Urinary tract infection (UTI) is a significant concern for parents as well as for children who acquire them. While primary care physicians and pediatricians are the front line, dealing with the initial management of UTI, they turn to urologists when faced with more complicated infections. This article reviews the diagnosis and management of UTI, and examines scenarios in which the clinician should have a heightened level of concern when dealing with UTI in the pediatric population.

The comprehensive epidemiology of UTI has been well described. The overall incidence of UTI in the prepubertal pediatric population is 3% in girls and 1% in boys. The incidence of UTI varies with age and sex. Infant girls have an incidence of 0.4% to 0.1%, which increases to 0.9% to 1.4% between the ages 1 and 5 years, and peaks with an incidence of 0.7% to 2.3% in school-aged girls. In contrast, infant boys have an incidence of UTI of 0.188% (circumcised) and 0.702% (uncircumcised), which decreases to 0.1% to 0.2% between ages 1 and 5 years, followed by 0.04% to 0.2% in school-aged boys. In febrile children presenting to the emergency department, UTI is more common than in healthy children, with an incidence between 3% and 5% in most studies. Racial differences also exist, including a low incidence in African American children and higher incidence in Caucasian girls relative to other races.

Other risk factors associated with UTI include anomalies of the urinary tract (anatomic, functional, or neurologic) and systemic abnormalities (diabetes mellitus, compromised immune system, and so forth).

The pathogenesis of UTI is based both on the bacteria that cause infection and on patient-specific factors. Bacteria common in UTI are predominantly of enteric origin. Escherichia coli is the most frequent cause of all types of UTI, while group B streptococcal infection is relatively more common in neonates. Bacteria tend to colonize the periurethral area, migrating in a retrograde fashion to reach the urinary tract. Bacteria may also be introduced into the urinary tract via instrumentation. Systemic infections may also result in UTI through seeding of the urinary system. Once present within the urinary tract, bacteria can be cleared by the emptying of urine or can adhere to the urothelial lining, resulting in infection. After colonization of the urinary tract, virulence factors such as fimbriae may assist bacteria in causing an infection.

Diagnosis of UTI is based on clinical symptoms and the results of a urine culture. Classic symptoms of UTI in adults are dysuria, frequency, hesitancy, and flank pain. Unfortunately, young children often lack the ability to identify and describe these symptoms. Symptoms in children...
tend to be less specific in nature and parents commonly report their symptoms as fever, irritability, lethargy, poor feeding, incontinence, and pungent urine odor. Children presenting with these symptoms, or with unexplained fever, should have UTI eliminated as a diagnosis. On performing a genitourinary examination, no specific abnormalities are consistently present. Definitive diagnosis of a UTI requires a properly obtained urine culture. Perineally "bagged" urine is useful only for excluding UTI, as there is a high chance that any growth is the result of skin colonization. Clean catch urine specimens also have a higher false-positive rate in young children, likely due to periurethral colonization. This collection technique can be more useful in older children.

The 2 most reliable sources of urine for culture are a catheterized urine specimen or a suprapubic aspirate. The drawbacks of catheterized urine include the potential for (a) introduction of bacteria, which may lead to an iatrogenic infection, and (b) psychological trauma to the patient. Suprapubic aspirates avoid introduction of pathogens into the urinary tract and give a reliable specimen; however, the use of this technique is limited by physician comfort. A suprapubic aspirate is obtained by blind passage of a small-gauge (21F or 22F) needle through the abdominal wall approximately 1 to 2 cm cephalad to the pubic symphysis into a bladder that is palpably full.4 The use of bedside ultrasonography enhances the ability to safely perform this technique by ensuring an adequately full bladder and allowing assessment of structures between the abdominal wall and bladder, while topical anesthesia can decrease patient discomfort.

Imaging for UTI is a subject of ongoing debate beyond the scope of this article. Prior teaching deferred imaging for a nonfebrile UTI, while recommending renal/bladder ultrasonography and voiding cystourethrography (VCUG) for a febrile UTI. More recently, the top-down approach has been advocated as a method of avoiding VCUG and concentrating effort on those at greatest risk of renal scarring.5 This approach, which will be discussed in detail elsewhere in this issue, focuses on using a dimercaptosuccinic acid (DMSA) scan to document pyelonephritis and/or renal scarring. Additional lower tract imaging with a VCUG is performed on patients with documented renal involvement. DMSA scans are considered the gold standard for detection of acute pyelonephritis and renal scarring (Fig. 1), with 92% sensitivity when compared with histology in an animal model.6 As always, limitation of radiation exposure is a goal in pediatrics, and use of imaging modalities that limit radiation exposure while providing the necessary details will continue to increase as techniques improve. Magnetic resonance imaging (MRI), including MR urography, has increasingly been used to image the urinary tract and to identify renal scarring, with some literature questioning whether MRI is superior to DMSA.7 While these studies avoid radiation exposure, they often require sedation or general anesthesia when performed in children. Renal/bladder ultrasonography (RBUS) is less sensitive for detecting pyelonephritis than DMSA scan, with one study noting only 22% detection of DMSA-confirmed scarring using RBUS.8 Ultrasound, however, does allow for assessment of renal abnormalities, such as hydronephrosis and duplication anomalies, as well as monitoring of renal growth and the presence of parenchymal thinning; it does so without the need for sedation or anesthesia, and without ionizing radiation exposure.

Classification of UTI has been complicated by the number of prior systems that have been used. Classification by site of infection prompts designation as cystitis (bladder infection) or pyelonephritis (kidney infection). Unfortunately, clinical symptoms alone do not always accurately differentiate upper from lower tract UTI. Previous work using ureteral catheterization to localize the site of infection demonstrated upper tract bacteria in less than 50% of those with fever and flank pain, but in 20% of asymptomatic patients.9 Infections can also be designated as uncomplicated versus complicated, or initial versus recurrent.

Recurrent UTI may be further categorized as unresolved bacteriuria, bacterial persistence, or reinfection. Unresolved bacteriuria results from inadequate treatment of a known pathogen. Persistence implies appropriate treatment of the UTI, but persistence of the infecting organism

Fig. 1. Renal scarring. In this DMSA scan, note the normal left kidney, while the right kidney shows a photopenic area and loss of renal contour consistent with scarring at the right upper pole.
within a nidus of infection or within an area that is isolated from treatment. On immediate posttreatment urine culture the same bacterial pathogen will quickly return. Reinfection requires repeated UTI with different bacteria, which may include different bacterial serotypes and clones. The importance of differentiating between persistence and reinfection is that persistence may be surgically correctable.

TREATMENT OF UTI

Treatment of UTI focuses on the site of infection, presence of fever, and the pathogen causing the infection. Ampicillin and gentamicin continue to be the mainstay of empirical treatment of pyelonephritis. The use of a third-generation cephalosporin may be considered with the knowledge that its coverage will not include Enterococcus and that there is emerging extended-spectrum β-lactam resistance. When a patient has recently been on antibiotics, it is worthwhile to consider using alternative choices due to the possibility of resistant bacteria. Once afebrile for 24 to 48 hours, consideration can be given to transitioning to oral (PO) antibiotics. Improvement in serum markers such as the white blood cell count or C-reactive protein is also encouraging when considering transition to oral antibiotics. The use of longer duration of intravenous (IV) antibiotics has not been shown to be superior to an early transition to PO therapy in preventing scarring based on DMSA scans at 9 months. In all cases, the combination of IV and oral therapy should include 10 to 14 days of appropriate antibiotics, with neonates and more severe infections favoring the longer duration.

Although traditional teaching has been that febrile UTI should be treated promptly with IV antibiotics in an inpatient setting to avoid renal scarring, recent data have brought this teaching into question. In a study by Hewitt and colleagues from Italy, the frequency of renal scarring on DMSA scan at 1 year was similar (approximately 30%) in those treated early in a comparison with treatment by a delayed fashion. Nonetheless, treatment should be started as soon as possible to relieve symptoms and with the hope of avoiding renal scarring. Even with upper tract involvement, outpatient treatment of UTI has been shown to be safe and effective, particularly in older children who are tolerating oral intake and are clinically stable. In these cases, outpatient treatment with trimethoprim/sulfamethoxazole (TMP/SMX), cephalosporins, or fluoroquinolones are viable options. Nitrofurantoin is inadequate when renal involvement is suspected as a result of poor tissue levels. In addition, daily intramuscular (IM) injection of a once-a-day broad-spectrum antibiotic (such as ceftriaxone) is an option. This treatment should be continued either until identification/sensitivities can direct oral therapy, or for the entire outpatient course when more convenient than parenteral antibiotics using a peripherally inserted central catheter. A conservative approach of hospital admission for IV antibiotics is justified when the clinical picture, social scenario, or patient age (particularly neonates) dictates. In these cases, IV rehydration and broad-spectrum antibiotics are administered.

Cystitis in children can safely be treated using nitrofurantoin, sulfonamides, TMP/SMX, trimethoprim alone, and cephalosporins. In addition, ciprofloxacin is also used in children, for whom it is approved as a second-line therapy in complicated UTI. Use of ciprofloxacin in children is reserved for more serious cases due to concerns over potential cartilage damage. Fortunately, in studies of children who received ciprofloxacin, complications have been reversible after discontinuation. Most often, TMP/SMX or nitrofurantoin is a good initial therapy for uncomplicated cystitis until final urine culture and sensitivities have returned. Regional resistance to TMP/SMX is known, and this should be taken into account in the decision to use TMP/SMX as initial therapy. Once final sensitivities are reported, treatment should be adjusted to ensure appropriate antibiotic coverage of the infecting organism. The addition of an IM antibiotic dosage has not been shown to be of significant benefit in febrile UTI and its usage in cystitis is likely not warranted. Duration of treatment is largely age based in this population. A 3-day course is adequate in the clinically stable child with uncomplicated cystitis, while longer treatment courses (7–10 days) are likely appropriate for children younger than 2 years. Although a recent study from Canada has shown feasibility of outpatient ambulatory treatment with parenteral antibiotics in 1- to 3-month old children with febrile UTI, the very young and those who are dehydrated, unable to tolerate oral medications, or toxic appearing warrant a conservative approach with admission for parenteral antibiotics and hydration.

WHEN TO WORRY LESS

It is important for clinicians to be familiar with situations in which there is a relatively low risk for patients. These scenarios can be perplexing for parents and primary care physicians who do not encounter such urologic scenarios on a consistent basis. For example, urine cultures growing Lactobacillus species, coagulase-negative...
staphylococci, and Corynebacterium species are not considered pathogens in otherwise healthy children of 2 months to 2 years old, and treatment is unnecessary. 19

During the period of toilet-training, children are at an increased risk of lower UTI because of changes in voiding and stooling habits. Less than optimal hygiene, in combination with the newly developed ability to hold one’s urine, can lead to UTIs. While still warranting treatment, these infections may be more related to functional changes. In the case of an isolated UTI during toilet-training, establishing good voiding and stooling habits is the primary goal after initial treatment of the UTI.

The presence of a UTI in the setting of corrected or spontaneously resolved reflux can cause significant anxiety for parents and primary care physicians, while not posing as great a risk as perceived. After the initial diagnosis of vesicoureteral reflux (VUR), parents often become conditioned to associate UTI and the risk of damage to the kidneys. The correction of VUR does not decrease the risk of a child developing a lower UTI but only eliminates the reflux of infected urine into the kidney, thereby preventing or delaying the development of upper UTI. It is important to ensure that parents understand the purpose of VUR correction, are informed that VUR correction does not alter host susceptibility to UTI, and are counseled to seek appropriate treatment for UTI.

Finally, a clinical scenario that is challenging to understand is asymptomatic bacteriuria. Clinical situations exist in which colonization of the urinary tract is inevitable. In these situations, the presence of bacteria is normal and does not require treatment despite a positive urine culture. Examples of scenarios in which the urinary tract can be expected to be colonized are patients with long-term indwelling tubes, patients performing clean intermittent catheterization (CIC), patients with intestinal neobladders or augmented bladders, and patients in whom the urinary tract is opened to the skin (vesicostomy, ureterostomy, and so forth). In these cases, routine bacteria cultured from the urinary tract and not causing significant clinical symptoms (dysuria, incontinence, fever, and so forth) should not be treated. One should also favor observation for bacteria noted on a screening urinalysis performed in an asymptomatic patient without complicating factors. Treatment of these asymptomatic bacteria will only allow recolonization with different, potentially more pathogenic bacteria and increase the risk of antibiotic resistance. Fever in a setting of asymptomatic bacteriuria should be worked up as a fever of unknown origin, including urine culture and blood cultures, with treatment as a UTI reserved for cases in which another source is not identified. Pyuria on a concurrent urine analysis can aid in confirming the diagnosis of clinical UTI. While the aforementioned situations are examples of times when excessive concern is not warranted, one should always use common sense when approaching these issues. When additional symptoms, repeated infections, or a confusing clinical scenario presents, further investigation and an increased clinical index of suspicion for the presence of more serious urologic issues is always reasonable.

WHEN TO WORRY

The authors now focus attention on situations in which UTI is more complicated, often requiring a high index of clinical suspicion and a low threshold to proceed to admission, broad-spectrum antibiotics, further investigation, and pediatric urology consultation. Attempts have been made to sort these infrequent scenarios into more generalized groups; however, many pathologic processes could be placed under multiple headings. The rare nature of very complicated UTI makes research comparing different approaches to treatment difficult. Prospective placebo-controlled studies do not exist. In these complex cases, there are undoubtedly multiple effective ways to approach treatment. When the literature does not provide clear evidence supporting one approach, information is provided on the clinical pathway followed by the authors for managing these difficult situations.

Some general principles apply in these complex clinical scenarios. The presence of abnormal anatomy, particularly abnormal drainage, should always prompt additional workup in the presence of UTI. The presence of prior renal scarring should also prompt additional concern, as these patients are starting with fewer functioning nephrons and have established they are susceptible to renal injury. Failure of a patient to respond to conventional treatment of a UTI should also prompt concern. Additional workup should be performed to confirm that culture-specific antibiotics are being used, that adequate drainage exists, and that the antibiotics reach all sites of bacterial infection.

**Bad Pathology**

While a single febrile UTI is a cause for concern, the presence of repeated febrile infections should alert all physicians to the need for a more extensive evaluation. One must be concerned about the presence of a physiologic or anatomic patient factor as the origin. While most renal scarring is felt
to occur with the first episode of pyelonephritis, the “big bang theory,” recurrent pyelonephritis can cause increased renal scarring. A comprehensive workup, with special focus on voiding and bowel habits, family history of recurrent UTI, and activities preceding the infections, should be undertaken. Urine culture results should be reviewed to assess for evidence of bacterial persistence. If true persistence exists, further imaging should be performed to evaluate for a source of the bacteria. Renal bladder ultrasonography and voiding cystourethrography will allow one to quickly assess the upper and lower tract anatomy while minimizing radiation exposure. Additional imaging may be required based on the clinical situation. In a toilet-trained child, a urinary flow rate and postvoid residual should be obtained to assess bladder emptying. Consideration should be given to antibiotic prophylaxis.

Pyonephrosis and emphysematous pyelonephritis are 2 severe infections of the kidney. Pyonephrosis is the presence of purulence and sediment within the renal collecting system. Presenting with a picture similar to pyelonephritis, these patients may not have resolution with antibiotics alone because of the presence of obstruction. In children most pyonephrotic kidneys are nonfunctional or have very poor function. Treatment always involves broad-spectrum antibiotics and frequently drainage of the collecting system, either via retrograde stent or nephrostomy tube placement. Emphysematous pyelonephritis is an infection with air seen in the collecting system on imaging. This entity is extremely rare in children. Percutaneous drainage and antibiotics should be considered first-line therapy. Nephrectomy, which was previously considered the treatment of choice, should be reserved for those who do not respond to conservative management.

Renal abscesses (Fig. 2) have become relatively rare in the pediatric population since the advent of modern antimicrobial drugs. These infections may develop via ascending infection, in which case the offending organism will be those seen in UTI (E coli and so forth) or via hematogenous spread, in which case staphylococcal infection is more common. Focal bacterial nephritis (acute lobar nephronia) is an acute form of bacterial nephritis affecting 1 or more renal lobules, with some series demonstrating up to 25% progression to abscess. Symptoms associated with abscesses are often those of severe pyelonephritis. Abscesses of 3 cm or less respond well to conservative management with antibiotics and observation in patients with normal urinary tracts and immune systems. Surgical drainage of the kidney was historically the gold standard of care; however, more recently percutaneous drainage using computed tomography (CT) or ultrasound guidance has been found to be effective. In either situation sampling of the abscess fluid with aerobic, anaerobic, and fungal cultures should be performed to assist in care. A single percutaneous drainage procedure may be adequate with smaller abscesses, whereas very large abscesses may warrant placement of a drain to both avoid reaccumulation and facilitate antibiotic penetration. Broad-spectrum antibiotics should be employed, initially guided by urine or blood culture results, then by culture of the abscess fluid. When a urinary tract source is suspected, ampicillin and gentamicin remain good first options, whereas an extended spectrum penicillin or cephalosporin is a good first choice when a hematogenous source is suspected. Follow-up imaging to confirm resolution of the abscess should be obtained.

Xanthogranulomatous pyelonephritis (XGP) is a grave renal infection resulting from chronic
bacterial pyelonephritis and obstruction. XGP is named after the xanthoma cell, a foamy lipid-laden histiocyte that is seen on histology in this infection. Although primarily a condition that affects adults, XGP is occasionally seen in children, most often males younger than 8 years. It is most often unilateral, causing significant destruction to a kidney. XGP may lead to a total loss of renal function on the affected side, although it is often focal within the kidney in children. The most common causative organisms are *Proteus mirabilis* and *E.coli*. Radiographic imaging is notable for the presence of obstruction, most often due to a calculus. The XGP kidney classically has been described as having an appearance on CT scan similar to a “bear paw” as a result of dilated calyces and abscesses. Pediatric patients with XGP have clinical symptoms ranging from vague complaints to hemodynamic instability and sepsis. In a stable patient with evidence of XGP, drainage of the collecting system, via stent or nephrostomy tube, may allow for true assessment of residual renal function. Placement of additional drains may be needed if nonoperative management is considered safe and desirable. Unfortunately, surgical intervention is required in the majority of cases, with the need for total nephrectomy. In rare circumstances a partial nephrectomy may be effective.

### Bad Anatomy

The presence of an anatomically or functionally abnormal segments of the urinary tract can lead to rapid clinical deterioration when a patient develops a UTI. Renal insufficiency is one example of a functional issue. Impairment in renal function, as indicated by an elevated serum creatinine, limits the bioavailability of the antibiotics, making careful monitoring of serum levels necessary. For example, the potentially nephrotoxic antibiotics gentamicin and vancomycin require close management to minimize the risk of renal injury. Imaging options in patients with compromised renal function may also be impacted. IV contrast for CT scans and fluoroscopic examinations can be nephrotoxic, particularly for those with renal insufficiency. Gadolinium, which is used as contrast for MRI, may cause nephrogenic systemic fibrosis when used in patients with an estimated glomerular filtration rate less than 30 mL/min/1.73 m². These limitations may cause difficulties in diagnosing more complicated urinary pathology in this patient population. Another situation in which renal function should prompt heightened concern is the solitary kidney. When a patient with a known solitary kidney presents with a febrile UTI, their clinical condition should be carefully evaluated to ensure appropriate antibiotics and adequate renal drainage.

The presence of poorly functioning and nonfunctional renal segments should prompt additional concern when treating pyelonephritis, as these areas can pose problems caused by poor antibiotic penetration. Examples of UTI in such segments include infection of a dysplastic upper pole moiety in a duplicated system or infection of a devascularized segment of kidney after renal trauma. In these cases, antibiotic administration may be ineffective and facilitating drainage, via ureteral stenting or percutaneous decompression, should be considered. Surgical excision of such segments may also be necessary.

The topic of vesicoureteral reflux (VUR) will be thoroughly addressed elsewhere in this issue. UTI in the setting of VUR can be a cause of significant concern. Previous studies have established that VUR without infection poses little risk for renal scarring or damage. When accompanied by infection, however, VUR can lead to pyelonephritis and subsequent renal scarring, with the potential for reflux nephropathy in severe cases. Primary management of VUR is a subject of much debate, particularly the role of antibiotic prophylaxis. In a patient on antibiotic prophylaxis, development of one or more breakthrough infections is concerning. Assessment of compliance with antibiotic prophylaxis and confirmation of appropriate antibiotic dosing should be performed. Recent studies have shown compliance with continual antibiotic prophylaxis to be only 40%. The patient’s social situation should be assessed to ensure that medical care is sought in a timely fashion when UTI symptoms are present. Renal imaging for assessment of renal growth and new scarring should be undertaken. In these situations it may be necessary to consider the options for surgical correction of reflux.

Neuropathic bladder is another scenario in which anatomic and functional concerns can lead to serious consequences in the case of UTI. Inadequate bladder emptying, high-pressure storing of urine, and high-pressure voiding can complicate the management of UTI. When accompanying neurologic issues exist (such as myelomeningocele or spina bifida) or in patients who have undergone bladder reconstruction, the clinical symptoms may be masked. Symptoms may not be present until an infection is severe or septic shock imminent. A high degree of suspicion is necessary in these patients, with a low threshold for imaging of the upper tracts and evaluation of the bladder. High-pressure storage can lead to a trabeculated bladder and secondary VUR with
resultant risk to the kidneys if UTI occurs. High-pressure voiding or detrusor-sphincter dyssynergia might lead to bladder diverticula and chemical or infectious epididymitis. Inadequate emptying places these patients at risk for bladder stones. Stones may be infectious or noninfectious in origin. Infectious stones are often a source of bacterial persistence that will not resolve until stone extraction is complete.

Patients in whom there is difficulty catheterizing the urethra provide another challenge in the setting of a UTI. Difficulty catheterizing can be due to the size of the patient or the patient’s urethra (particularly in very premature, very low birth weight babies) or due to variations in urethral anatomy. When urethral issues occur that make routine catheterization difficult, options are more limited in the pediatric population than in adults. Pediatric coude catheters of small sizes are often not readily available. Frequently these coude catheters are made of latex. Caution should be observed in using these products in a population with a higher risk of latex allergy. Congenital anomalies such as an enlarged utricle (Fig. 3), urogenital sinus abnormalities, and urethral valves might also make catheterization difficult. A history of complex hypospadias repair can make catheterization difficult for even the most experienced pediatric urologist. Flexible cystoscopy, which would normally be performed at the bedside in adults, is not as convenient or immediate an option in pediatric patients because of the need for general anesthesia. When there is concern for UTI, a suprapubic aspirate may be necessary to obtain a urine sample. While providing a very reliable urine sample when correctly performed, repeated taps can be of a concern to parents and increase risks of complication. If continuous bladder drainage is required as part of therapy, consideration of a suprapubic tube or vesicostomy may be warranted. Prune belly syndrome (PBS) is another potential complicating factor in the treatment of a UTI. PBS is a congenital defect of the anterior abdominal wall musculature (Fig. 4A) associated with undescended testes and megacystis/megaureters (see Fig. 4B). In this case the urinary system, though not obstructed, has a degree of stagnation and impaired flow. Treatment of UTIs in these cases may be compromised by this poor drainage. Less commonly, PBS can be associated with urethral anomalies that include prostatic hypoplasia, urethral atresia, and other obstructive lesions.26 These urethral anomalies may complicate catheterization. The decision to catheterize these patients requires expert care and sterile technique, as the possibility exists of seeding the stagnant urinary system with bacteria if not already infected. Once seeded, clearing infection can be more difficult in these cases.

**Bad Drainage**

Those patients in whom segmental urine drainage is persistently compromised are also at risk for increased severity of infection. Causes of obstruction can be similar to those seen frequently in adults (stones, strictures, ureteropelvic junction [UPJ] obstruction, and mass effect) or those diagnosed infrequently in adults (ectopic ureter, ureterovesical junction obstruction, megaureter, ureterocele). Symptoms may be difficult to discern in younger children. Fever is often the first sign. Failure to defervesce or improve with appropriate antibiotics should prompt further investigation. This evaluation may lead to the initial diagnosis of segmental obstruction. In children with known

![Fig. 3. Ultricle.](image)

(A) Note bladder and urethra with a dilated, fluid-filled structure posteriorly on this bladder ultrasonograph. Cystoscopy at the time of hypospadias repair confirmed the presence of a large utricle, which complicated catheterization. (B) Note the presence of a utricle during VCUG in a patient who is extremely difficult to catheterize.
impaired drainage, the presence of UTI should prompt early evaluation of the affected side(s) with appropriate imaging studies. In all cases of impaired urine drainage, partial or complete, the principles of management follow those in adults (drainage, cultures, and broad-spectrum antibiotics).

Renal stones are less common in children than adults, but may be increasing in frequency. A single infection in the presence of nonobstructing stones requires only standard treatment of the UTI. Imaging to monitor for movement of the stone and careful instruction of the patient/parents regarding the signs and risks of obstruction should be part of the care plan. When obstructing stones are present with infection, the principles of treatment parallel those in adults. Drainage is essential, with ureteral stenting (size and length appropriate for the pediatric patient) or percutaneous nephrostomy tube as options. Ureteral stenting will allow passive dilatation of the pediatric ureter and facilitate subsequent stone extraction via ureteroscopy (see Fig. 5B). Percutaneous nephrostomy tube placement will provide access to the kidney, and will be helpful if percutaneous nephrolithotomy is planned. The stability of the patient, availability of staff, and coordination of scheduling are all factors that influence the choice of drainage modality.

UPJ obstruction (UPJO) is the impaired drainage of urine from the renal pelvis into the ureter. The most common causes of UPJO in children are a congenital aperistaltic segment of ureter and compression from a lower pole crossing blood vessel. UPJO is frequently seen in young children, a group particularly vulnerable because of their inability to communicate early signs of infection. Most UPJO are in the spectrum of partial obstruction, and therefore conservative management with careful IV hydration and antibiotics can be the first-line approach. In this situation, close clinical follow-up is essential. Monitoring temperature curves, white blood cell counts, C-reactive protein, and serial ultrasonography provides guidance in therapeutic decision making. When there is evidence of a deterioration of the patient’s clinical condition, drainage via ureteral stent or nephrostomy tube should be performed. Placement of a ureteral stent can often be very challenging due to the small size of the patient, tortuosity of the ureter, and caliber of the ureteral lumen. Severe infections provide additional

![Image](image-url)
evidence to support pyeloplasty once the patient is recovered from the infection. The presence of either a nephrostomy tube or indwelling ureteral stent is likely to cause reactive inflammation in the renal pelvis; however, their presence can be incorporated into the postoperative management strategy. Mid-ureteral obstruction, although rare, may also occur. Common causes are external compression due to mass, congenital strictures, and iatrogenic strictures in the setting of prior instrumentation. Management of infection in these clinical situations proceeds based on the principles described immediately above.

Ureterovesical junction obstruction, ectopic ureters, and ureteroceles are 3 common sources of distal ureteral obstruction that can pose a challenge when treating UTI. If drainage is needed in any of these situations, placement of a ureteral stent can be complicated or near impossible due to difficulty passing guide wires or stents in a retrograde fashion. The length and tortuosity of the obstructed ureter can also be a challenge to retrograde stent placement (Fig. 7). In these cases, drainage options include antegrade placement of a ureteral stent, simple nephrostomy tube placement, or placement of a nephroureteral stent. Ectopic ureters can provide an additional challenge for retrograde stenting, as the ureteral orifice often enters at or near the bladder neck, making cystoscopic identification difficult. When ectopic ureters do not insert into the bladder or urethra, locating the distal ureter for stent placement may not be possible. Percutaneous nephrostomy tube placement is preferred, to allow drainage as well as provide an option for subsequent antegrade imaging. Ureteroceles (Fig. 8) pose unique opportunities, as internal drainage to the bladder may be accomplished by creation of a healthy cystoscopic incision into the ureterocele. The possibility of causing future reflux into the moiety associated with the ureterocele is likely in this situation.

Another special challenge of drainage occurs in situations in which urinary tract reconstruction has been performed. Whether through ureteral reimplantation or subtrigonal injection of implant material for VUR, ureterocalycostomy for UPJO,

Fig. 6. UPJ obstruction. (A) Note the presence of a massively dilated renal pelvis in this patient with UPJ obstruction. This patient presented with a febrile UTI and was found to have significant sediment (asterisk) within the kidney. (B) When free of infection, the massively dilated pelvis shows no evidence of sediment on ultrasonograph.

Fig. 7. Dilated, tortuous ureter due to ureterocele. Note the significant tortuosity and dilatation of the ureter to the upper pole of the right kidney in this MRI. The upper pole ureter of this duplicated system is also associated with a large ureterocele, which can be seen filling a large portion of the contrast-filled bladder.
transverse ureteroureterostomy, or ureteropyeloscopy for strictures, reconfiguration of the ureters can complicate attempts to drain the affected kidney(s) if obstruction occurs. Cross-trigonal reimplantation in the correction of VUR may cause difficulty in catheterizing the ureteral orifices. Use of flexible cystoscopes, angle-tipped wires, and percutaneous bladder access to provide the appropriate angle for intubating the ureteral orifice are techniques that may aid in stent placement. The presence of extensive bladder trabeculation in the setting of reconfigured ureters can further complicate attempts at internal stenting. This condition may be seen in patients with neuropathic bladders or severe dysfunctional elimination syndrome in whom ureteral reimplantation has been performed. The addition of intravenous indigo carmine or methylene blue may help in locating these ureteral orifices. Subtrigonal injection of dextranomer/hyaluronic acid (Deflux, Oceana Therapeutics, Inc, Edison, NJ, USA) may cause anxiety in the face of UTI by mimicking distal ureteral stones on CT scan. In rare situations, subtrigonal injections have caused obstruction (<0.7%), but ureteral stenting can be accomplished in these settings.

**Bad/Rare Bugs**

The infecting organism in any UTI plays a large role in how severe an infection becomes, through possession of virulence factors, resistance to antibiotics, and other mechanisms. The classic example of a mechanism through which bacteria possess greater virulence is fimbriae, specifically P-fimbriae. Fimbriae (or pili) are surface structures involved in adherence. P-piliated *E.coli* possess fimbiae that bind the human red cell P-group antigen, leading to an increased risk of pyelonephritis. Another factor favoring more virulent bacteria is the presence of mannose-resistant hemagglutination, which is found in most *E.coli* that cause pyelonephritis. Previous work has established that most bacteria causing pyelonephritis in children are associated with P-pili or mannose-resistant hemagglutination. Additional mechanisms used by bacteria include hydrophobic properties and iron-binding capabilities. Additional proteins have been associated with *E.coli* causing pyelonephritis; however, none are currently clinically relevant.

Development and usage of new antibiotics has brought about antibiotic resistance in bacteria. While resistance to penicillin remains the highest, in recent years resistance to TMP/SMX has been increasing. In addition, frequent use of fluoroquinolones for a variety of infections has led to increased resistance to these antibiotics, which have high utility and good coverage in the urinary tract. Within pediatrics the issue of antibiotic resistance takes on greater importance because of the limited number of antibiotic options approved for use in children. The most common oral antibiotics used in pediatric urology remain amoxicillin, cephalexin, TMP/SMX, and nitrofurantoin. Antibiotic resistance to nitrofurantoin remains low, leading some to recommend it as first-line treatment for the uncomplicated afebrile UTI. Unfortunately, its lack of tissue levels limits utility in more serious infection.

Examples of bacteria affecting the urinary tract with significant issues related to resistance include: methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus*, and extended-spectrum β-lactamase (ESBL) bacteria, particularly *E.coli*. Increasingly found within hospitals and the community, ESBL bacteria pose significant problems due to the limitations in antibiotics that may be used to treat them. Extended-spectrum β-lactamase–producing enterobacteriae are able to inactivate β-lactam antibiotics via hydrolysis. One study from Taiwan noted an...
increased risk of ESBL bacteria causing UTI in children on cephalixin prophylaxis. Surveys from multiple countries have demonstrated coreistance to other antibiotics appearing within these bacteria, which has prompted the use of carbapenems as the first-line antibiotics in treating these infections. 

Atypical infecting organisms in the urinary tract can also cause infection. A complete discussion of these organisms is beyond the scope of this article. However, these atypical organisms may be more difficult to diagnose due to their slow growth and endemic regions, which may differ greatly from the area of diagnosis. In addition, these atypical organisms may possess antibiotic resistance, causing significant difficulty in treatment. One of the more common atypical causes of UTI is fungal infection. Fungal UTI is most often caused by Candida albicans and presents as a nosocomial infection affecting patients on antibiotics with indwelling catheters. In these situations, any indwelling catheter should be changed. Consideration should be given to urine alkalization and starting antifungal therapy, with the knowledge that resistance to standard antifungals may be present. Bladder irrigation with amphotericin B may be necessary in resistant cases. Upper tract fungal balls may require percutaneous removal followed by antifungal irrigation. Aspergillosis is a fungal infection most commonly seen in immunocompromised individuals, which may require amphotericin B irrigation. Other examples of atypical pathogens include tuberculosis, which can occur in the urinary tract leading to strictures; schistosomiasis, which is a parasite frequently leading to bladder fibrosis and an increased risk of bladder cancer; and enterobiasis, which has been implicated in chronic UTI.

**Bad Genes/Immune System**

Antibiotic use has led to a host of strong pathogens with variable patterns of resistance. Despite exposure to potent pathogens, the majority of people do not develop UTI, pointing to the importance of patient factors in the development of UTI. Unfortunately, this remains an area in which research has not seen significant advances with applicability in the clinical environment. The discovery of P-fimbriae as a virulence factor led to additional research on the P blood group and its role as a receptor. Studies have shown a high prevalence of P1 blood group in both refluxing and nonrefluxing girls with recurrent pyelonephritis. Other blood groups, such as ABO and Lewis, as well as secretor phenotypes may also influence UTI. Certain Lewis blood types (a−b−, a+b−) have been found to have a 3-times greater risk of recurrent UTI than those with a−b+. While providing a basis for recurrent UTI in some patients, these patient factors are not modifiable nor are they of significant utility in current clinical practice.

A variety of disease states and treatments can impair the immune system and can lead to an increased risk of infection and increased severity of infections that do occur. Examples include the very young (neonates), the immunosuppressed (due to transplants or chemotherapy), human immunodeficiency virus (HIV) patients, and diabetics. Neonates have a higher risk of infection because of an incompletely developed immune system and deficiency of IgA. This risk of infection can be minimized through breastfeeding, which is protective against infection, likely through maternal IgA. These patients require a conservative approach, with a low threshold for admission for febrile UTI.

The prevalence of febrile UTI in transplant patients has ranged from 15% to 33% in studies. Although E coli remains the most common bacteria, published series have demonstrated increased frequencies of other bacteria, including those with greater antibiotic resistance. Any infection in these patients causes concern due to immunosuppression and the risks to the transplant kidney. After treatment of the acute infection, consideration should be given to a complete evaluation of anatomic, functional, and social factors that might be contributing to infection. Patients on chemotherapy also represent an at-risk population due to their lowered immunity, frequent inpatient status, and increased likelihood of procedures. UTI in patients on chemotherapy should be treated aggressively with broad-spectrum antibiotics, keeping in mind the potential nephrotoxicity of chemotherapeutic and antibiotic agents. Upper tract imaging to rule out anatomic abnormalities or obstruction should be considered in these patients. Viral UTI is rare in immunocompetent individuals, but not uncommon in the immunocompromised patient. While potentially causing significant symptoms, such as hemorrhagic cystitis, these infections are self-limited and treatment is generally supportive in nature.

Patients with HIV are at increased risk of UTI from routine bacterial pathogens, particularly when CD4 counts fall below 500/mm³. HIV also increases the risk of UTI due to atypical pathogens such as fungi, parasites, mycobacteria, and viruses. Diabetes is known to increase the risk of UTI in adults and children, with more serious infections being more common in diabetics as well. Because the prevalence of diabetes in children is
increasing, the complications of this disease, including UTI, can be expected to increase as well.

**Bad Social Situation**

How severely a UTI affects a child can be significantly influenced by the social and family situation. Economic, language, racial, and cultural issues may prevent or delay families from seeking care. In these cases, once a patient has presented, careful consideration should be given to the potential risks and benefits of outpatient versus inpatient treatment. Whether a family can afford a prescribed medication, whether they will remember to administer the medication, and whether one considers them reliable should the patient’s condition worsen are just 3 of the many factors that must be taken into account. When these questions are posed and uncertainty remains, it may be the safest course to admit the sick child for observation, in the hope of avoiding progression of the infection or loss of renal mass related to medical noncompliance.

Teenage pregnancy is rapidly becoming a social situation in which treatment of UTI can be very challenging. In these patients there can be significant risks due to UTI for both baby and mother. Although asymptomatic bacteriuria would normally not be treated, in pregnant women it increases the risk of symptomatic infection, preterm labor, and low birth weight.42 As such, in pregnant women all bacteriuria should be treated. Women who have previously displayed an increased risk of infection or who have predisposing factors should be counseled regarding risks as they relate to pregnancy.

**Nosocomial Infection**

A final situation that warrants brief discussion is nosocomial infections. Nosocomial UTI is an infection acquired while in a hospital. A whole article could be written about the epidemiology, pathology, treatment, and implications of nosocomial UTI. These infections can be significant because they occur in a population that is already ill and often involve resistant bacteria. Financial challenges also exist, as Medicare has eliminated payment for nosocomial UTI treatment and any additional care that occurs as a result of these infections.43 Basic principles underlie prevention of nosocomial UTI: appropriate hand washing and cleaning, appropriate care for indwelling tubes (including removal at the earliest medically appropriate time), and antibiotics when deemed necessary.

**SUMMARY**

UTI in children is a frequent cause of worry for parents and physicians. While many infections will not be severe in nature, one should always consider potential complicating factors that may exist in the pediatric population. When a UTI does not resolve routinely or when more complicated scenarios present, knowledge of these complicating factors can allow accurate diagnosis. Consideration should be given to the many approaches to treatment in developing a treatment plan for each individual patient.

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