Urolithiasis, more commonly referred to as kidney stones, is a frequent emergency department (ED) complaint (Box 1). The National Hospital Ambulatory Medical Care Survey (NHAMCS) estimates that kidney stones account for approximately 2 million outpatient visits and $2.1 billion in health care expenditures per year.1–3 In the year 2000, annual ED visits for kidney stones reached approximately 600,000.1 It is essential, therefore, for emergency practitioners to develop expertise in the diagnosis and acute management of this disease process.

**EPIDEMIOLOGY**

Whether from increasing identification or lifestyle changes, the prevalence of kidney stones is increasing in all age groups. It is estimated that approximately 12% of men and 6% of women will experience a symptomatic kidney stone in their lifetime, although this gender gap has narrowed over the last decade.4–7 The peak incidence is between the ages of 20 and 50 years, and kidney stones remain relatively uncommon in children younger than 10 years. In addition to gender and age variations, Caucasians are almost 3 times as likely as African Americans to develop kidney stones, with Hispanics and Asians at intermediate risk. Epidemiologic studies in the United States have also noted a regional distribution, often referred to as a “stone belt,” in the southeastern United States. This regional variation appears to be related to temperature, sunlight, and beverage consumption.8–10
ETIOLOGY

While the exact etiology is unknown, distinct phenotypes exist that may influence the specific mechanism of stone development. Most stones are composed of calcium oxalate and less often calcium phosphate, which together account for approximately 80% of all stones. Uric acid (5%), struvite (10%–15%), cystine (1%), and stones of mixed composition account for the remainder.11 On rare occasions, medications, such as the retroviral protease inhibitor indinavir, have been found to precipitate in the urine and to form medication stones.12,13

It is believed that most stones form when dissolved salts in the urine reach a supersaturation point and crystals form. The development of kidney stones begins with the formation of a nucleus around which the stone grows. There are several hypotheses regarding how this process of stone nucleation, retention within the kidney, and growth occurs. One proposed theory links atherosclerotic plaques in the vasa recta arterioles of the renal papillary ducts that erode into the renal tubules and form kidney stones.11 This theory may explain why urolithiasis is more common in patients with diabetes, hypertension, or obesity.14–17 Other theories have implicated the lack of urinary inhibitors (urine citrate and magnesium), the presence of nanobacteria that play a role in nucleation, or the presence of Randall plaques, which are areas of salt deposition in the renal papillae that may serve as an anchoring site for stone retention.11,18,19

Irrespective of the underlying mechanism, the development of kidney stones is influenced by urine composition. Certain disease processes, genetics, and lifestyle habits affect urine composition, making some patients more susceptible to kidney stones (Box 2). In addition to factors that promote crystal formation, the urine contains substances, such as urine citrate and magnesium, which inhibit crystal formation.11,39,40

With further delineation of the pathophysiology of kidney stones, guidance and interventions directed toward prevention may be developed.

The etiology of renal colic or the pain cycle related to kidney stones has a complex mechanism as well (Fig. 1). While there is mechanical injury to the ureteral wall from the passage of kidney stones, the pain associated with urolithiasis is attributed to the obstruction of the urinary tract and the resulting increase in renal pelvic pressures leading to renal capsular distention, stimulation of nocireceptors, and hyperperistalsis of the ureter. With complete obstruction, peak hydrostatic renal pelvic pressures are generally reached within 2 to 5 hours. In the first 90 minutes, there is an increase in

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**Box 1**

Urolithiasis terminology

- Renal Stone Definitions
  - Urolithiasis
    - Calculi in urinary tract, including kidneys, ureters, bladder, and/or urethra
  - Nephrolithiasis
    - Calculi in the kidney
  - Ureterolithiasis
    - Calculi in one or both ureters
  - Kidney stone
    - Common terminology that refers to calculi in the kidneys but often includes calculi in the lower urinary tract as well

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Graham et al
renal blood flow from dilation of afferent preglomerular arterioles, causing an increase in urine production and an increase in renal pelvic pressures. Over the next several hours, renal blood flow begins to decrease while intraluminal ureteral pressure continues to increase. By 24 hours, the renal pelvic hydrostatic pressure has dropped because of a reduction in ureteral peristalsis, decreased renal arterial blood flow, decreased urine production on the affected side, and increased lymphatic drainage. Pain generally abates with the decrease in pelvic pressure. However, most stones are only partially obstructing with episodes of complete obstruction as the stone migrates, thus pain may be episodic or prolonged. These complex interactions between the autoregulation of renal blood flow and the renal nervous system are mediated via interactions at the molecular level, involving prostaglandins, thromboxane, angiotensin, and antidiuretic hormone. Knowledge of this process has aided in directing treatment toward these specific factors.41,42

CLINICAL PRESENTATION

The classic presentation of urolithiasis is an abrupt, unilateral flank pain that radiates to the groin. The pain is often described as waxing and waning, with maximal intensity lasting 20 to 60 minutes and a dull throbbing flank pain that persists between episodes of colic. As the stone descends in the ureter, the pain may localize to the abdominal area overlying the stone and radiate to the ipsilateral groin. As the stone approaches the ureterovesicular junction, lower-quadrant pain radiating to the tip of the urethra, urinary urgency, urinary frequency, and dysuria are characteristic. One-third of patients report gross hematuria associated with these episodes. Nausea and vomiting are also common, due to the shared splanchnic innervation of the renal capsule and intestines.

Physical examination typically demonstrates a patient who is writhing in distress, trying to find a comfortable position on the stretcher or in the examination room. On abdominal examination, tenderness at the costovertebral angle or lower quadrant may be present, but peritoneal signs should be absent. The skin may be pale, cool, and clammy. However, fever is not common with kidney stones, and if present is suggestive of infection. Although the physical examination is of limited utility in the diagnosis of urolithiasis, it is valuable in ruling out other intra-abdominal pathology such as abdominal aortic aneurysm, diverticulitis, appendicitis, and gynecologic pathology that may mimic renal colic.

EMERGENCY DEPARTMENT EVALUATION

The diagnosis of urolithiasis includes a history and physical examination, evaluating the patient’s risk factors, evolution of symptoms, the presence or absence of infection, and the exclusion of renal colic mimics (Box 3). The history should also identify factors that may increase the risk of complications related to stone disease, such as previous kidney transplant, immunosuppression, or a solitary functioning kidney.

Confirmatory imaging is not mandatory for all patients with a suspected kidney stone. For instance, in a patient with known urolithiasis, no risk factors for complications, a typical presentation, and ensured follow-up, conservative treatment that focuses on pain control may be a cost-effective and safe ED approach. However, confirmatory imaging should be considered in all patients with a suspected first-time diagnosis of urolithiasis, those with atypical presentations, those with a concern for infection, and patients who are not improving with conservative measures. It is important to recognize that the shared innervation of the genitourinary system with other intra-abdominal organ systems can lead to misdiagnosis. In patients with acute unilateral flank pain, several studies have reported the incidence of urolithiasis on
Box 2
Risk factors for urolithiasis

- Nonmodifiable
  - Family history (2.5× increased risk)
  - Structural Anatomy of Urinary System
    - Calyceal diverticulum
    - Horseshoe kidney
    - Ureterocele
    - Vesicoureteral reflux
    - Ureteral strictures
  - Medical History
    - Gastric bypass
    - Hypertension
    - Diabetes
    - Metabolic syndrome
    - Primary hyperparathyroidism
    - Sarcoidosis
    - Crohn disease
    - Gout
    - Renal tubular acidosis
    - Hyperthyroidism
    - Multiple myeloma
- Modifiable
  - Low fluid intake
  - Low calcium diet
  - High animal protein diet
  - High oxalate intake
  - High sodium diet
  - Hot weather
  - Obesity
  - Decreased exercise
- Medication
  - Medication stones
    - Indinavir
    - Triamterene
    - Acyclovir
  - Promote calcium stones
    - Loop diuretics
    - Acetazolamide
    - Theophylline
    - Glucocorticoids
noncontrast computed tomography (CT) to be between 62% and 69%, and the rate of alternative diagnoses between 10% and 45%.\textsuperscript{43–47}

Ill-appearing patients in whom there is a suspicion of infection and an obstructing kidney stone must receive an expedited evaluation. Management should include directed resuscitation, early antibiotics, rapid diagnosis, and consultation with urology.

![Mechanisms of pain in renal colic](image)

and/or interventional radiology. An infected, obstructing kidney stone is a urological emergency that requires emergent decompression.

**CONFIRMATORY STUDIES**

**Urinalysis**

Urinalysis is a rapid, noninvasive, inexpensive test that is readily and widely available. While it may play a role in the clinical suspicion for urolithiasis, it is neither sensitive nor

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<table>
<thead>
<tr>
<th>Renal colic mimics</th>
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<tbody>
<tr>
<td><strong>Gynecologic</strong></td>
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<tr>
<td>O Hemorrhagic cyst</td>
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<td>O Dermoid cyst</td>
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<td>O Endometrioma</td>
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<td>O Ovarian neoplasm</td>
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<td>O Ovarian torsion</td>
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<td>O Fibroid</td>
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<td>O Ectopic pregnancy</td>
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<td>O Pelvic inflammatory disease</td>
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<td><strong>Gastrointestinal</strong></td>
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<td>O Appendicitis</td>
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<td>O Diverticulitis</td>
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<td>O Biliary disorders</td>
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<td>O Pancreatitis</td>
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<td>O Small bowel obstruction</td>
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<tr>
<td><strong>Urological</strong></td>
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<td>O Pyelonephritis</td>
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<tr>
<td>O Urinary tract infection</td>
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<tr>
<td><strong>Vascular</strong></td>
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<tr>
<td>O Abdominal aortic aneurysm ± aortic dissection</td>
</tr>
<tr>
<td>O Renal artery thrombosis</td>
</tr>
<tr>
<td>O Renal infarction</td>
</tr>
<tr>
<td>O Mesenteric artery dissection or embolism</td>
</tr>
<tr>
<td>O Intraperitoneal or retroperitoneal hemorrhage</td>
</tr>
<tr>
<td><strong>Musculoskeletal</strong></td>
</tr>
<tr>
<td>O Mechanical low back pain</td>
</tr>
<tr>
<td>O Fractures</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
</tr>
<tr>
<td>O Herpes zoster infection (shingles)</td>
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specific enough to use as a sole diagnostic test. Initial studies that compared microscopic hematuria on urinalysis to intravenous pyelography (IVP) found an 86% to 100% sensitivity in detecting ureterolithiasis in patients with acute flank pain. However, studies that have compared urinalysis and noncontrast CT, the current diagnostic test of choice, found hematuria was present in only about 85% of patients with confirmed kidney stones.

Though not an adequate test to screen for urolithiasis, urinalysis does allow the emergency clinician to evaluate for infection. While the presence of leukocyte esterase has been associated with noninfectious inflammation of the ureter, it may also signal infection, as does the presence of nitrites, bacteria, and white blood cells in the urine. On the other hand, the clinician should also not be falsely reassured if the clinical presentation is suggestive of an associated urinary tract infection but the urinalysis does not correlate. It is well recognized that proximal urinary tract infections with an obstructive stone may have a “negative” urinalysis. Unfortunately, there are no studies that correlate the findings on urinalysis with urinary tract infections in association with kidney stones; therefore, emergency medicine clinicians should maintain a high clinical suspicion and consider the clinical presentation when interpreting urinalysis results.

Noncontrast Helical Computed Tomography

Noncontrast helical CT is able to directly visualize or detect secondary signs in the majority of kidney stones, with the exception of indinavir stones. Thus, CT has become the study of choice for confirming the diagnosis of urolithiasis. In multiple investigations, CT has demonstrated specificities nearing 100% and sensitivities of 96% to 98%. Furthermore, studies that have directly compared CT to IVP, plain abdominal radiographs, and ultrasonography (US) have shown CT to be superior in the diagnosis of urolithiasis as well as aiding in identifying alternate diagnoses.

CT is able to determine the presence of obstruction, as well as the size and the location of kidney stones, which may aid in prognosis. The likelihood of detecting obstruction seems to vary with the duration of symptoms. In a report of 227 patients with acute ureterolithiasis, the following findings were visualized at 2 hours from symptom onset: ureteral dilatation (84%), collecting system dilatation (68%), and perinephric stranding (5%). However, detection of these findings significantly increased at 8 hours after symptom onset: ureteral dilatation (97%), collecting system dilatation (89%), and perinephric stranding (51%).

Even if the stone cannot be directly visualized on CT, secondary signs of stone and stone passage may be found. These signs include hydronephrosis, hydrourerter, perirenal stranding, and periureteral stranding. In particular, when CT scans are equivocal because of difficulty in distinguishing stones from phleboliths overlying the course of the ureter, the presence of a “rim” sign due to the circumferential edema from ureteral stones is helpful in making the diagnosis of urolithiasis.

There is a growing concern regarding the long-term risk to patients from exposure to ionizing radiation. While CT is superior to other modalities in terms of sensitivity, specificity, and accuracy in the diagnosis of kidney stones, it does expose patients to higher levels of radiation than alternative diagnostic imaging modalities. For instance, whereas CT exposes the patient to 4.5 to 18 mSv of radiation, kidney-ureter-bladder (KUB) plain radiographs and IVP expose the patient to significantly less radiation (0.7 and 3.7 mSv, respectively). In response to these concerns, some institutions have adopted a low-dose CT protocol for kidney stones with reduced radiation dosages ranging from 0.7 to 2 mSv. Sensitivities and specificities of 95% to 97% and 95% to 100%, respectively, have been reported. While comparable with standard CT,
low-dose CT may be less accurate in patients with a body mass index greater than 30 kg/m² and in those with stones less than 2 mm in size.62–67

Another recent advance in CT imaging that may prove beneficial in the diagnosis of urolithiasis is dual-energy computed tomography (DECT). DECT uses both a high-energy source and a low-energy source, which simultaneously conveys two datasets to the image processor. This technology provides a more detailed image of tissue composition, and is being evaluated for a variety of diagnoses. Preliminary studies of DECT suggest that this imaging modality may be able to predict stone composition, which would facilitate treatment decisions. Clinical trials are currently under way to determine whether DECT imaging protocols can be developed that limit patient radiation exposure while maintaining a high detection rate of urolithiasis and stone composition.68,69

**Ultrasonography**

US is the procedure of choice for pregnant women, children, and patients for whom reduced radiation exposure is felt to be a priority. The literature suggests that US has a pooled sensitivity and specificity of 45% and 94%, respectively, for the detection of ureteral calculi,70 with sensitivities of 85% to 90% and specificities of 90% to 100% for the identification of hydronephrosis.58,70–76 Therefore, US often cannot visualize the stone itself but can identify the resulting obstruction. Successful US depends on the body habitus of the patient and the skill level of the operator.

The use of US in combination with a KUB radiograph may improve overall accuracy. In one small study, the combination of US and abdominal radiography provided comparable results with those observed with noncontrast helical CT alone. However, more research is needed before drawing conclusions about this diagnostic imaging option.72

**Abdominal Plain Film**

Because 85% to 90% of stones are radiopaque, theoretically the KUB should be able to detect these stones; however, detection is limited by the size of the stone and shadowing from overlying bony structures. In 1985, Roth and colleagues77 evaluated the utility of plain abdominal radiographs in diagnosing kidney stones in the ED, and found that radiographs only had a sensitivity of 62% and a specificity of 67%. Other retrospective chart reviews have estimated the sensitivity of KUB in the range of 40% to 60%.78

In addition to their limited ability to detect urolithiasis, radiographs are also unable to identify urinary tract obstruction or alternative pathology if a kidney stone is not present. KUB may be an appropriate modality to track the progression of stone passage in selected patients. As mentioned earlier, it may also be combined with US in those patients with a known history of a radiopaque stone as a means to reduce the repeated radiation exposure from other imaging modalities.

**Intravenous Pyelogram**

An IVP in the emergency setting usually consists of a baseline KUB, followed by an injection of intravenous contrast medium and then a series of time-delayed radiographs evaluating the excretion of contrast through the renal system. The IVP has a higher sensitivity and specificity than an abdominal plain radiograph for the detection of kidney stones, and a detection rate as high as 70% to 90%.56 IVP can only directly visualize radiopaque stones, but can detect filling defects from both radiopaque and radiolucent stones. Of importance, it also provides both structural and functional information, including the site, degree, and nature of obstruction. The drawbacks of IVP
include radiation exposure, risk of nephrotoxicity, contrast reaction, and a comparatively long study time, particularly when multiple delayed films are required.

**Magnetic Resonance Imaging**

Magnetic resonance (MR) urography may be used if there is a specific indication to reduce radiation exposure, such as in pregnant patients. However, its use in the diagnostic workup of urolithiasis is unclear.

**ACUTE EMERGENCY DEPARTMENT MANAGEMENT**

Most patients with acute renal colic can be managed conservatively with pain control, hydration, and expectant stone passage. Emergent urological consultation in the ED is warranted for patients with urosepsis, renal obstruction with suspicion of a proximal urinary tract infection, acute renal failure, anuria, or intractable pain or vomiting.

**Pain Management**

Analgesia is the mainstay of treatment for acute renal colic. It is generally accepted that the pain from kidney stones occurs with the passage of a stone into the ureter and the ensuing obstruction. With acute renal obstruction, pain is triggered by the increase in collecting system pressure, ureteral spasm, and renal capsular distention, which is modulated via prostaglandins (see Fig. 1). Because of the theoretical benefit of nonsteroidal anti-inflammatory drugs (NSAIDs) via their prostaglandin inhibition and ability to decrease ureteral smooth muscle tone, research has focused on the efficacy of NSAIDs as compared with established opioid analgesics.

A review of the literature would suggest that NSAIDs are at least as effective as opioids in controlling renal colic pain. In 2004, a systematic review of 20 trials with 1613 participants found that both NSAIDs and opioids were able to achieve short-term pain relief. However, NSAIDs were associated with fewer side effects, particularly nausea and vomiting, when compared with opioids. The study concluded that given the favorable side-effect profile, the effective analgesia, and the lower requirement for rescue analgesia, NSAIDs were the preferred analgesic for renal colic. This study was limited by the broad spectrum of medications and protocols included in the analysis. Another study that compared morphine (5 mg), ketorolac (15 mg), or a combination of morphine and ketorolac at the same dosages, suggested that it was the combination of NSAIDs and opioids that was most effective. In this study, combination therapy with intravenous morphine and ketorolac was associated with a greater reduction in pain at 40 minutes than with either agent alone, as well as a higher likelihood of complete pain relief at 20 minutes and a lower likelihood of requiring rescue narcotic medication.

In patients with preexisting renal disease or severe dehydration, NSAIDs may interfere with the kidney’s autoregulatory response to acute obstruction and cause acute kidney injury (AKI). Thus NSAIDs, particularly ketorolac, should be used cautiously in the elderly, patients with multiple comorbidities, and those with dehydration. As with all NSAIDs, ketorolac inhibits platelets and has been associated with bleeding, predominantly gastrointestinal bleeding. Its use is therefore contraindicated in patients with a recent gastrointestinal bleed, active peptic ulcer disease, or a suspicion of intracranial hemorrhage. A relative contraindication exists for women who are nursing, due to the potential prostaglandin inhibition in neonates. Although most urologists are comfortable with the use of ketorolac for the acute management of renal colic, if emergent surgery or a urological procedure is anticipated, a conversation with the urologist may be helpful in guiding treatment in the ED.
Despite these concerns, in most patients NSAIDs are a safe and effective option for analgesia, and should be considered part of the first-line management of renal colic in addition to opioids. In fact, the literature suggests that a combination approach with opioids and NSAIDs may be the most effective method to manage renal colic in the ED, but further research is needed to clarify the most effective medication, dosage, and route of administration.

**Hydration and Diuretics**

While some have postulated that high-volume fluid therapy with or without diuretics to increase urine output may facilitate stone passage and decrease the pain associated with renal colic, there is a paucity of literature to support this theory. Many clinicians have concerns that forced hydration will actually worsen hydrostatic pressures and pain in patients with acute ureteral obstruction. In one small study of 43 ED patients, there was no difference in pain scores or the rate of stone passage in patients who received 2 L of saline over 2 hours versus those who received 20 mL of saline per hour.84,85 Given the lack of randomized controlled studies, and a series of small studies that suggest no benefit, hydration should be aimed at repleting volume in patients who are dehydrated or who have an elevated serum creatinine. Forced diuresis is not recommended.

**Medical Expulsion Therapy**

Though not considered acute ED care, the use of calcium channel blockers or $\alpha$-antagonists is becoming common practice. Multiple studies suggest that these agents, thought to relax ureteral smooth muscle, augment the stone expulsion rate when compared with standard therapy.86–97 In one large meta-analysis, patients treated with a calcium channel blocker (nifedipine) or $\alpha$-antagonist (tamsulosin) had a 65% greater likelihood of stone passage at the 2- to 6-week follow-up.93 In a 2007 meta-analysis of medical expulsion therapy (MET), 16 studies with 1235 patients using $\alpha$-antagonists and 9 studies with 686 patients using the calcium channel blocker nifedipine, suggested that both agents significantly improved spontaneous stone passage of distal ureteral stones compared with standard therapy. $\alpha$-Antagonists improved the time to stone expulsion by 2 to 6 days compared with controls; the average time to expulsion with $\alpha$-antagonists was 14 days. Calcium channel blockers also showed improvement over standard therapy and demonstrated a mean passage time of 28 days. Of importance, the meta-analysis noted that adverse effects were reported in 4% of patients receiving $\alpha$-antagonists and in 15% of patients receiving calcium channel blockers.98 Most of the side effects in both groups were considered mild, and included nausea, vomiting, dizziness, headache, and asthenia. Transient hypotension was noted in a few cases but did not result in discontinuation of treatment.

Despite the large number of patients included, both meta-analyses were limited by the “methodologic quality within the studies reviewed.”98 A recent small but well-conducted multicenter, randomized, double-blinded trial of tamsulosin use with kidney stones found no statistically significant improvement in the stone passage rate, the time to stone expulsion, or the number of episodes of renal colic.99 Thus, the efficacy of tamsulosin and MET in improving the spontaneous passage of kidney stones is unclear, and further rigorous research is required to clarify this issue.

Given that this therapy is generally well tolerated and may improve the rate of expulsion of kidney stones, a trial of tamsulosin or nifedipine may be considered at discharge. Based on the literature, tamsulosin seems preferred to nifedipine, due to its reported shorter time to stone passage (14 days vs 28 days) and fewer adverse
effects (4% vs 15%). The decision to initiate MET from the ED should also take into consideration the age, comorbidities, and home medications of the patient. For instance, an elderly patient with hypertension who is on a variety of medications may not tolerate MET as well as a 20-year-old healthy patient with no medical conditions, due to a duplication in medication class or the additive effect of home medications.

Other Therapies

Several small studies have found that intranasal desmopressin is effective in controlling the pain associated with renal colic.100–105 Desmopressin is a synthetic structural analogue of antidiuretic hormone, which decreases free water loss in the kidney and is thought to decrease the hydrostatic pressures in acute obstruction that cause pain. However, given the drug’s potential for side effects including hyponatremia, thrombosis, seizure, headache, and hypertension, desmopressin is not an ideal drug for the elderly or for those with significant comorbidities such as coronary disease.101 At this time desmopressin is not considered first-line management for renal colic, and further studies are needed to determine its efficacy and safety in an emergency setting.

While corticosteroids have been used as part of the acute management of urolithiasis, there are no studies that evaluate their efficacy independent of other therapies. Many of the MET trials included steroids as part of their protocols. When studies of \(\alpha\)-blockers versus control were compared with those of \(\alpha\)-blockers and corticosteroids versus control, the incremental benefit of steroids was questionable.93 A similar finding was noted for steroid use with calcium channel blockers. These findings were confirmed in a 2007 meta-analysis that found inconclusive evidence for low-dose steroids promoting stone passage.98 Although steroids may improve the inflammation associated with urolithiasis, their routine use is currently not recommended.

PROGNOSIS

Stone passage is dependent on the size, shape, and location of the kidney stone. Most stones 4 mm or less in diameter pass spontaneously. For stones larger than 4 mm in diameter, there is a progressive decrease in the spontaneous passage rate as the size of the stone increases (Table 1). Shape is also important, and in particular the width of the kidney stone predicts the likelihood of spontaneous passage. In addition, stones that have reached the distal ureter are more likely to pass without intervention. Only about half of the stones in the proximal ureter are expelled spontaneously, while approximately 80% will pass if at the ureterovesicular junction.106,107

Recurrence is common. In the absence of preventive measures, the probability of recurrence of symptomatic kidney stones at 5 years is 50%, and 60% by 10 years. Fortunately, the recurrence rate can be decreased by up to 50% in those treated with medication or dietary interventions.5,6

Although renal failure and permanent functional injury to the kidney are uncommon with urolithiasis, it is prudent to factor the potential of renal dysfunction into management decisions. Decreases in renal blood flow begin 5 to 18 hours after obstruction, and the degree of reversibility is unclear.108–110 In one study of 358 patients with ureteral stones, nuclear scintigraphy detected impaired renal function in 27% of asymptomatic patients. Surprisingly, 7% had persistent renal impairment up to 17 months after stone passage.111 Other studies suggest irreversible damage after 4 weeks of obstruction.112 Because the patient’s symptoms and stone size do not predict loss of renal function and because there is no clear time threshold for irreversible damage, intervention should be considered in any patient with ureteral obstruction unless the ability to closely monitor renal function is available.113,114
In the United States most patients can be treated conservatively with pain management and outpatient urology follow-up for definitive care. Of the 2 million outpatient visits for urolithiasis in 2000, only about 10% were admitted, with an average inpatient hospitalization stay of 2.5 days. Admission is indicated for intractable pain and vomiting, single kidney or transplanted kidney with obstruction, concomitant urinary tract infection with obstruction, or hypercalcemic crisis. Admission should also be considered for patients with high-grade obstructions and those with worsening renal function.

**DISCHARGE INSTRUCTIONS**

Discharge instructions should include outpatient urology follow-up, pain management, and instructions to return to the ED for uncontrolled pain, fever, intractable vomiting, or symptoms persisting for longer than 2 weeks. Capture of the kidney stone by straining the urine can aid urologists in determining the stone composition and directing future treatment. Even if the stone composition is unknown, patients may benefit from increasing fluid intake until urine is a clear color, decreasing the intake of animal protein to less than 52 g/d, and restricting salt intake to less than 50 mmol/d. Decreasing intake of foods such as spinach, rhubarb, chocolate, and nuts will also decrease oxalate excretion and decrease the risk of recurrent stones in susceptible individuals. While counterintuitive given that most stones consist of calcium oxalate, dietary calcium intake should remain high, at greater than 30 mol/d. Low-calcium diets have been associated with an increase in urinary oxalate and increased stone formation. If the type of stone is known, directed treatments may be added to the outpatient regimen.

**UROLOGY CONSULTATION**

Emergent urological consultation in the ED for decompression and admission is warranted for patients with an obstructing stone with a proximal infection, urosepsis, acute renal failure, anuria, or intractable pain, nausea, or vomiting. Urgent urology follow-up in 1 to 2 days is indicated in well-appearing patients with a nonobstructing kidney stone and associated urinary tract infection, as well as those with a borderline creatinine who are tolerating oral fluids. In these circumstances, a discussion with the urologist before discharge is recommended. Outpatient urology referral in 5 to 7 days is recommended in patients with a stone larger than 10 mm in diameter, those who fail to pass the stone after a trial of conservative management, and those with uncontrolled pain or a history of multiple stones. Even patients with a first-time diagnosis

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Table 1

<table>
<thead>
<tr>
<th>Size of Stone (mm)</th>
<th>Rate of Spontaneous Passage (%)</th>
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<tbody>
<tr>
<td>1</td>
<td>87</td>
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<tr>
<td>2–4</td>
<td>76</td>
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<tr>
<td>5–7</td>
<td>60</td>
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<td>7–9</td>
<td>48</td>
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<tr>
<td>≥9</td>
<td>25</td>
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of urolithiasis with spontaneous stone passage may be considered for outpatient urology referral, as some patients may benefit from a metabolic evaluation and determination of stone composition. However, it is not clear whether routine screening is a cost-effective practice for first-time kidney stones.

Current options for treatment of stones that do not pass include shock wave lithotripsy (SWL), ureteroscopic lithotripsy, percutaneous nephrolithotomy, and laparoscopic stone removal. SWL is the treatment of choice in 75% of patients with retained stones, and works best for stones in the renal pelvis and upper ureter. With advances in SWL technology, most patients tolerate the procedure well. Of note, approximately one-third of patients undergoing SWL do develop a transient fever, but fewer than 10% of patients develop obstruction by stone fragments or urinary tract infection. Both SWL and ureteroscopy are considered first-line management options for ureteral stones that require removal, with ureteroscopy yielding higher stone-free rates, but with an increased incidence of complications compared with SWL.108

SPECIAL POPULATIONS AND COMPLICATIONS

Infected Kidney Stone

It is well accepted that an upper urinary tract infection in the setting of an obstructed kidney is a urological emergency that requires emergent intervention and decompression. Unfortunately, there are no studies that help characterize which clinical factors are most often associated with this life-threatening complication. Pyonephrosis should be considered in patients with signs or symptoms of sepsis, and in those with systemic leukocytosis, fever, pyuria, or bacteriuria in the setting of an obstructing kidney stone. Patients with immunosuppression, diabetes, or an abnormal genitourinary anatomy are at a higher risk for this complication. Emergent decompression by urology or interventional radiology based on local institutional preference is the treatment of choice. Admission for intravenous hydration and antibiotics is also recommended.

Aerobic gram-negative enteric organisms, including Escherichia coli and Klebsiella, Proteus, Enterobacter, and Citrobacter species, are typical pathogens. If there is a history of recent hospitalization, antibiotic use, or immunosuppression, enterococcal bacteria and fungal etiologies may also be considered. Initial antibiotic regimens may include ampicillin plus gentamycin or piperacillin. For those with a penicillin allergy, intravenous ofloxacin or ciprofloxacin would be appropriate alternatives, depending on local resistance patterns.

In a well-appearing patient, urinary tract infections associated with a nonobstructing stone can be managed with oral antibiotics and close outpatient follow-up in 24 hours. Prophylactic antibiotics have not been shown to decrease the risk of upper urinary tract infections. While potentially beneficial both before and after urological procedure, prophylactic antibiotics are not recommended in routine emergency management of kidney stones.98

Renal Stents

Ureteral stents are used to promote drainage of the upper urinary tract, and are considered a temporizing measure to alleviate obstruction while waiting for kidney stones to pass or for more definitive urological intervention. Ureteral stents may be placed emergently if obstruction is complicated by azotemia, infection, obstruction of a solitary kidney, or pain refractory to analgesia. Complications of renal stents frequently include pain, hematuria, and an increased sense of urinary urgency and frequency. Though rare, serious complications of upward migration, infection, and
septic shock are also possible. The position of ureteral stents can be evaluated by 
KUB or CT imaging.

**Pregnancy**

Symptomatic kidney stones during pregnancy occur in approximately 1 in every 1500 
to 3000 pregnancies.\(^79,115,116\) During pregnancy, increased progesterone levels and 
decreased bladder capacity from the gravid uterus can cause urine stasis, which 
promotes stone formation. Most pregnant patients with kidney stones present in the 
second or third trimester.

Renal and pelvic US is the test of choice when an obstructing calculus is suspected. 
However, normal physiologic hydronephrosis of pregnancy must be distinguished 
from abnormal pathologic hydronephrosis secondary to obstruction. Other options 
to evaluate kidney stones in pregnancy include MR urography, low-dose CT, or 
a limited intravenous pyelogram.\(^79,116\) All diagnostic decision making should be 
made in conjunction with the patient, obstetrician, urologist, and radiologist, and 
take into account patient characteristics as well as stage of pregnancy.

Because most stones will pass spontaneously, treatment is generally the same as 
for the nonpregnant patient, except for the avoidance of NSAIDs. Cystoscopy with 
insertion of a ureteral stent or ureteroscopy to remove or fragment the stone may 
be required in the patient who is septic, has persistent severe pain, or has obstruction 
of a solitary functioning kidney. Pregnancy significantly increases the risk of stent 
encrustation, possibly necessitating frequent ureteral stent exchange every 4 to 6 
weeks until delivery.

SWL is contraindicated in pregnancy, but ureteroscopic stone removal appears to 
have a similar safety profile in pregnant and nonpregnant patients. There is limited 
literature regarding the prognosis and outcomes of pregnant patients with urolithiasis, 
although there is a possibility that preterm labor may be triggered by stone disease.\(^79\)

**PEARLS AND PITFALLS**

- CT is the diagnostic test of choice for renal colic, but protocols that limit radiation 
exposure to the patient are preferred.
- Though still under investigation, MET with tamsulosin is an acceptable part of 
treatment, but patients should have close follow-up and be warned of potential 
side effects including transient hypotension, dizziness, nausea, and vomiting.
- An infected, obstructing kidney stone is a urological emergency and requires 
emergent decompression.
- Mimics of renal colic should be considered in all patients who present with unilat-
eral flank pain.

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