically >50 weeks). The timing of hernia repair is controversial when the diagnosis is made in the neonatal period, and entails balancing the risks of anesthesia in the neonatal period versus the risk of bowel incarceration. Hernias may be present in approximately 15% of premature infants and the risk of incarceration rises the longer it remains untreated.[7,8] For this reason, hernias in premature and low-birth-weight infants are commonly fixed before hospital discharge, although the decision to defer surgery is reasonable if the caretakers can be educated and have the capacity to seek urgent medical attention in case of incarceration.[9] This is an ongoing controversy that is the impetus for an ongoing prospective trial.[10]

Communicating hydroceles have historically been treated similarly to true hernias. However, recent data suggest they can be safely managed conservatively. A variety of small studies have suggested that most communicating hydroceles spontaneously resolve if given enough time.[11,12] Current practice patterns from the American Academy of Pediatrics Section on Surgery vary widely, including prompt treatment similar to hernia versus waiting up to 2 years of age.[13]

Surgery

An inguinal approach to hernia/hydrocele repair is traditional because of a low complication rate, low morbidity, good cosmesis, and the ability to successfully achieve a high ligation of the hernia sac at the level of the internal inguinal ring to minimize the risk of recurrence.[14] Key components of the surgery include exposing the external oblique fascia, sharp incision of the fascia to preserve the ilioinguinal nerve, and careful dissection of the sac away from the spermatic cord structures. With this approach, postoperative complications are rare, including bleeding, wound infection, reactive hydrocele, and injury to the genital tract (testis atrophy, secondary cryptorchidism, vas deferens injury). Hernia recurrence is about 1%.[14,15]

Laparoscopic and scrotal approaches to pediatric inguinal hernia repair have also been described. The potential concern regarding the scrotal approach is the ability to achieve a high sac ligation. However, numerous series have demonstrated successful outcomes with similar recurrence risk, decreased operative time, and improved cosmesis.[16,17] Meanwhile, laparoscopic hernia repair has also been successful via a peritoneal closure[18] and extraperitoneal approach.[19,20] A potential advantage is the ability to easily assess and address the contralateral inguinal ring, which may be patent in about 40% of children with clinical unilateral hernias, and presents clinically in about 10% of patients.[21,22] Exploration of the contralateral ring via open approaches is no longer common because of the unlikely clinical significance.

CRYPTORCHIDISM

Background

Cryptorchidism, or undescended testis, is commonly treated by pediatric urologists or pediatric surgeons. The incidence is approximately 3% to 5% of newborn males and increases to 30% in premature infants.[23–25] The primary reasons for treating the condition are the risk of fertility decline in the affected testis, decline in hormonal function of the affected testis, an increased risk for testicular torsion or trauma, and the increased risk of testicular malignancy. Spontaneous descent postnatally occurs, but further descent is unlikely beyond 6 months of age[26] and observation should not delay prompt treatment. Timely orchiopexy in infancy has been shown to preserve testicular function and likely diminish the risk of malignancy.[27,28] Although men with bilateral cryptorchidism have significantly reduced fertility rates of approximately 62%,[29] unilateral cryptorchidism leads to a fertility rate of approximately 90%, which is not significantly different from the general population.[30]

Diagnosis

The most important aspects of the history are determining if the family ever notices the testis in an intrascrotal position, particularly in relaxed, warm environments, such as the bathtub, where the testis location would likely be maximally descended. Additional history should note premature delivery, which increases the risk for cryptorchidism, and previous inguinal surgery, a risk factor for secondary ascent.

A thorough physical examination typically starts with the child in a supine position, although sitting cross-legged can also be tried. Examination is most commonly started with a sweeping motion of the nondominant hand from the anterior superior iliac spine inferomedially toward the groin. If the testis is palpable, the dominant hand can attempt to grasp the testis. With a combination of sweeping and pulling, the testis can often be drawn into the scrotum. Palpable undescended testes can be classified by their location in the upper scrotum, the superficial pouch, or the inguinal canal. A nonpalpable testis should be considered intra-abdominal until proven otherwise.

It is challenging to distinguish testicular retraction from a truly undescended testis. The cremasteric reflex frequently draws testes into seemingly inguinal locations, particularly in toddler-aged boys. If there is a question of retractile versus undescended testis, the testis should be held in a dependent intrascrotal position for 30 seconds to fatigue the cremaster muscle. If the testis remains in a dependent position after release, then it is safely considered retractile. If it immediately ascends out of the scrotum, it should be considered undescended. This assessment is critical because it determines the need for surgery. The natural history of the retractile testis is to gradually descend into a more obvious scrotal position with age and testis size increase.

Imaging and laboratory tests are typically unnecessary in boys with cryptorchidism. The diagnostic accuracy of ultrasound or computed tomography (CT) imaging declines significantly in cases of intra-abdominal testes when imaging may be theoretically most helpful.[31] More importantly, results of imaging studies do not influence management decisions. Diagnostic laparoscopy or open surgery is necessary regardless of whether or not the study identifies a testis. Indications for laboratory evaluation are also uncommon. The most important exception is concurrent hypospadias and cryptorchidism, which is concerning for possible disorder of sex differentiation. Karyotype and referral for endocrine evaluation is appropriate.

Treatment

The mainstay of treatment of the undescended testis is surgery. Hormonal therapy with human chorionic gonadotropin or gonadotropin-releasing hormone has been used historically with the aim of stimulating descent through androgen production. However, multiple series have demonstrated suboptimal outcomes and this approach is no longer recommended in the United States.[32] Surgery is optimally performed between 6 and 18 months of age when the risks of anesthesia have reached a nadir, but the timing is early enough to avoid histologic degradation.[33]

The surgical approach depends on the location of the testis and the first step to any orchiopexy procedure is to re-examine the patient under anesthesia. A previously nonpalpable testis may become palpable in about 20% of cases, obviating abdominal exploration. For the palpable undescended testis, an incision over the inguinal canal is most common. Key principles of the procedure include protecting the cord structures, including the vessels and vas deferens; transecting the cremaster muscle fibers; and dividing the spermatic fascial attachments to the testis and cord. Undescended testes are frequently associated with an inguinal hernia. The most important maneuver to achieve mobility of the testis is to isolate the patent or obliterated processus vaginalis off of the anteriomedial surface of the cord and ligate it proximally. The testis is then fixated into the ipsilateral hemiscrotum as dependently as possible with a fixation suture or with a sutureless subdartos pouch. Fixation sutures may position the testis more securely but risk parenchymal damage.[34] With this approach, success rates may exceed 95% with rare testicular atrophy or secondary ascent. More recently, a primary scrotal approach has also proved to be successful,[35,36] although many surgeons reserve this approach for testes that are close to or can be drawn into the scrotum.

In cases of nonpalpable testes, abdominal exploration is indicated. Diagnostic laparoscopy has replaced open exploration and most commonly reveals the following situations:

1. Blind-ending gonadal vessels above the internal inguinal ring indicate a “vanishing testis” that likely suffered an early prenatal vascular event. There is no need to proceed at this point (**Fig. 2**).
2. A viable intra-abdominal testis is discovered. Depending on the location and comfort level of the surgeon, options include primary laparoscopic orchiopexy, a one-stage Fowler-Stephens orchiopexy where the spermatic artery is divided and the testis survives on the vas deferens and cremasteric arteries,[37] or a two-stage Fowler-Stephens procedure where the artery is divided in the first stage and the testis is repositioned 6 months later using additional collateral vessels (**Fig. 3**).
3. Cord structures are seen entering the internal ring, indicating either a testis that was missed on examination or a testicular nubbin within the canal or scrotum. Nubbins or dysplastic-appearing testes are usually excised because of concern of future malignancy (**Fig. 4**).

Laparoscopic orchiopexy is a challenging procedure, particularly if the testis is located superiorly in the abdomen. Success rates may diminish to 80% or lower.[38]

CIRCUMCISION

Background

Circumcision is one of the oldest surgical procedures, dating back to antiquity.[39] It is routinely performed for social, religious, and cultural reasons and the prevalence

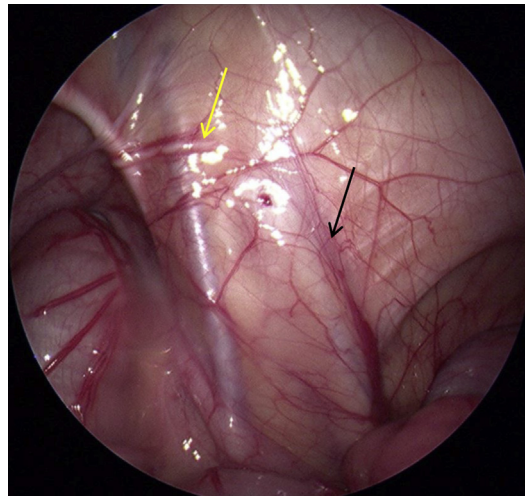


Fig. 2. Right internal ring with blind ending vas (*yellow arrow*) and vessels (*black arrow*).

highly depends on the geographic region.[39] Providers who counsel families about the decision to circumcise should provide objective information regarding the potential benefits of being circumcised and the risks of the surgical procedure. In the United States, approximately 60% of male newborns undergo neonatal circumcision,[40] but it may be deferred because of low birth weight, unfavorable anatomy (buried penis, incomplete foreskin), or comorbid conditions. Indications for circumcision later in life include urinary tract infections (UTIs) or sequela related to phimosis.

Circumcision Benefits

Circumcision reduces the bacteria that accumulates under the prepuce and reduces the risk of UTI in the infant period.[41] Given the low risk of UTI in infant males (~1%), the number of circumcisions needed to prevent a UTI is approximately 100; however, there may be a more substantial benefit in children at increased risk for UTI. There

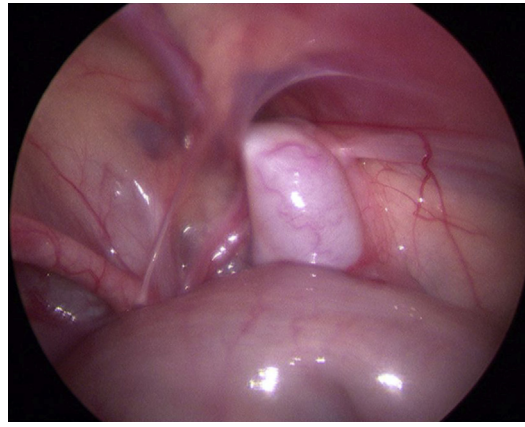


Fig. 3. "Peeping" intra-abdominal testis.

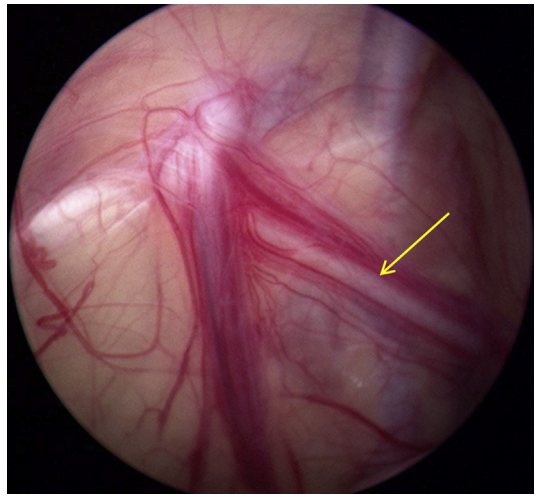


Fig. 4. Closed internal inguinal ring with vas deferens (*arrow*) and vessels.

are a variety of proposed reasons why circumcision may influence the risk of infection. The prepuce is thin and may be more susceptible to microabrasions, there may be entrapment of pathogens within the uncircumcised prepuce, and the prepuce has a particularly high concentration of CD4 T cells.[42–44]

Other infectious benefits include reducing the risk of human immunodeficiency virus transmission[45] and a lower prevalence of human papillomavirus infection[46] and herpes simplex virus type 2 transmission.[47] Other sexually transmitted infections do not seem to be significantly affected by circumcision status.[48] Additional benefits of male circumcision include decreasing the risk of invasive penile cancer.[49] Because the incidence of penile cancer is already low, it would likely require thousands of circumcisions to prevent one case. Improved hygiene of the uncircumcised penis is likely a better preventive strategy because it avoids procedure complications. Finally, there seems to be a modest protective effect of male circumcision against cervical cancer in the respective female partners[50] likely related to the difference in human papillomavirus infection transmission.

Neonatal Circumcision

There are three common techniques for performing circumcision in the neonatal period: (1) the Gomco clamp, (2) the Plastibell, and (3) the Mogen clamp. Key components to all three techniques include adequate local anesthesia (dorsal penile nerve block or penile ring block typically), estimating an appropriate amount of prepuce to be removed, reducing penile adhesions to visualize the glans, correctly placing the device, leaving the device in place long enough to provide hemostasis, and removal of the redundant prepuce. Each technique is performed safely with low complication rates of 0.2% to 3% depending on the definition.[51,52] Contraindications include some anatomic congenital anomalies, including hypospadias (**Fig. 5**), buried penis syndrome (**Fig. 6**), or ambibuous genitalia. Bleeding diatheses or failure to administer Vitamin K in the neonatal period are relative contraindications. Bleeding is the most common complication that can typically be controlled by a compression dressing. Major complications, such as glans amputation or urethral injury, are very rare. Late complications, including excessive residual skin (incomplete circumcision), penile



Fig. 5. Hypospadias (true meatus marked with arrow) with dorsal hooded foreskin.

adhesions, skin bridges, meatal stenosis, cicatrix scar formation, and epithelial inclusion cysts, are more common and can be treated electively.

Postnewborn Circumcision

The incidence of circumcision complications is significantly higher outside of the neonatal period.[53] The risk of significant bleeding, infection, and cosmetic defects is



Fig. 6. Buried penis, prominent suprapubic fat pad.

substantially greater compared with neonatal circumcision. Furthermore, general anesthesia is required because the procedure takes longer and involves ensuring hemostasis and suturing skin edges. General anesthesia carries a low risk of significant morbidity or mortality (1 death per 400,000)[54] and is minimized by ensuring patients are in an optimal state of health. Specifically, general anesthesia should be performed in a facility familiar with pediatric anesthesia and should not be performed with active airway disease or recent upper respiratory infection.[55]

Risk-Benefit Assessment

It is currently not possible to fully weigh the medical benefits of circumcision against the risks associated with the procedure. The Centers for Disease Control and Prevention study found that male circumcision before the first sexual encounter was cost-effective for the prevention of human immunodeficiency virus in the United States.[56] This study did not take into account the other potential infectious benefits of circumcision and did not attempt to assess the significance of the surgical complications. The optimal time to perform circumcision seems to be in the neonatal period when the risk profile is lowest and an operative procedure under general anesthesia can be avoided. Ideally, parents should receive factually correct, nonbiased information about circumcision before delivery so a fully informed decision is made in the neonatal period. For these reasons, the American Academy of Pediatrics takes the position that the preventive and public health benefits associated with newborn male circumcision outweigh the risks, and this should justify access to this procedure for those families who choose it.[57]

GENITOURINARY TRAUMA

Introduction

Trauma is the leading cause of mortality in the pediatric population, largely from motor vehicle accidents.[58–60] Fortunately, injuries to the genitourinary tract are rare, but can be responsible for significant morbidity.[61] Similar to any evaluation of the trauma patient, a comprehensive history and physical examination should be performed as quickly as possible. In a child with blunt or penetrating abdominal trauma, key details for the urology perspective include the mechanism of injury; associated multiorgan injury; and the presence of hematuria, abdominal or flank tenderness, rib fractures, and abdominal contusions or abrasions. Penetrating injury to the flank or abdomen is particularly worrisome for genitourinary injury and a likely indication for further imaging. The presence of multisystem trauma, gross hematuria, and substantial microscopic hematuria are additional details that also warrant further investigation.[62–64]

Unlike in the adult trauma setting, blood pressure and heart rate are not sensitive indicators of shock in children. Tachycardia may be a result of anxiety or pain from the trauma and children are capable of compensating for significant blood loss through vasoconstriction and increased cardiac output. If an injured child's blood pressure does decrease because of hypovolemia, it is a late sign of instability. For this reason, adults with blunt trauma and microhematuria without hypotension are often observed. However, because hypotension is an unreliable predictor of pediatric renal injury, all children with a history of significant blunt abdominal trauma and any degree of hematuria should undergo imaging of the urinary tract regardless of vital signs.

The physical examination should focus on abdominal and genital signs of injury. A mass or ecchymosis of the flank may represent a perinephric hematoma or urinoma. Eccymosis of the perineum in a butterfly configuration indicates blood tracking within Colles fasica. Scrotal or labial hematoma or edema can result from genital trauma or

pelvic injury. Blood at the urethral meatus or urinary retention must raise suspicion for urethral injury. The presence of these findings warrants further evaluation in the stable patient.

Renal Trauma

The kidney is the most common site of genitourinary injury, resulting in approximately half of all genitourinary injuries in children. Most (>80%) injuries to the kidney are from blunt trauma, whereas the remaining injuries are penetrating in nature.[61] Notably, renal injury seldom occurs in isolation. Approximately 80% of all grades of renal injury have other associated organ injuries.[58,65] Current management of renal injuries has shifted toward a nonoperative approach with up to 85% of blunt renal injuries managed nonoperatively.[61] Goals of either a conservative or surgical approach should focus on preservation of renal tissue and kidney function while minimizing the morbidity and mortality of the injury to the child.

Hematuria is an important indicator of injury to the kidney; however, more than 50% of children sustaining renal trauma may fail to demonstrate hematuria on presentation and the degree of hematuria does not correlate with injury severity.[66–68] Children's higher sympathetic tone and the less reliable correlation between hematuria and injury dictate a greater reliance on the clinical history and the presence of associated injuries compared with adults.

Indications for radiographic work-up in the pediatric trauma patient include penetrating injury to the abdomen or flank; blunt trauma resulting from significant deceleration, such as a high-velocity motor vehicle collision or fall; blunt trauma leading to other significant multiorgan injuries; and gross hematuria or microscopic hematuria greater than 50 red blood cells per high-power field.

Contrast-enhanced CT is the primary imaging modality used to assess injury to the urinary tract and is necessary to properly stage renal injury. Most emergency departments have an established renal protocol including noncontrast, contrast, and delayed phases to evaluate the renal blood vessels, parenchyma, and the entire collecting system, respectively. Conversely, ultrasonography is not reliable in renal trauma situations. Ultrasonography misses an unacceptable proportion of renal lacerations and low-grade renal injuries.[69] Ultrasound is accurate in monitoring perinephric fluid, such as urinoma or hematoma, however. For this reason, it may be more appropriate to monitor defined injuries periodically with ultrasound rather than reimaging with CT scan as is common following adult trauma.[70,71] The modality and timing of reimaging following renal trauma is physician dependent, but generally not necessary for low-grade trauma.

The degree of renal injury is assessed by a grading scale (**Table 1**)[72] and is a critical tool in determining appropriate management. Renal contusions or hematomas are considered grade 1 injuries and are the most common injuries to the kidney constituting 80% of renal trauma.[73,74] Grade II and III renal injuries occur when the renal parenchyma tears. Tears less than 1 cm are considered grade II and greater than 1 cm are grade III. These lacerations are considered minor if they are limited to the parenchyma of the kidney and do not extend into the collecting system. These injuries likely produce more pain and nausea than contusion and may lead to extensive perinephric hematomas, but there should not be urinary extravasation. Conservative management is appropriate for lower grades of renal injury (I–III) and commonly involves bed rest until hematocrit measurements have stabilized and hematuria has resolved. Re-evaluation with ultrasound can reliably detect an expanding urinoma or hematoma. Following discharge, limited activity should be recommended for 2 to 6 weeks according to the clinician's impression. This approach has proved to be highly successful in

Table 1
Renal injury grading scale

Grade	Injury	CT Appearance
I	Contusion	Microscopic or gross hematuria
	Hematoma	Subcapsular, nonexpanding without parenchymal tear
II	Hematoma	Nonexpanding perirenal hematoma
	Laceration	<1.0-cm parenchymal depth of renal cortex without collecting system rupture or urinary extravagation
III	Laceration	>1.0-cm parenchymal depth of renal cortex without collecting system rupture or urinary extravagation
IV	Laceration	Parenchymal laceration extending through renal cortex, medulla, and collecting system
	Vascular	Main renal artery or vein injury with contained hemorrhage
V	Laceration	Completely shattered kidney
	Vascular	Avulsion of renal hilum, with devascularized kidney

avoiding long-term complications, such as hypertension, loss of renal function, and hydronephrosis.[75] Patients that decline clinically or are unstable may require additional CT imaging and possible intervention, such as exploration with an attempt at renal repair, placement of a ureteral stent, or angiographic embolization.

Severe lacerations that extend into the kidney and disrupt the collecting system are considered grade IV injuries. Bleeding can be extensive and may fill the Gerota fascia space completely. Although the amount of blood may be impressive, this is not necessarily an indication to intervene surgically. As the space within Gerota fascia fills with blood, blood loss may be contained and tamponaded by the hematoma itself. The diagnosis of urinary extravasation also indicates a grade IV injury and requires delayed imaging by CT scan for accurate diagnosis. Grade IV injury may also result from injury to the hilar vessels with contained hemorrhage.

Wide separation of multiple renal fragments indicates a “shattered kidney” and is the most common appearance of a grade V injury. It can be difficult to determine what segments are poorly perfused because of severe contusion and what tissue may be truly devitalized. Massive bleeding and extravasation within Gerota fascia is common. Major hilar injury leading to devascularization also defines grade V renal injuries. The warm ischemia time inherent to this type of injury makes salvage unlikely and surgery is generally reserved for nephrectomy to stabilize active hemorrhage. Even under ideal circumstances, salvage rates for kidneys with renal pedicle injuries are less than 30%.[76,77]

The management of severe renal injury (grades IV–V) is more controversial and requires an individualized approach. A significant consideration is that surgical intervention may lead to nephrectomy rates higher than 85%.[78] Patients who are hemodynamically stable with isolated high-grade renal injuries are candidates for nonoperative management. Nonetheless, surgery is indicated for patients with a vascular pedicle injury or shattered kidney that place the patient at risk for life-threatening hemorrhage. Absolute indications for operative intervention also include an expanding or pulsatile retroperitoneal hematoma and the inability to stop hemorrhage by selective angioembolization. Relative indications for exploration are significant urinary extravasation, nonviable renal tissue, arterial injury, and expanding hematoma or if accurate staging is not possible. Surgical management should first focus on control of the renal pedicle and aorta. When hemostasis is achieved, inspection of the kidney and collecting system can be performed. Devitalized tissue should

be debrided and any defects in the parenchyma closed and covered if possible. Urinary extravasation can be managed with a ureteral stent or nephrostomy tube. A successful outcome for emergency repair of a severe pedicle injury or thrombosis is unlikely given the amount of warm ischemia the injured kidney undergoes during the evaluation and resuscitation of the patient. Attempts at salvage in these situations should be limited to extreme circumstances, such as a solitary kidney or bilateral renal injuries.

There is a variety of important complications associated with renal injury. The most significant early complications include bleeding, infection, and urinary extravasation or urinoma. The risk of bleeding is highest immediately following the trauma and admission for close observation is necessary. Strict bed rest and serial hematocrits are the mainstay of treatment for conservative management of low-grade renal injuries. Signs of hemodynamic instability, including hypovolemia and severe hypotension that does not respond to blood transfusion, should prompt consideration of surgical exploration or angiography with potential embolization. Primary angioembolization may reduce the morbidity associated with surgical exploration, and is useful for segmental artery bleeding or delayed hemorrhage. The risk of delayed hemorrhage may be 25% of patients with grade III to IV renal trauma who are managed conservatively.[79–81]

Ureteral Trauma

The incidence of ureteral injury is uncommon, constituting less than 3% of genitourinary trauma.[82] The ureter is largely protected by its anatomic location and is also a small target with inherent mobility. Severe blunt injury, classically from significant deceleration, may cause disruption of the ureteropelvic junction. Penetrating injury, such as gunshot wounds or stab wounds, is more common and is associated with other organ injury in 97% of cases.[83] Gunshot wounds, in particular, are capable of injuring the ureter even if it is outside the path via a blast effect. Finally, iatrogenic injury is possible in laparoscopic, pelvic, or endoscopic procedures. Recognition at the time of injury is critical to minimize sequelae.

A high index of suspicion for ureteral injury must be maintained to avoid missing the diagnosis. Hematuria may be present in only 23% to 45% of cases and CT scans may miss up to 75% of cases, particularly without delayed imaging to visualize contrast throughout the collecting system.[84,85]

The timing and specific intervention for ureteral injury depend on such factors as the timing of diagnosis, the severity of injury, and the patient's overall condition. Early recognition of an injury, such as an intraoperative iatrogenic injury, should prompt immediate repair. Key features of an appropriate ureteral repair consist of a tension-free, spatulated anastomosis over a ureteral stent. Devitalized segments should be excised to reapproximate healthy edges. In cases where direct reanastamosis is not possible, options include further mobilization of the kidney and ureter, psoas hitch or Boari flap with or without ureteral reimplantation, and transureteroureterostomy. These considerations may be dictated by the location and extent of the injury. Nephrectomy is avoided even for the longest ureteral insults by ileal transposition.

Delayed recognition of ureteral injuries is common and presents a more complex management problem. If the injury is recognized within 5 to 7 days, surgical intervention remains an option. If outside of this window, reconstruction should be delayed several months. Temporary diversion with a nephrostomy tube or internal stenting can bridge this gap or be used in an unstable patient unfit for surgery.

If a significant ureteral injury is not addressed properly, the primary complication is urinary extravasation into the retroperitoneum resulting in urinoma or abscess formation. Initial management in this situation includes drainage with a nephrostomy tube or

prolonged ureteral stent with percutaneous drainage of the urinoma or abscess. Ureteral strictures are a particularly troublesome long-term complication. Their presentation may be insidious and serial ultrasound imaging following ureteral injury is imperative to rule out progressive hydronephrosis and signs of obstruction.

Bladder and Urethral Injury

Pediatric bladder and urethral trauma are usually associated with other severe injuries that include pelvic fracture. Consequently, mortality rates are higher. Motor vehicle collisions are a leading cause of pelvic blunt trauma and inappropriately fastened lap belts may increase the risk of bladder injury. Compared with the adult setting, the bladder in a child is located in a more abdominal position, particularly when full. This anatomic difference makes the pediatric bladder more susceptible to external injury. The less developed rectus abdominal muscles also offer less protection. Bladder and urethral injuries are capable of producing a considerable amount of blood loss into the pelvis and perineum. Large pelvic hematomas may cause a mass effect significant enough to cause urinary retention.

The hallmark signs of bladder and urethral injury are suprapubic pain, tenderness, inability to urinate, gross hematuria, and blood at the urethral meatus. Indications for imaging the bladder include the presence of gross hematuria and/or urinary retention in conjunction with a pelvic fracture. All penetrating injury concerning for bladder injury should prompt imaging to rule out bladder injury.

Most urethral injuries from a straddle mechanism do not cause significant extravasation of urine because the urethra is crushed as opposed to lacerated. However, bleeding into the perineum can be substantial and leads to the pathognomonic "butterfly pattern" by spreading within the limits of Colles fascia. Although digital rectal examination has historically been performed to assess for the presence of the concurrent rectal or prostatic injury, recent studies have shown that digital rectal examination is less than 15% accurate in diagnosing either a displaced prostate injury or rectal injury.[86,87]

The initial trauma CT scan may not be adequate to completely characterize lower urinary tract injury. The urethra will not have contrast material within it and delayed-phase imaging must demonstrate an adequately full bladder. Other modalities to assess bladder injury include cystography or intravenous pyelography. Oblique and postdrainage films should be included. CT cystography is perhaps the most sensitive and specific test but involves significant radiation exposure and should be used judiciously. No matter which modality is chosen, the bladder should be filled to at least 50% capacity and should stop at the maximum of estimated bladder capacity. Common equations for estimating the pediatric bladder capacity are (Age + 2) $\times$ 30 mL and Kilograms $\times$ 7 mL in infants less than 1 year old. The classic appearance of an intraperitoneal bladder injury on cystogram is a starburst pattern of contrast outlining loops of bowel.

The retrograde urethrogram is the best imaging study for investigating the urethra. Oblique views are necessary to rule out posterior extravasation and complete continuity of the urethra. A Foley catheter may be placed into the bladder under radiographic guidance in cases of an intact urethra with a small tear. If a catheter has been placed previously, it should not be removed. A feeding tube can be placed in the meatus alongside the catheter to perform the study and assess injury. Alternatively, if the patient has already voided and examination does not suggest urethral injury, a urethral catheter can be placed immediately without a retrograde study.

The primary clinical distinction in bladder injury is determining an intraperitoneal versus extraperitoneal injury site. Intraperitoneal rupture accounts for approximately

one-third of cases.[88] Children with intraperitoneal rupture may develop hyponatremia, hypokalemia, and elevated serum urea and creatinine. Intraperitoneal rupture is less common and typically occurs at the dome of the bladder. Although intraperitoneal rupture is generally an indication for operative intervention, this decision is somewhat controversial in children. Successful nonoperative management may be reasonable for small, isolated injuries.[89,90] This decision may be an option for stable patients with small injuries who can be observed carefully. Laparotomy for other associated injuries is an opportunity to inspect the bladder and repair any injuries.

Extraperitoneal rupture is more commonly associated with pelvic fracture.[91] This incidence is significantly lower in children, which is attributed to more elastic pelvic attachments. Most extraperitoneal injuries are managed by catheter drainage alone. If gross hematuria persists or worsens during this period, open repair can be considered. Furthermore, the presence of a bony spicule necessitates operative intervention.

Conservative management should be similar regardless of the injury site. Continuous bladder drainage is typically continued for 10 to 14 days in cases of conservative management or following operative repair. Confirmation of adequate healing can be confirmed by a negative cystogram before catheter removal.

The most important acute goals for urethral injury are minimizing infectious complications with broad-spectrum antibiotics and establishing urinary drainage. If possible, placement of a urethral catheter helps alignment and provides bladder drainage. In cases of complete disruption and urethral disassociation, urethral catheter placement may not be possible. Appropriate management in this scenario remains controversial, with accepted options including immediate primary realignment of the urethra or suprapubic drainage and delayed reconstruction.

Penile Trauma

Patterns of penile injury are largely determined by patient age and are rarely subtle. Penile injuries in the neonate are most commonly iatrogenic from neonatal circumcision injury. Zipper injuries may result in contusion or pressure necrosis of the prepuce.[92] The “hair tourniquet” may lead to preputial edema and inflammation. As children reach toddler age and begin toilet training, toilet seat injuries become common.[93] Penile lacerations and amputations have been reported from dog or other animal bites.[94] Animal attacks may be the most significant injuries seen in childhood. Verification of the animal’s tetanus and rabies vaccination status is necessary.

Superficial contusions and lacerations can typically be managed with topical antibiotic ointments, but may require minor debridement and skin approximation depending on the mechanism, patient anxiety level, and severity of injury. Empiric antibiotics may be prescribed to decrease the risk of cellulitis. Most circumcision injury can be managed by healing through secondary and antibiotic ointment.[95] Zipper injuries to the penis more commonly occur in uncircumcised boys and may be treated with mineral oil to slip the trapped skin from the zipper or by cutting of the median bar of the zipper with bone cutters.[96]

Amputation injuries may be managed with primary reanastamosis up to 8 hours after injury.[97] Partial amputation injuries may be treated nonoperatively with intermittent application of epinephrine-soaked sponges to control hemorrhage in the absence of associated urethral injury. As with any other body part, the amputated penis should be cooled as quickly as possible to reduce ischemic injury.

Genital injury caused by animal bite should be assessed under anesthesia to fully assess the extent of trauma. Broad-spectrum antibiotics and tetanus prophylaxis

should be administered before treatment. Debridement of devitalized tissue and aggressive irrigation of the wound have been shown to reduce the risk of wound infection from 59% to 12%.[98] Split-thickness skin grafts should be applied to denuded areas to minimize wound contraction. Investigation for potential abuse or neglect should be initiated in these cases to reduce the risk of future injury.

Scrotal/Testicular Trauma

Injury to the testis is commonly associated with straddle injury, where the testis is forced against the pubic ramus, causing tearing of the tunica albuginea. Injuries may also result from hits or kicks to the scrotum during sporting events or rough-housing. Trauma to the scrotum without underlying testicular injury tends to resolve within a short time. In patients with pain that initially resolves after a short period but recurs after several days, traumatic epididymitis should be considered. However, pain persisting greater than 2 hours after trauma is suspicious for more significant testicular injuries, including testicular torsion or rupture. Testicular torsion associated with scrotal injury, although uncommon, has been reported.[99,100] A history of trauma is the presenting symptom in 4% to 8% of all cases of testicular torsion.[101] Acute scrotal swelling may also be associated with intraperitoneal pathology, such as appendicitis, peritonitis, liver laceration, or splenic rupture.[102–104]

If physical examination and imaging, such as ultrasound, are indeterminate or suggest significant testicular injury, early scrotal exploration is recommended. Rates of salvage in cases of testicular rupture have been reported at 90% if performed within 72 hours[105] and may also decrease convalescence. In cases of penetrating scrotal injury, a careful physical examination should be performed to determine the depth of penetration and to ensure adequate cleansing and debridement.

Cases of isolated hematocele may be followed nonoperatively in the absence of impaired testicular flow. Isolated epididymitis may also be treated with supportive care including scrotal elevation and nonsteroidal analgesics. In the absence of ischemic changes, testicular fracture without disruption of the tunica albuginea may be observed. If nonoperative management is selected, follow-up with physical examination and ultrasonography should be used to monitor resolution of injury.

Vaginal Trauma

Vaginal injuries are relatively rare in the pediatric population and are typically caused by straddle injuries.[106,107] Pelvic fractures may result in penetrating injury caused by bone spicules and traction injury caused by shear forces.[108] Because of the proximity of the urethra and vagina and the susceptibility of the urethrovaginal septum to injury, traumatic urethral injuries in girls should prompt an evaluation for associated vaginal injuries.[109]

Prompt diagnosis is essential to avoid fistulae, stenosis, or other long-term complications of unrecognized vaginal injuries.[110,111] Physical examination may show evidence of labial bruising, bleeding at the introitus, vulvar edema, or hematuria. Examination in the emergency room can underestimate the extent of injuries. Lighting may be inadequate and patients are often unable to fully cooperate with a sensitive or uncomfortable examination, leading to an incomplete examination.[112] Based on these findings, examination under anesthesia should be performed when any doubt exists as to the extent of the injury.

Operative management is seldom required for genital trauma in young girls. However, sexual abuse or assault may be identified in 25% of girls with genital injury.[113] Cystoscopy, vaginoscopy, and rectal examination should be performed to fully evaluate associated injuries. For more extensive vaginal lacerations, primary repair should

be performed to reduce the rate of vaginal stenosis and urethrovaginal fistulae. Vaginal lacerations may be repaired in layers with absorbable sutures. Perioperative use of antibiotics may help reduce the risk of secondary infection and wound dehiscence. Postoperative care includes the avoidance of extreme lower extremity abduction, sitz bathing, and the use of topical antibiotic ointments. For injuries that extend into the introitus, the use of permanent monofilament sutures in an interrupted fashion is recommended to reduce postrepair dehiscence risk.

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