Nephrolithiasis

Carl R. Menckhoff

Ureteral calculi smaller than 5 mm in diameter spontaneously pass through the urinary tract in 90% of cases, whereas stones larger than 8 mm in diameter cause impaction in 95% of instances.

Impaction most commonly occurs at the ureterovesical junction, the ureteropelvic junction, or the pelvic brim.

Abdominal aortic aneurysms are commonly misdiagnosed as renal colic.

Hematuria is absent in 15% of patients with symptomatic nephrolithiasis.

Stone impaction may occur anywhere along the path of the genitourinary tract. The resultant ureteral obstruction can shift hydrostatic pressure and cause blood flow to be redistributed to the opposite renal artery. The overall rate of glomerular filtration decreases as renal excretion becomes a task of the unaffected kidney. A transient increase in serum creatinine may follow this decrease in the glomerular filtration rate.

Although an initial rise in creatinine may quickly resolve, irreversible kidney damage can begin to occur after 7 days of complete obstruction.

Table 112.1 compares ureteral stone size with the percent likelihood of spontaneous passage.

Stone impaction most commonly occurs at the ureterovesical junction, the narrowest part of the genitourinary tract. Other common areas of impaction include the ureteropelvic junction (where the renal pelvis narrows from 1 cm down to 3 mm) and the pelvic brim. Abdominal aortic aneurysms are commonly misdiagnosed as renal colic. Hematuria is absent in 15% of patients with symptomatic nephrolithiasis.

KEY POINTS

- Ureteral calculi smaller than 5 mm in diameter spontaneously pass through the urinary tract in 90% of cases, whereas stones larger than 8 mm in diameter cause impaction in 95% of instances.
- Impaction most commonly occurs at the ureterovesical junction, the ureteropelvic junction, or the pelvic brim.
- Abdominal aortic aneurysms are commonly misdiagnosed as renal colic.
- Hematuria is absent in 15% of patients with symptomatic nephrolithiasis.

BOX 112.1 Risk Factors for Renal Calculus Formation

- Family history of nephrolithiasis
- Age (third to sixth decade of life)
- Male gender
- Living in a hot, dry climate
- Low water intake
- Primary hyperparathyroidism
- Type 1 renal tubular acidosis
- Crohn disease
- Laxative abuse
- Sarcoidosis
- Recurrent urinary tract infections
- Milk-alkali syndrome
- Sedentary lifestyle
- Diet high in animal protein

Scope and Outline

Renal colic is defined as severe, spasmodic pain caused by the impaction or passage of a calculus in the renal pelvis or ureter. Symptomatic nephrolithiasis will develop in approximately 15% of the U.S. population during their lives; the majority of these patients seek treatment in the emergency department (ED).

Epidemiology

Most cases of renal colic occur in men between 20 and 50 years of age. The incidence of first-time ureteral stones in men is 0.3% per year, with recurrence rates of 37% and 50% at 1 and 5 years, respectively. The most significant risk factors for renal stone disease are listed in Box 112.1.

Pathophysiology

Renal stones form when the urine becomes supersaturated with calcium, oxalate, cystine, uric acid, or struvite. Hypercalciuria accounts for the development of 60% of calculi and results from increased intestinal absorption, decreased renal tubular reabsorption, or excessive bone resorption of calcium. Decreased urine output can further promote calculus formation as a result of reductions in citrate, magnesium pyrophosphate, and other inhibitors of urine crystallization. Table 112.1 describes features of the five main types of renal calculi.

Anatomy

Stone impaction most commonly occurs at the ureterovesical junction, the narrowest part of the genitourinary tract. Other common areas of impaction include the ureteropelvic junction (where the renal pelvis narrows from 1 cm down to 3 mm).
Table 112.1  The Five Main Types of Renal Calculi

<table>
<thead>
<tr>
<th>MINERAL TYPE</th>
<th>FREQUENCY (%)</th>
<th>CAUSES</th>
<th>PEARLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium oxalate</td>
<td>70</td>
<td>Hypercalciuria&lt;br&gt;High calcium intake (cheese, milk, antacids)&lt;br&gt;Jejunal hyperabsorption&lt;br&gt;Hyperparathyroidism&lt;br&gt;Hyperoxaluria&lt;br&gt;Dietary (tea, coffee, sodas, plums, rhubarb, cranberries, citrus fruit, green leafy vegetables)&lt;br&gt;Inflammatory bowel disease</td>
<td>Most common</td>
</tr>
<tr>
<td>Calcium phosphate</td>
<td>10</td>
<td>Type 1 renal tubular acidosis</td>
<td>Most dense</td>
</tr>
<tr>
<td>Struvite (magnesium-ammonium-phosphate)</td>
<td>10</td>
<td>Urinary tract infections with urea-splitting bacteria such as Klebsiella, Serratia, Enterobacter, Pseudomonas, Proteus, Staphylococcus&lt;br&gt;Alkaline urine (pH &gt; 7.6), staghorn calculi</td>
<td></td>
</tr>
<tr>
<td>Uric acid</td>
<td>10</td>
<td>Hyperuricosuria (dietary: meat, fish, poultry)</td>
<td>Radiolucent&lt;br&gt;Least dense</td>
</tr>
<tr>
<td>Cystine</td>
<td>1</td>
<td>Inborn error of metabolism causing increased cystine secretion</td>
<td>Rare, radiolucent, staghorn calculi</td>
</tr>
</tbody>
</table>

Table 112.2 Renal Calculus Size and Likelihood of Spontaneous Passage

<table>
<thead>
<tr>
<th>STONE SIZE (DIAMETER)</th>
<th>PERCENT LIKELIHOOD OF SPONTANEOUS PASSAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5 mm</td>
<td>90</td>
</tr>
<tr>
<td>5-8 mm</td>
<td>15</td>
</tr>
<tr>
<td>&gt;8 mm</td>
<td>5</td>
</tr>
</tbody>
</table>

and the pelvic brim (where the ureter arches anteriorly across the iliac vessels) (Fig. 112.1).

CLINICAL PRESENTATION

HISTORY
Renal colic is classically manifested as a sudden onset of excruciating, intermittent flank pain that radiates to the groin. This swift onset of pain is often accompanied by a deeper flank ache, nausea, and vomiting. The severe, spasmodic pain of renal colic is thought to be caused by hyperperistalsis of smooth muscle from the calices to the ureter. The dull, deep, aching pain reflects ureteral obstruction and distention of the renal capsule.

The location of the ureteral calculus determines the symptoms, as outlined in Table 112.3.

PHYSICAL EXAMINATION
Patients with renal colic typically appear uncomfortable and are commonly described as “writhing” on the gurney. Findings on the abdominal examination are generally unremarkable, although thin patients with distal ureteral stones and obstruction may exhibit some tenderness. Tenderness at the costovertebral angle can develop as a result of worsening hydronephrosis; this sign is mild or absent early in the course of the disease. Abnormal findings on physical examination should raise suspicion for alternative diagnoses, as reviewed in Table 112.4.

DIFFERENTIAL DIAGNOSIS
Many disease processes can mimic symptomatic nephrolithiasis. Abdominal aortic aneurysm, aortic dissection, renal artery
dissection, and renal infarction are the most lethal conditions that may manifest similar to renal colic. In one study, abdominal aortic aneurysms were initially misdiagnosed as kidney stones in approximately 20% of patients older than 60 years. Dissection, and renal infarction are the most lethal conditions that may manifest similar to renal colic. In one study, abdominal aortic aneurysms were initially misdiagnosed as kidney stones in approximately 20% of patients older than 60 years. Box 112.2 lists the differential diagnosis for renal colic.

**Table 112.3 Ureteral Calculus Location and Associated Symptoms**

<table>
<thead>
<tr>
<th>LOCATION OF CALCULUS</th>
<th>SYMPTOMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal pelvis or calyx</td>
<td>Deep flank ache</td>
</tr>
<tr>
<td>Proximal or middle part of the ureter</td>
<td>Severe flank pain radiating to the groin</td>
</tr>
<tr>
<td>Distal end of the ureter</td>
<td>Flank discomfort and/or low abdominal pain</td>
</tr>
<tr>
<td>Bladder</td>
<td>Dysuria, frequency, urgency, retention, suprapubic discomfort</td>
</tr>
</tbody>
</table>

**Table 112.4 Physical Examination Findings and Potential Alternative Diagnoses**

<table>
<thead>
<tr>
<th>FINDING</th>
<th>CONSIDERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vital Signs</td>
<td></td>
</tr>
<tr>
<td>Fever</td>
<td>Infected stone, pyelonephritis, perinephric abscess</td>
</tr>
<tr>
<td>Hypotension</td>
<td>Sepsis, abdominal aortic aneurysm</td>
</tr>
<tr>
<td>Abdomen</td>
<td></td>
</tr>
<tr>
<td>Bruit</td>
<td>Abdominal aortic aneurysm, renal artery stenosis</td>
</tr>
<tr>
<td>Pulsatile mass</td>
<td>Abdominal aortic aneurysm</td>
</tr>
<tr>
<td>Pronounced costovertebral angle tenderness</td>
<td>Pyelonephritis</td>
</tr>
<tr>
<td>Lower abdominal or pelvic tenderness</td>
<td>Ectopic pregnancy, appendicitis, pelvic inflammatory disease, tuboovarian abscess, ovarian torsion</td>
</tr>
<tr>
<td>Genitourinary</td>
<td></td>
</tr>
<tr>
<td>Testicular tenderness</td>
<td>Torsion, epididymitis, orchitis</td>
</tr>
<tr>
<td>Mass</td>
<td>Hernia, cancer</td>
</tr>
<tr>
<td>Pulmonary</td>
<td></td>
</tr>
<tr>
<td>Focal findings</td>
<td>Lobar pneumonia</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td></td>
</tr>
<tr>
<td>Asymmetric lower extremity pulses</td>
<td>Abdominal aortic aneurysm</td>
</tr>
<tr>
<td>Skin</td>
<td></td>
</tr>
<tr>
<td>Vesicular rash</td>
<td>Herpes zoster</td>
</tr>
</tbody>
</table>

**DIAGNOSTIC TESTING**

**LABORATORY TESTS**

**Urinalysis**

A bedside urine dipstick test or urinalysis should be performed in all patients with suspected renal colic to evaluate for hematuria and infection. Urine culture should be ordered if leukocytes, nitrites, or bacteria are identified.

Hematuria is a common but inconsistent finding in patients with ureteral stones. The amount of gross or microscopic hematuria does not correlate with stone impaction or the degree of obstruction; rather, hematuria results from direct ureteral trauma caused by the passing stone. Hematuria is absent in 15% of patients with ureteral stones. Alkaline urine (pH > 7.6) may indicate infection with a urea-splitting organism, a common finding in patients with struvite stones. Urine pH lower than 5.0 suggests the presence of a uric acid stone.

Uric acid or oxalate crystals may be detectable in urine in a variety of conditions; this finding does not imply the presence of nephrolithiasis, however, and should be interpreted with caution.

**Urine Pregnancy Test**

Urine human chorionic gonadotropin levels should be checked in female patients of childbearing age. Although pregnant patients may have renal colic, a newly positive result should raise suspicion for ectopic pregnancy in the differential diagnosis.

**Blood Tests**

Blood urea nitrogen and creatinine can be measured if the symptoms have been prolonged or renal impairment is a concern, but these tests are not routinely indicated.
Fig. 112.2 Noncontrast renal protocol computed tomography scan showing moderate hydronephrosis of the left renal pelvis (arrow).

Fig. 112.3 Noncontrast renal protocol computed tomography scan showing a stone at the left ureteropelvic junction (arrow).

If a complete blood count is obtained, increased leukocytosis should be interpreted with caution because it can indicate either pain-induced demargination or infection.

A baseline hemoglobin level should be considered in the evaluation of patients with persistent gross hematuria or hemodynamic compromise.

**IMAGING**

ED imaging (Table 112.5) is used to confirm the diagnosis of nephrolithiasis, evaluate stone size, identify obstruction, and exclude alternative diagnoses. Patients with decreased renal reserve (solitary kidney, uncontrolled diabetes mellitus, uncontrolled hypertension), concurrent infection, first occurrence of stone disease, advanced age, and prolonged or unrelenting symptoms should undergo imaging during their initial evaluation. Indications for emergency imaging in cases of suspected renal colic are summarized in Table 112.6.

<table>
<thead>
<tr>
<th>TEST</th>
<th>SENSITIVITY (%)</th>
<th>SPECIFICITY (%)</th>
<th>PROS AND CONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computed tomography</td>
<td>94-100</td>
<td>96-100</td>
<td>Pros: no contrast agent used, rapid, identifies alternative diagnoses</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cons: radiation exposure, cost</td>
</tr>
<tr>
<td>Intravenous pyelography</td>
<td>52-85</td>
<td>97-100</td>
<td>Pro: functional study</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cons: need for contrast agent, radiation exposure, duration of imaging</td>
</tr>
<tr>
<td>Ultrasonography</td>
<td>66-93</td>
<td>83-100</td>
<td>Pros: no contrast agent used, no radiation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cons: false-negative results in patients with small, nonobstructing stones</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cons: lower sensitivity and specificity</td>
</tr>
</tbody>
</table>

**Helical Computed Tomography**

Noncontrast helical computed tomography (CT) of the abdomen and pelvis is the preferred imaging modality for the evaluation of patients with suspected nephrolithiasis. CT imaging for renal stones can be performed without contrast material, demonstrates both high sensitivity (94% to 100%) and specificity (96% to 100%), and allows alternative diagnoses to be simultaneously identified. Sagittal images are obtained at 5-mm intervals from the top of the kidney to the bottom of the bladder (Figs. 112.2 and 112.3).

**Intravenous Pyelography**

Intravenous pyelography (Fig. 112.4) has a sensitivity of 52% to 85% and specificity of 97% to 100% for detection of ureteral calculi. It provides a visual interpretation of renal function, as well as genitourinary anatomy. The earliest sign of ureteral obstruction on an intravenous pyelogram
is a delayed nephrogram; other abnormal findings include a “standing column” (the entire ureter seen on one image; **Fig. 112.5**), hydroureter, hydronephrosis, contrast cutoff at the point of impaction, and extravasation of contrast material. The use of intravenous pyelography is limited by the need for contrast material, decreased sensitivity in comparison with helical CT, and the length of time required to obtain multiple delayed images.

### Table 112.6 Indications for Diagnostic Imaging of Patients with Suspected Renal Colic

<table>
<thead>
<tr>
<th>FINDING</th>
<th>INDICATION FOR DIAGNOSTIC IMAGING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solitary kidney, uncontrolled diabetes,* uncontrolled hypertension*</td>
<td>To exclude obstruction in a patient with decreased renal reserve</td>
</tr>
<tr>
<td>Advanced age</td>
<td>To exclude alternative diagnoses, especially vascular disease</td>
</tr>
<tr>
<td>Concurrent infection</td>
<td>If concurrent with obstruction, a urologist should be involved to evaluate the need for intervention</td>
</tr>
<tr>
<td>Prolonged symptoms</td>
<td>To evaluate for prolonged obstruction, which may cause renal impairment</td>
</tr>
<tr>
<td>Refractory symptoms, first occurrence*</td>
<td>To exclude alternative diagnoses, especially ischemia or infarction</td>
</tr>
</tbody>
</table>

*Relative indication.

**Fig. 112.5** Intravenous pyelogram showing the entire left ureter in one view. This is known as a standing column and is caused by lack of ureteral peristalsis because of a ureteral stone.

**Fig. 112.4** Normal findings on an intravenous pyelogram.

**Fig. 112.6** Renal ultrasound showing moderate hydronephrosis.

### Sonography

Ultrasonography is a useful modality for identifying hydronephrosis caused by ureteral obstruction (**Fig. 112.6**). Advantages include its ease of use and rapid acquisition of diagnostic images at the bedside without the need for contrast agents or radiation. It is the imaging technique of choice for the evaluation of suspected renal colic in pregnancy. Ultrasonography is limited by false-negative results, which occur in patients with small calculi that do not cause significant obstruction or hydronephrosis. The sensitivity and specificity of ultrasonography for the diagnosis of urologic stone disease is 66% to 93% and 83% to 100%, respectively.18-20
setting of ureteral obstruction, thereby improving symptoms through a decrease in urine production and ureteric pressure. Ketorolac (Toradol) (30 mg intravenously or 60 mg intramuscularly) has efficacy equivalent to the oral administration of 800 mg of ibuprofen, although the latter may be less well tolerated in patients with concomitant nausea.

Some urologists debate the routine use of NSAIDs for the treatment of nephrolithiasis because these medications may promote bleeding after the placement of a ureteral stent. Data to support such observations are inconclusive.

**Opiates**

Intravenous narcotics provide adequate relief of symptoms for most patients with renal colic. Opiates have similar analgesic effects at equivalent dosing. Although meperidine (Demerol) demonstrates smooth muscle relaxation when tested in vitro, this spasmolytic effect does not appear to improve its clinical utility in therapy for renal colic. Given the potential for drug interactions with meperidine, preferred opiates for ED use include hydromorphone (0.015 mg/kg) and morphine (0.1 mg/kg starting dose).

**Plain Radiography**

The utility of plain radiography (kidney-ureter-bladder [KUB] projection performed in the supine position) is dependent on the radiodensity of the suspected kidney stone. Although 90% of stones are radiopaque (Fig. 112.7), uric acid and cystine calculi are radiolucent. KUB imaging is limited technically by overlying soft tissue, air, and bone; low sensitivity (58% to 62%) and specificity (67% to 69%) are observed in clinical practice. The combination of ultrasonography and KUB radiography improves the usefulness of these imaging modalities. Studies that used both ultrasound and plain radiography for the detection of nephrolithiasis demonstrated a sensitivity and specificity of 89% and 100%, respectively, when both tests were positive and a sensitivity and specificity of 95% and 67%, respectively, when either test was positive.

**TIPS AND TRICKS**

A young, healthy patient with the typical findings of renal colic, a history of previous nephrolithiasis, no signs of infection, and easily managed symptoms may be discharged with analgesics, antiemetics, and a urine strainer for follow-up within 7 days. All other patients require evaluation of the need for imaging and possible urology consultation.

Multiple studies have shown that both NSAIDs and opiates are effective and appropriate treatments of renal colic. One metaanalysis of 19 studies showed that NSAIDs and opiates are equally effective in the acute management of renal colic symptoms. Many experts recommend the use of NSAIDs followed by opiates for continued pain.

**MANAGEMENT OF OTHER SYMPTOMS**

Tamsulosin (Flomax), an α-adrenergic blocker, reduces ureteral spasm. Early studies suggested that oral tamsulosin (0.4 mg/day) helps promote ureteral passage of juxtavesical stones. There continue to be more studies supporting such treatment as well as studies now indicating that tamsulosin may be useful for more proximal stones as well. Calcium
channel blockers have been studied for their smooth muscle relaxant effects, and some studies suggest that they also promote stone expulsion. Antiemetics should be administered to patients experiencing concomitant nausea or vomiting. Intravenous crystalloid administration was once thought to promote stone migration by stimulating ureteral peristalsis; however, no supporting evidence has shown that hydration consistently improves symptoms by this mechanism.

### RED FLAGS

Patients older than 60 years: Consider a vascular cause of their pain.

Signs of infection: Exclude concurrent obstruction.

Large calculi: 5-mm stones have a 50% chance of passing; stones larger than 8 mm have a 5% chance of passing.

**DISPOSITION**

Patients with uncomplicated renal colic whose symptoms are easily controlled should be discharged with analgesics, a urine strainer, antiemetics, and follow-up within 7 days. Stones captured by urine straining should be brought to the urologist for pathologic evaluation. Return precautions include uncontrolled pain, protracted vomiting, and fever (Fig. 112.8).

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**Fig. 112.8** Guideline algorithm for the evaluation, treatment, and disposition of patients with presumed renal colic. CT, Computed tomography; IV, intravenously; US, ultrasonography.
A urologist should be consulted if patients have uncontrollable pain or evidence of infection. The presence of white blood cells in urine may indicate an infection and, in the presence of obstruction, warrants urology consultation for urgent stone removal or stenting.

**Box 112.3 Indications for Admission or Consultation with a Urologist**

**Indications for Admission**
- Obstruction with significant infection
- Solitary kidney with obstruction or a stone unlikely to pass spontaneously
- Refractory pain
- Refractory emesis

**Indications for Consultation with a Urologist**
- Infection
- Stone unlikely to pass spontaneously
- Moderate to severe hydronephrosis
- Solitary kidney
- Intrinsic renal disease

Some patients will have a few white blood cells in their urine (e.g., <10) but no clinical signs of infection. These patients will be otherwise asymptomatic following medication for pain (i.e., afebrile). In the absence of concomitant obstruction, urgent stone removal in such cases is not routine. Patients with coexisting, complicating diseases may be treated with antibiotics and observed in the hospital. Patients without underlying disease may be treated with antibiotics as an outpatient and monitored carefully. A urine culture should be performed for patients with white blood cells in their urine.

**Box 112.3** summarizes common indications for admission or urology consultation.

**REFERENCES**

*References can be found on Expert Consult @ [www.expertconsult.com](http://www.expertconsult.com).*
REFERENCES