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Renal Calculi: Emergency Department Diagnosis And Treatment

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Abstract

The acute treatment of kidney stones (urolithiasis) addresses pain management and focuses on the effects of the morbidity associated with an obstructed renal system. Minimal fluid intake, resulting in decreased urine production and a high concentration of stone-forming salts, is a leading factor in renal calculi development. Radio-opaque calcareous stones account for 70% to 75% of renal calculi. Microscopic hematuria in the presence of acute flank pain is suggestive of renal colic, but the absence of red blood cells does not exclude urolithiasis. Furthermore, many inflammatory and infectious conditions cause hematuria, demonstrating the low specificity of urinalysis testing. The diagnostic modality of choice is a noncontrast computed tomography (CT); ultrasonography is preferred in pregnant patients and children. Combining opioids with non-steroidal anti-inflammatory drugs (NSAIDs) is the optimal evidence-based regimen to treat severe symptoms. Rapid intravenous (IV) hydration has not shown a benefit. Potentially life-threatening diagnoses including abdominal aortic aneurysm, ovarian torsion, and appendicitis may mimic renal colic and must be ruled out.

CME Objectives

Upon completion of this article, you should be able to:

1. Describe the presenting signs and symptoms of patients with acute flank pain suggestive of renal colic.
2. Identify the appropriate ED work-up of patients with flank pain.
3. Describe the pathophysiology of calculus formation and its effect on the urinary system.
4. Discuss the appropriate management inclusive of radiographic study options.
5. Discuss the controversies related to repeat CT scans.

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Case Presentation

It's 8:30 PM and you receive a call from your chairman asking you to stop by the next morning regarding a patient you saw a few days earlier on a busy evening shift. The patient was 46 years old and complained of new-onset right flank pain for 1 day. He had no significant past medical history except chronic back pain, was on no medications, had no allergies, and was a social drinker. He had no other complaints, had stable vital signs, and his examination was only remarkable for mild CVA tenderness. You elected to treat him with oral analgesics and dipped his urine for blood. The patient had reduction of his pain with NSAIDs, and his dip showed no blood. He was discharged to home with a diagnosis of musculoskeletal back pain. The chart seemed to be in order, so why was the chairman concerned?

A 38-year-old woman presents complaining of 4 hours of left back pain. She admits to fevers, chills, and vomiting. She has a medical history of HIV and asthma. Her medications include albuterol and an HIV drug regimen. Social and surgical histories are unremarkable. She is febrile, tachycardic, and in moderate distress with a "colicky" type of presentation. She has blood drawn, urine sent for urinalysis and pregnancy test, and a noncontrast CT of her abdomen and pelvis is ordered to look for a kidney stone. You're certain it will be positive, but you wonder if her HIV is a complicating factor.

Your last patient of the shift is a 57-year-old woman complaining of 4 hours of abdominal pain. She has a history of hypertension and hyperlipidemia. Her medications include an antihypertensive and her "high cholesterol pill." She is noted to be restless and in mild distress with tachycardia, which you attribute to pain. Her abdomen is diffusely tender, and she has a moderate amount of blood on her urine dip. You order labs and a KUB followed by an ultrasound to rule out a kidney stone. She is medicated with morphine and is signed out to a colleague with the plan to control her pain and check her studies. When you follow up on her outcome the next morning, you are reminded that the last patient of the day does not always get the best assessment.

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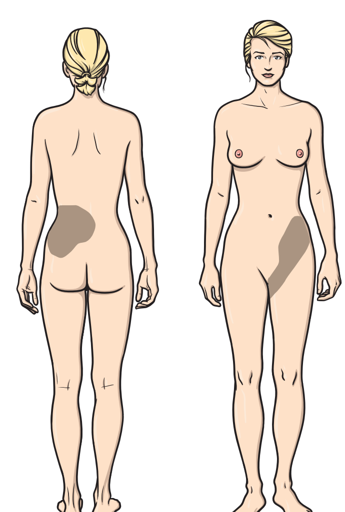
EM Practice Guidelines Update: "Current Guidelines For Advanced Trauma Life Support," www.ebmedicine.net/ATLS

Introduction

Acute flank pain is a common presenting complaint to the emergency department (ED), requiring a broad differential diagnosis and work-up. Nephrolithiasis appears to be the most frequent cause of flank pain, affecting 3% to 5% of the population in industrialized countries.[1] The term *nephrolithiasis* is directly derived from Greek, *nephros* (kidney) and *lithos* (stone). The stone is a calculus of mineral or organic solids that can form anywhere in the urinary tract (urolithiasis) or more specifically in the ureter (ureterolithiasis). As the stone passes through the urinary tract, it can be eliminated uneventfully (asymptomatic crystalluria) or can obstruct urinary flow, causing "colicky" pain as it passes.

Renal colic is defined as severe intermittent flank pain that radiates to the groin, lower abdomen, or genitalia due to the passage of a stone through the urinary system. **(See Figure 1.)** Pain is often accompanied by nausea, vomiting, dysuria, and hematuria. A diagnosis of kidney stones can have a considerable influence on patient morbidity and healthcare costs. In a well-designed population-based data

Figure 1. Location Of Flank Pain



review, over 3.4 million urolithiasis patient encounters were identified from multiple national data sets, which estimated that urolithiasis had a cost of $2.1 billion per year, making it a significant health problem in the United States.[2]

The acute treatment of kidney stones addresses not only adequate pain management but also focuses on the effects of partial or complete obstruction on the renal system and the time to passage of the stones. A key point in the evaluation of these patients is the need for and type of imaging study. Traditionally, these patients were evaluated with kidney, ureter, bladder (KUB) x-rays, ultrasound, or intravenous pyelogram (IVP) (excretory urography). However, the diagnostic study of choice is now noncontrast spiral CT.

In this issue of *Emergency Medicine Practice,* the current understanding of flank pain associated with urinary stone disease is discussed. The literature is reviewed regarding how and why stones are formed in the urinary system, what medications are best used to manage the pain and possibly enhance stone excretion, what studies can be used to evaluate the extent of disease, and what other diagnoses should be considered in patients presenting with flank pain.

Critical Appraisal Of The Literature

An extensive literature search through the National Library of Medicine's PubMed database and review of existing guidelines was completed. The PubMed search was limited to English language clinical trials, meta-analyses, and practice guidelines over the last 10 years that included the Medical Subject Headings (MeSH) of *renal colic, flank pain, kidney calculi,* or *ureteral colic.* This search yielded 211 articles; each of these was browsed for relevance to diagnosis and management in the hospital setting, and their references were reviewed. Relevant articles were then searched with the SciVerse Scopus database to identify additional citations of the articles. A search through The National Guideline Clearinghouse (www.guideline.gov) and The Cochrane Database of Systematic Reviews (www.cochrane.org) was also completed.

Epidemiology, Etiology, And Pathophysiology

Epidemiology

The lifetime prevalence of kidney stone formation has been estimated at anywhere from 1% to 12%, with the probability of having a stone varying according to gender, race, age, and geographic location.[3,4] A population-based cross-sectional survey of 15,364 United States residents from 1976-1994 established a 5.2% prevalence of kidney stones, an increase from a prior prevalence of 3.8%.[5] These increasing numbers are likely due to better detection of stones due to the greater use and sensitivity of imaging studies such as the nonenhanced CT. Kidney stones typically affect men approximately 2 to 3 times more frequently than women.[2] Caucasians have the highest prevalence of kidney stones, followed by Hispanics, Asians, and Africans.[6] Incidence rates, defined as the onset of an individual's first kidney stone, vary by age, sex, and race. For men, the incidence begins to rise after age 20 and peaks between ages 40 and 60.[1] Women have a bimodal incidence, with a second peak in incidence after age 60, believed to be due to the onset of menopause and the loss of the protective effect of estrogen.[4,7] Geographic distribution of kidney stone formation has been widely reported, with areas of hot or dry climates, such as desert or tropical areas, showing an increased prevalence. Soucie et al showed increased prevalence in the United States from north to south and west to east, with the highest prevalence being in the Southeast.[6] These studies, however, do not take into account genetic or dietary factors that may outweigh the effects of climate and geography.

Etiology

There are many studies linking a particular factor to an increased risk of urinary stone formation, but no single factor can predict the likelihood of developing kidney stones. There is a general consensus that low fluid intake results in decreased urine production and a subsequent high concentration of stone-forming salts. The majority of research, however, has been focused on the unique characteristics of the different types of kidney stones, specifically calcium stones, struvite stones, and uric acid stones.

Calcium Stones

Calcium stones account for approximately 75% of all kidney stones. The most common abnormality found in patients with calcium stones is hypercalciuria. There are many medical conditions that lead to increased calcium levels, including hyperparathyroidism,[8] hypercalcemia of malignancy,[9] sarcoidosis,[10] and increased absorption of calcium from the gut,[11] among others. Medications such as thiazide diuretics have also been implicated in causing hypercalciuria. If a specific cause can be found, it can be addressed directly to prevent calcium stone formation; otherwise, it has been recommended to follow a low-salt, low-protein diet instead of a low-calcium diet, to prevent stone formation.[12]

Struvite Stones

Struvite stones account for approximately 15% of all kidney stones. Formation of a struvite stone requires a combination of ammonia and alkaline urine. The ammonia is believed to come from the splitting of urea by urease, an enzyme produced by colonized bacteria. The most common urease-producing bacteria include *Proteus, Klebsiella, Pseudomonas,* and *Staphylococcus.*[13] Women or patients with anatomic abnormalities that predispose them to recurrent urinary tract infection are at an increased risk of developing struvite stones.

Uric Acid Stones

Uric acid stones account for approximately 6% of all kidney stones. Uric acid stone formation is influenced by low urine volume, low urinary pH, and hyperuricosuria, with low urine pH being the most important factor.[14] Even though the pathogenesis of low urine pH is multifactorial and not completely understood, recent research suggests that diabetes mellitus, obesity, and hypertension may be risk factors for the development of uric acid stones.[15,16]

Pathophysiology

Urine is a metastable solution that contains many compounds and salts including calcium, oxalate, phosphate, and uric acid. Kidney stones form when urine becomes supersaturated with stone-forming salts. These salts precipitate out of solution and form crystals, which accumulate at anchoring sites to form a stone. **(See Figure 2.)**

The concentrations of calcium, oxalate, and phosphate in urine makes it supersaturated, which would normally favor crystal formation. There are, however, inhibitory molecules in the urine that prevent crystal formation by raising saturation levels needed for crystal formation and by reducing the rate of crystal growth and aggregation. Citrate has been shown to act as an inhibitor of both calcium phosphate and calcium oxalate stone formation.[17,18] Additionally, glycoprotein nephrocalin, Tamm-Horsfall mucoprotein, and uropontin have been shown to inhibit crystal aggregation.[19-21] These inhibitory factors enable urine to become supersaturated before stone formation occurs.

The actual mechanism by which crystals aggregate and form stones once they have precipitated out of solution is still not completely understood. There are several competing theories that have tried to explain this mechanism. One theory proposed by Miller et al argues that oxalate crystals damage the renal tubular epithelial cells, which in turn promotes adherence of the crystals to the epithelial cells.[22] Competing theories argue that crystals aggregate around plaque formations. Randall et al first observed plaque formations as a possible cause of renal calculi in 1937.[23] This theory has since been reexamined by Low et al, who showed that Randall's plaques occurred in 74% of stone-formers compared to 43% of the control group.[24] Although the exact mechanism of stone formation is not understood, it can be thought of as a multifactorial process that involves the balance between high concentrations of stone-forming salts and insufficient inhibitory proteins.

The pain associated with urinary stone formation is classically called *colic*. This is defined as a severe intermittent or spasmodic pain typically beginning abruptly in the flank and increasing rapidly. It may also be steady and continuous, radiating to the abdomen and pelvis as the stone migrates distally. Autonomic nerve fibers serving the kidneys as well as the genital organs (testicle and ovary) are involved in pain transmission. Pain occurs due to stimulation of specialized nerve endings upon distention of the ureter, renal pelvis, or renal capsule. The location of the stone is thought to manifest a particular pattern of pain radiation. **(See Table 1.)**

Figure 2. Kidney Stone, Approximately 8 mm In Size

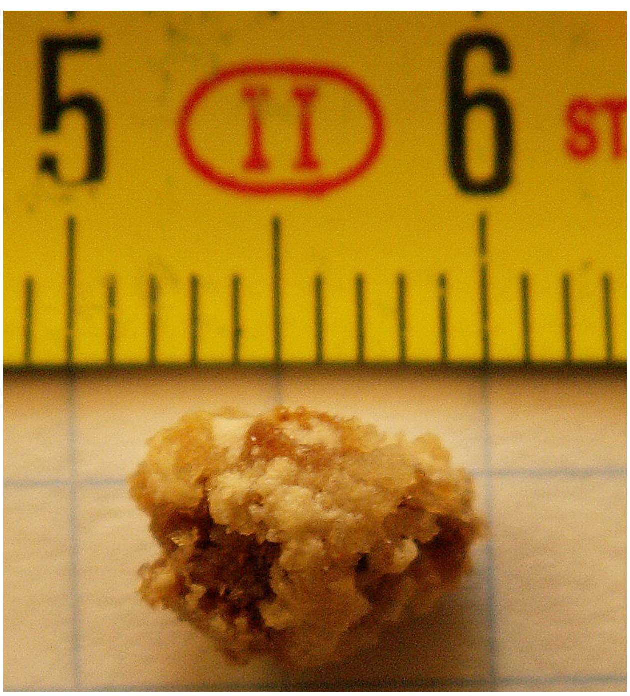


Table 1. Location Of Stone Relative To Perceived Area Of Pain

Location	Perceived Area of Pain
Proximal ureter or renal pelvis	• Radiation of pain typically to ipsilateral testicle/labia due to common innervations (T11-T12) • Posterior flank region
Middle third of ureter	• Lower and more anterior flank
Level of ureterovesical junction	• Lower flank, radiates to scrotal or vulvar skin • Associated with voiding symptoms such as urinary frequency and urgency

Each episode of pain is likely due to an stone acutely lodged in a new and more distal position in the ureter. Stones lodged in the ureter are typically found in 3 locations: the ureteropelvic junction, at the level of the iliac vessels, and the ureterovesical junction. **(See Figure 3.)** These stones also act as foreign bodies that precipitate further stasis and may lead to infection.

Differential Diagnosis

It is critical for the emergency clinician to differentiate acute flank pain caused by renal colic from other life-threatening conditions. **(See Table 2.)** It is suggested that at least half of patients with acute flank pain have no evidence of stone disease on CT, and an alternative diagnosis is often found.[25] A prospective chart review of 4000 CTs identified calculi in 28% of patients and an alternate cause of pain in 10%.[26] In another study, a review of 714 consecutive CT reports for patients presenting to an ED with acute flank pain who underwent renal stone protocol found that 455 had urolithiasis, whereas 259 were found to be without urinary stones. Significant alternate diagnoses were noted in 196 (27.4%).[27] The most common alternative diagnoses were cholelithiasis (5%), appendicitis (4%), pyelonephritis (3%), ovarian cyst (2%), renal mass (1.4%), and abdominal aortic aneurysm (AAA) with and without rupture (1.4%).

A number of disorders can cause flank pain, many of which are not associated with the urinary system. A complete differential diagnosis should consider causes of flank pain from the vascular, pulmonary, and gastrointestinal systems, among others.

Vascular Causes Of Flank Pain

Abdominal aortic aneurysm rupture and aortic dissection are catastrophic mimics that can cause flank pain. Bedside emergent ultrasound or unenhanced CT have some limitations in detecting dissection and hemorrhage from a leaking aneurysm but may be used to detect aneurysm size, as size is the greatest predictor of which patients have the potential to rupture.

Pulmonary Causes Of Flank Pain

Pulmonary embolism and basilar pneumonia may present as acute flank pain because the lung bases approximate the area of the flank. Case reports exist for patients who underwent radiologic studies to detect a urinary tract stone, and findings were consistent with a pulmonary infarct secondary to an embolism.[28] Plain x-rays and CT scans can differentiate lung causes of acute flank pain.

Gastrointestinal Causes Of Flank Pain

Appendicitis may present with lower flank pain and can be identified by CT, which will show a fluid-filled appendix as well as findings suggestive of complications of acute appendicitis. Patients with colitis, bowel obstruction, biliary disease, and ulcers may also present with complaints of flank pain. A careful history, examination, and radiologic studies may make the differentiation.

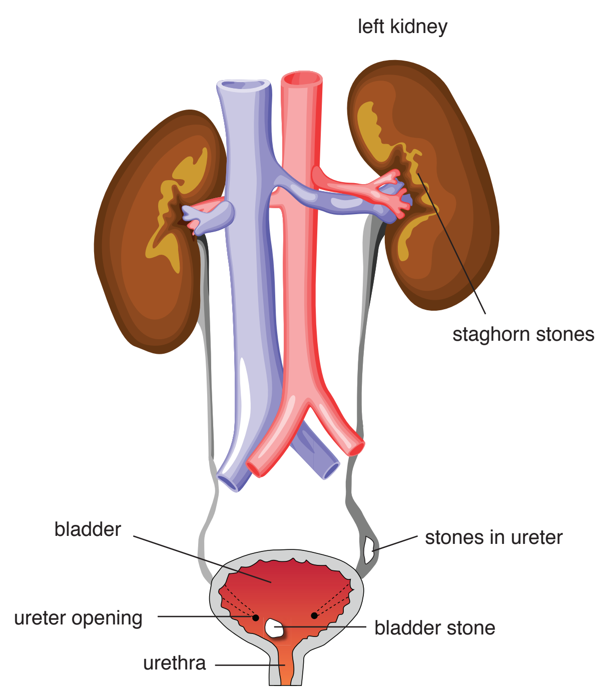
Other Genitourinary Causes Of Flank Pain

Ectopic pregnancy and ovarian cyst/torsion must be considered along with other renal causes such as acute pyelonephritis, nephritic syndrome, papillary necrosis, and renal infarcts. Patients who present with persistent flank pain without secondary signs or evidence of calculus on CT should be scanned with contrast to rule out renal infarcts.[29]

Table 2. Differential Diagnosis For Patients With Acute Flank Pain

Potentially Serious or Life-Threatening Causes	Non-life-threatening Causes
• Abdominal aortic aneurysm • Pulmonary embolism • Appendicitis • Renal vein thrombosis • Renal malignancies and infarction • Ectopic pregnancy • Bowel obstruction • Pancreatitis • Cholecystitis	• Musculoskeletal pain • Acute pyelonephritis • Renal cysts • Hepatitis • Varicella-zoster (shingles) • Peptic ulcers • Diverticulitis/colitis

Figure 3. Anatomy Of Renal System With Stone Locations



Prehospital Care

The prehospital care of a patient with acute flank pain secondary to calculus formation is primarily supportive. Because there are mimics carrying a significant mortality, providers may consider IV access and measures to alleviate excessive vomiting and pain. These should be considered especially in cases with long transport time.

Emergency Department Evaluation

History

Presenting History

At triage, a patient complaining of flank pain may have a calculus, or it could be an AAA awaiting rupture. The initial evaluation of a patient with flank pain should include a complete medical history and physical examination to further differentiate kidney stones from more life-threatening diagnoses. Typical symptoms include restlessness (with the patient unable to find a position of comfort) or intermittent colicky flank pain with radiation to the lower abdomen or groin. This is often associated with nausea with or without vomiting, due to the obstruction of a hollow viscus (ureter). As the stone enters the ureter, there may be lower urinary symptoms such as dysuria, frequency, or urgency. It is important to remember that most calculi may not cause significant symptoms until they begin to descend in the urinary tract.

In a well-designed retrospective review of 235 patients, women and those with atypical symptoms and the absence of hematuria were shown to have increased length of stays, undergoing many additional tests.[30]

Past Medical History

Past medical history may include risk factors such as positive family history, hyperparathyroidism, renal tubular acidosis, diabetes, gout, and known anatomic anomalies such as single or horseshoe kidneys. A careful examination of medications may also increase the clinical suspicion of renal calculus. Known offenders include carbonic anhydrase inhibitors (topiramate), calcium-containing medications, and protease inhibitors such as indinavir or sulfadiazine.

Physical Examination

A complete physical examination should be conducted, beginning with vital signs. Special notice should be taken of a fever, as it may indicate occult infection. Due to the agonizing pain associated with an acute obstruction, patients may be tachycardic and tachypneic and appear pale, cool, and clammy. Hypotension or altered mental status may be indicative of urosepsis. There may be presence of acute costovertebral angle (CVA) tenderness or mild lower abdominal tenderness in some patients. Significant pain on palpation or rebound or guarding suggests a more serious intra-abdominal process and should be further investigated. The abdomen should be carefully palpated for tenderness or pulsation over the abdominal aorta. A complete genital examination should look for evidence of testicular or ovarian torsion, epididymitis, or acute cervicitis/pelvic inflammatory disease.

Diagnostic Studies

Kidney stones represent a complex clinical problem. There are many factors to contemplate when considering what diagnostic tests should be ordered, eg, urinalysis, laboratory studies, and radiographic studies.

Urinalysis

Urinalysis (UA) can be used to detect the presence of red or white blood cells, protein, and crystals. While microscopic hematuria in the presence of acute flank pain is highly suggestive of renal colic, stones may occur in the absence of blood. Other conditions such as ovarian masses, appendicitis, and diverticulitis may also result in hematuria due to an inflammatory process in close proximity to the ureter.

The UA has been found to be nonspecific, and false positives may occur in circumstances such as AAA, infection, or menses.[31] Luchs et al conducted a well-designed retrospective review of 950 patients that correlated urinalysis results in patients with suspected renal colic to findings on unenhanced helical CT.[32] Their results showed the sensitivity (84%), specificity (48%), positive predictive value (72%), and negative predictive value (65%) of hematuria on microscopic urinalysis to be low, demonstrating that the presence or absence of blood on urinalysis is unreliable in determining which patients have kidney stones. While the UA is a complementary test that can be used to rule out infection, the presence or absence of red blood cells cannot be used to diagnose or exclude urolithiasis with a high degree of accuracy.

Laboratory Studies

A comprehensive metabolic evaluation is not cost-effective for all patients but should be considered in those with multiple recurrences, in pediatric patients, or in patients with significant risk factors. These evaluations include an analysis of stone composition, 24-hour urine collections (volume, pH, urinary substrates), and a full electrolyte panel. Detailed metabolic evaluations are rarely indicated in the acute setting and should occur after the resolution of the acute event.[33]

If "basic labs" are ordered, a leukocytosis may raise the suspicion for a renal or systemic infection, but in the absence of specific evidence-based recommendations, practice patterns relating to the routine use of complete blood counts (CBCs) are difficult to evaluate objectively. An assessment of renal function (blood urea nitrogen [BUN], creatinine) is warranted and may help in determining which radiologic study is ordered.

Radiographic Studies

Imaging plays a major role in the diagnosis and management of patients with acute and chronic urolithiasis, but controversy exists regarding when imaging is required and what type of imaging should be selected. Calculi composition, divided into calcareous (calcium-containing) and noncalcareous, can often dictate radiologic study selection when this information is known. **(See Table 3.)** When stone composition is unknown, however, the clinician must decide which radiographic study to order: KUB x-ray, IVP, ultrasound, or nonenhanced helical CT.

Kidney/Ureter/Bladder X-ray

Abdominal radiography of the kidney, ureter, and bladder was often used as the first step in the radiographic workup of patients with flank pain. **(See Figure 4.)** Although about 75% of stones are calcium-based and should be visible on plain film, due to varying radiographic technique and other factors, only about 60% are found to be visible on plain films. The KUB can aid in the detection of a calcified stone, determine its location and size, and provide an assessment of bowel gas patterns and fecal debris. A study by Levine and colleagues reviewed 178 patients with acute flank pain, finding KUBs with a sensitivity of 45% to 59% and specificity of 77% in the detection of urinary tract calculi.[34] With such low sensitivities and specificities, the KUB alone is insufficient in detecting kidney stones and should always be paired with another imaging modality such as ultrasound. If a stone has previously been shown to be radio-opaque, some clinicians advocate the use of KUB in following the stone's progression through the urinary tract.

Table 3. Stone Characteristics

Stone Composition	Types	Characteristics
Calcareous	• Calcium phosphate • Calcium oxalate	• 70% to 75% of all stones • Radio-opaque (seen on plain films as white)
Non-calcareous	• Uric acid • Cystine • Struvite • Other (xanthine, guaifenesin)	• 25% to 30% of all stones • Radiolucent (poorly visualized on plain films, grey to black colored)

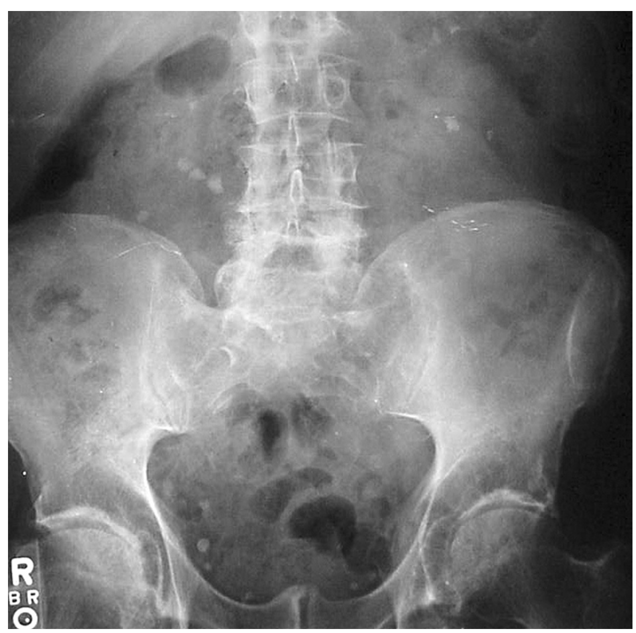
Intravenous Pyelogram

The use of plain abdominal radiographs combined with IV urography was first described in 1923 and was the standard imaging modality for many years. Calculi are identified by their intraureteral location, and the filling defect is noted with the contrast. **(See Figure 5, page 9.)** The IVP is still used in some institutions without availability of sonogram or CT and it is able to demonstrate the anatomy of the entire urinary tract. In a prospective study by Pfister et al in 2003, its sensitivity was 94.2% and specificity was 90.4%, which was within 5% of the results for CT.[35] The IVP assists in identification of anatomical abnormalities of the collecting system and may detect ureteral tumors. In addition, IVP gives a rough estimation of renal function, the degree of obstruction, and the location of calculi. Its limitations, however, have been well-documented, including its implication in contrast-induced reactions and nephrotoxicity. Although IVP was the gold standard for many years, its use has now fallen out of favor with the advent of newer imaging modalities.

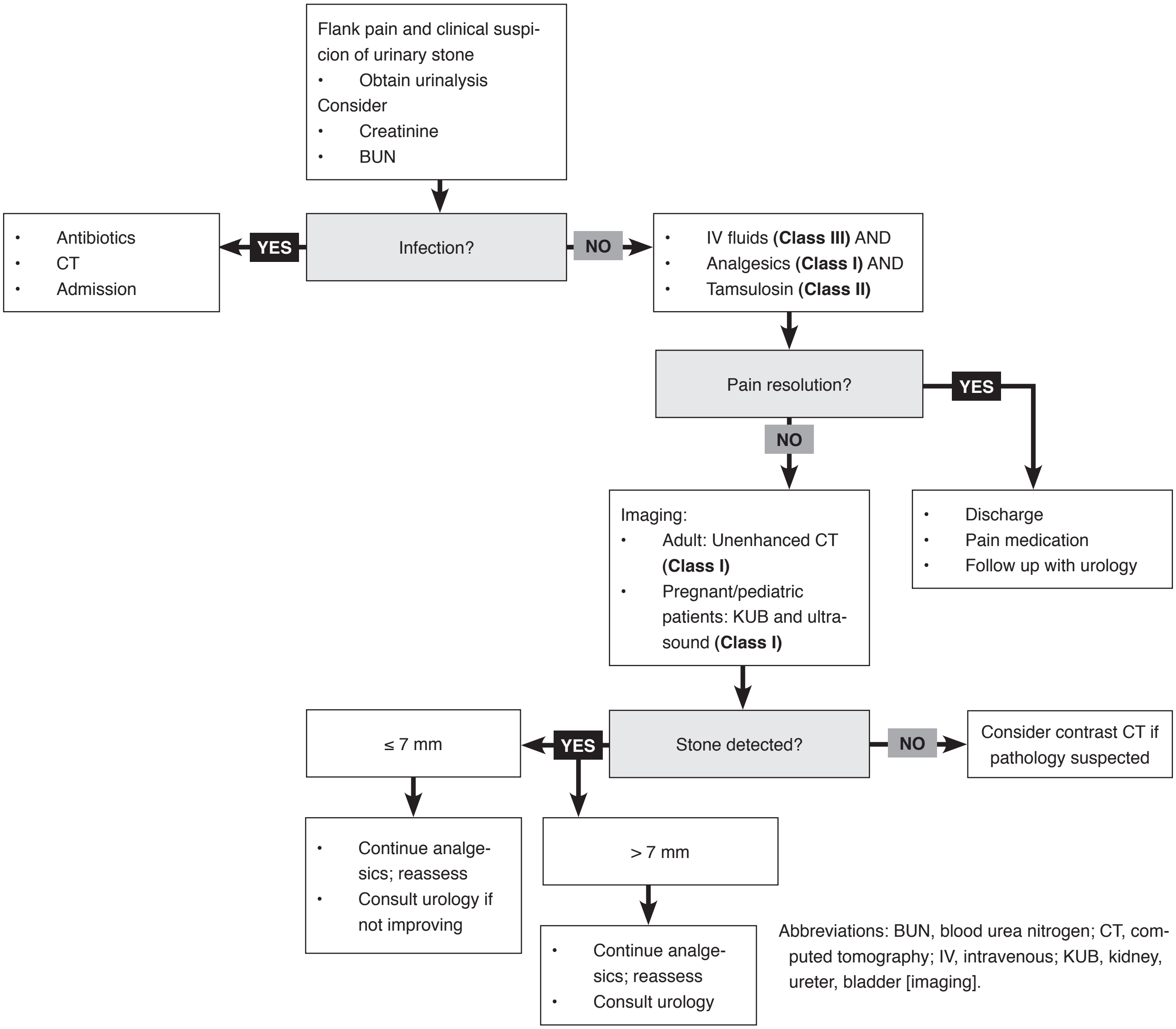
Ultrasonography

Ultrasonography is the modality of choice in those who should avoid radiation (ie, pregnant patients and children). As a bedside procedure, it can often be performed quickly to look for evidence of the stone itself or for hydronephrosis as a secondary sign of the presence of a stone.[36] The stone will typi-

Figure 4. Bilataeral Kidney Stones On KUB Plain Film



Clinical Pathway For Suspected Urinary Stones



Abbreviations: BUN, blood urea nitrogen; CT, computed tomography; IV, intravenous; KUB, kidney, ureter, bladder [imaging].

Class Of Evidence Definitions

Each action in the clinical pathways section of *Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Non-randomized or retrospective studies: historic, cohort, or case control studies
- Less robust RCTs
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

Significantly modified from: The Emergency Cardiovascular Care Committees of the American Heart Association and representatives from the resuscitation councils of ILCOR: How to Develop Evidence-Based Guidelines for Emergency Cardiac Care: Quality of Evidence and Classes of Recommendations; also: Anonymous. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part IX. Ensuring effectiveness of community-wide emergency cardiac care. *JAMA.* 1992;268(16):2289-2295.

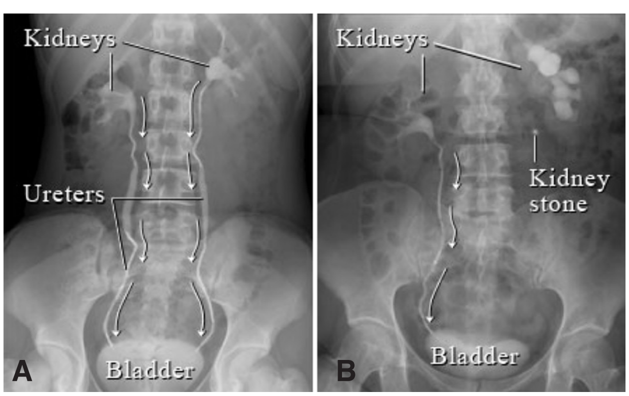
This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

cally be seen as a hyperechoic structure with posterior shadowing. **(See Figure 6.)** A prospective study of 318 patients evaluating the usefulness of sonography as an initial tool in patients suspected of having kidney stones noted ultrasound has a sensitivity of 98.3% and specificity of 100%.[37] The sensitivity and specificity will vary, however, with differing equipment, skill of the operator, and patient body habitus. Additionally, in the absence of renal calculi or hydronephrosis, sonography has a limited role in diagnosis of alternate pathologies. The use of ultrasound in special populations has an American College of Radiology Appropriateness Criteria of 6 out of 10 for acute-onset flank pain and 7 for recurrent symptoms of disease.[38]

Non-Enhanced Helical Computed Tomography

Non-contrast helical CT has supplanted conventional radiography and IVP in the evaluation of patients with suspected lithiasis. **(See Figure 7.)** It was introduced into clinical practice in 1989 when a single breath-hold resulted in images obtained by the helical path of the x-ray focus. The suggested CT scan window is the upper border of the body of T12 to the inferior border of the symphysis pubis using 5-mm or less cuts.[26,39] Some studies note varying section widths, such as 1.5 mm and 2.5 mm, in order to detect smaller calculi less than 3 mm.[40] It has been reported in comparative and observational studies that the unenhanced CT has a sensitivity of 94% to 100% and specificity of 92% to 100% in evaluating urinary and non-urinary flank pain.[41,42] Helical CT has the advantage of diagnosing nephrolithiasis when the stone has passed, which is missed by IVP.[43] Its sensitivity and specificity approach 100%,[44] making it the diagnostic modality of choice, when available. Computed tomography also has the added benefit of being able to make alternate diagnoses in these patients.

Figure 5. Intravenous Urography



View A shows normal flow of urine (white arrows). View B shows kidney stone blocking the normal flow of urine.
Reprinted courtesy of Intermountain Medical Imaging.

Several articles commented on secondary or indirect signs of calculus disease in the renal system as visualized on CT.[42,44] These secondary signs include: perinephric stranding, ureteral dilatation, perinephric fluid, collecting system dilatation, periureteral stranding, and nephromegaly. Secondary signs are indicative of a localized inflammatory reaction or irritation caused by the presence or passing of ureteral stones or other acute urinary obstruction. These indirect signs are thought to follow a well-defined time course corresponding to the physiologic changes caused by an acutely obstructing stone. The peak time of appearance of these secondary signs is reported to be 6 to 8 hours following obstruction, based on a study of 227 patients with stone diagnosis on CT.[44] These secondary

Figure 6. Ultrasound Of Kidney Stones Showing Shadowing Effect

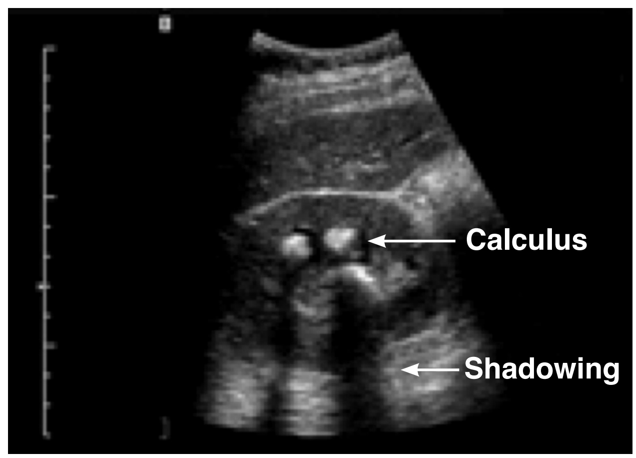


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Figure 7. Computed Tomography Of Left Kidney Stone

Used with permission of Rahmin A. Rabenous, MD.

signs increase in frequency as the duration of flank pain increases. Based on these findings, sensitivity of CT scanning may be higher during this window, 6-8 hours after onset of pain.

Despite their usefulness, CT scans are not without limitations. Because CT scans expose the patient to significant amounts of radiation and come at a considerable expense, the question can be posed: does every patient suspected of having kidney stones need a CT? A reasonable approach recommended by many clinicians is to use CT scans for initial episodes of kidney stones or if the diagnosis is unclear.[43] In contrast, Lindqvist et al performed a prospective randomized study of 686 patients and found that in patients that had complete resolution of pain with parenteral analgesics, immediate imaging with CT did not lead to reduced morbidity when compared to CT imaging done 2-3 weeks later.[45] The decision to order a CT, then, will depend on the patient characteristics and diagnostic comfort of the clinician.

Imaging Summary

Over the last several years, the diagnostic algorithm for flank pain suggestive of renal calculus has changed. For many years, IVP was the gold standard. In 1992, it was suggested that it be replaced by a KUB plain film and ultrasound. In 1993, it was suggested that the KUB and ultrasound be followed by an IVP for equivocal cases. Now, CT is the standard imaging modality, with sensitivities and specificities approaching 100%. While CT has been found to be the most accurate technique, the combination KUB/ultrasound is an alternative with a lower sensitivity and radiation dose with good practical value. The American College of Radiology Appropriateness Criteria summarizes their recommendations for imaging in patients suspicious for stone disease and those with recurrent symptoms.[38] **(See Table 4.)**

Treatment

Traditionally, parenteral narcotics had been used as primary therapy for renal colic, but several studies have shown the benefits of NSAIDs, (ie, ketorolac and diclofenac) in relieving pain through prostaglandin-mediated pain pathway inhibition and decreased ureteral contractility. Caution must be observed in patients with preexisting renal insufficiency or other contraindications to NSAIDs. A Cochrane review noted that both NSAIDs and opioids can significantly relieve the pain in acute renal colic, but opioids cause more adverse effects.[46] This conclusion resulted from 20 trials in 9 countries with a total of 1613 participants. On the other hand, Safdar et al conducted a prospective double-blinded randomized controlled trial of 130 patients who presented with a clinical diagnosis of acute renal colic. The patients were treated with morphine, ketorolac, or both, and it was found that a combination of morphine and ketorolac offered superior pain relief to either drug alone.[47]

Clinical practice has often suggested that the use of high-dose fluids improved outcomes in patients with acute ureteral colic. An early, small study by Pak et al quantitatively assessed the effect of urinary dilution on the crystallization of calcium salts. It concluded that urinary dilution was achieved in vitro by the addition of water in amounts of 1-2 liters per day.[48] A remote prospective 5-year study of 300 patients with idiopathic calcium stone disease concluded that a large water intake results in a strong reduction of supersaturations, thus preventing recurrences.[49] A 2010 Cochrane review found no evidence for the use of fluids or diuretics for the treatment of acute ureteral colic.[50] A trial of 60 patients compared no fluids for 6 hours versus 3 liters of IV fluids over 6 hours and found no significant difference in pain at 6 hours, surgical stone removal, or manipulation by cystoscopy.[50] Therefore, the authors concluded that acute hydration has no evidence-based benefits. The earlier studies do, however, support the use of increased fluid intake to prevent recurrences of stone formation.

Some clinicians advocate the use of antimuscarinic agents, such as hyoscine butylbromide, in the treatment of kidney stones, with the belief that it may provide analgesia by inducing smooth-muscle relaxation and decreasing ureteral spasms. Holdgate et al conducted a prospective randomized trial of 192 patients with a clinical diagnosis of acute renal colic who received morphine with and without hyoscine butylbromide.[51] They found no evidence that hyoscine butylbromide reduced opioid requirements in acute renal colic, suggesting that antimuscarinic agents should not be a part of a standard treatment regimen.

Clinically stable patients are typically given oral analgesics to treat the outpatient spontaneous passage of their kidney stones. These patients should have well-controlled pain, be without evidence of complete obstruction with hydronephrosis, have an adequate renal function reserve, and be tolerating fluids by mouth without difficulty. It is thought that most ureteral calculi smaller than 5 mm will pass spontaneously, typically within 4 weeks after the onset of symptoms. It is known that the rate of stone passage decreases as size of the stone increases. Stones larger than 7 mm may require surgical intervention. Definitive surgical treatment options include shock wave lithotripsy, ureteroscopy, or percutaneous nephrolithotomy, all of which are assessed by a urologist. Candidates for surgical management include those with persistent obstruction, failure of stone progression, or increasing or unremitting colic.[52]

Special Circumstances

Pregnancy

The diagnosis of kidney stones during pregnancy can be a challenge due to physiologic changes during pregnancy and imaging limitations. Approximately 90% of pregnant women develop unilateral or bilateral ureteral obstruction by the third trimester, although this obstruction is asymptomatic in the majority of cases.[53] Physiologic dilation of the renal calices, pelvis, and ureter often begin in the first trimester, and pregnancy-induced hydronephrosis is the most common cause of dilation of the urinary tract in pregnancy and may mimic colic.[53] Establishing an accurate diagnosis calls for weighing radiation exposure to the fetus against potential complications of delayed diagnosis (infection, premature labor, renal pathology). Abdominal ultrasound should be attempted, including color Doppler ultrasound. Computed tomography is unsuitable for routine use in pregnancy, though the risk versus benefit options need to be considered.

Table 4. ACR Appropriateness Criteria For Flank Pain[38]

American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: Acute Onset Flank Pain – Suspicion of Stone Disease

Variant 1: Suspicion Of Stone Disease

Radiologic Procedure	Rating	Comments	Relative Radiation Level
CT abdomen and pelvis without contrast	8	Reduced-dose techniques preferred	++++
US kidneys and bladder retroperitoneal with Doppler and KUB	6	Preferred examination in pregnancy, in patients who are allergic to iodinated contrast, and if NCCT is not available.	++
X-ray intravenous urography	4		+++
MRI abdomen and pelvis with or without contrast (MR urography)	4	See statement regarding contrast in text under "Anticipated Exceptions."*	O
X-ray abdomen (KUB)	1	Most useful in patients with known stone disease	++
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate.			

Variant 2: Recurrent Symptoms Of Stone Disease

Radiologic Procedure	Rating	Comments	Relative Radiation Level
CT abdomen and pelvis without contrast	7	Reduced-dose techniques preferred	++++
US kidneys and bladder retroperitoneal with Doppler and KUB	7		++
X-ray abdomen (KUB)	6	Good for baseline and post-treatment follow-up	++
X-ray intravenous urography	2		+++
MRI abdomen and pelvis with or without contrast (MR urography)	2		O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate.			

Relative Radiation Level	Adult Effective Dose Estimate Range, mSv	Pediatric Effective Dose Estimate Range, mSv
O	0	0
+	< 0.1	< 0.03
++	0.1-1	0.03-0.3
+++	1-10	0.3-3
++++	10-30	3-10
+++++	30-100	10-30

Abbreviations: CT, computed tomography; KUB, kidney, ureter, bladder; MR, magnetic resonance; MRI, magnetic resonance imaging; NCCT, noncontrast computed tomography; US, ultrasound.

*ACR recommends avoiding the use of intravenous gadolinium contrast in patients on dialysis and with glomeruler filtration rates < 30.

Recurrence

Patients with recurrent symptoms present a clinical challenge. The likelihood of calculus as the cause of flank pain is higher, but the risks and benefits of repeated radiation exposure must be taken into consideration. A well-designed 6-year study of 5564 CTs performed for renal colic found that 96% of patients underwent 1 or 2 studies, 4% had 3 or more, and 1 patient had 18 CTs during the study period.[54] This study suggests that patients with a history of kidney stones are at an increased risk of repeat CTs and the accumulation of high-dose radiation. Although a CT may be indicated for a patient with recurrent symptoms, it should be considered judiciously.

Pediatric Patients

The formation of stones in children is dependent upon the same metabolic and anatomic factors as in adults, with the presence of infection as a contributing cause. Several differences apply to kidney stones occurring in the pediatric population. **(See Table 5, page 15.)** In contrast to the adult population, boys and girls are equally affected by kidney stones. The clinical presentation is thought to be age-specific, with the typical flank pain and hematuria being more common in older children. Younger children may only show nonspecific signs of irritability and vomiting.

Pediatric patients with urinary stones are considered to be a high-risk group for developing recurrent stones. In a 2008 guideline published by the European Society for Paediatric Urology (www.espu.org), it was recommended that every child with a urinary stone have an outpatient full metabolic workup.[55] This workup should include a family and patient history, analysis of stone composition, a 24-hour urine collection, and blood work that may include electrolytes, BUN, creatinine, calcium, phosphorus, uric acid, albumin, and parathyroid hormone. Generally, ultrasonogra-

Risk Management Pitfalls For Renal Calculi (continued on page 13)

1. **"I dipped his urine, and it was negative for microscopic blood. I figured it was just musculoskeletal back pain and discharged him with muscle relaxants."**
   A negative UA for microscopic blood does not exclude urolithiasis. Similarly, a positive UA with red blood cells does not diagnose renal colic.

2. **"I was sure a renal calculus was the cause of the patient's radiating pain, nausea, vomiting, and dysuria, but the CT of her abdomen and pelvis was negative for a kidney stone."**
   All stones are not visible on CT. Crystal deposits formed as a result of pure protease inhibitors such as indinavir are not appreciated on CT scans. Additionally, calculi smaller than 3 mm can be difficult to detect. If the history fits, treat as a drug-induced stone.

3. **"I discharged the elderly man with a previous medical history of hypertension and diabetes after he presented with severe right flank pain and microscopic hematuria. I performed a bedside ultrasound to rule out AAA and diagnosed urolithiasis. He returned to the ER 1 day later with a perforated appendicitis."**
   The most common alternative diagnoses of renal colic are cholelithiasis (5%), appendicitis (4%), pyelonephritis (3%), ovarian cyst (2%), and abdominal aortic aneurysm with and without rupture (1.4%). Additionally, inflammatory and infectious conditions can cause hematuria. Misdiagnosing older patients with urolithiasis can greatly increase their morbidity and mortality.

4. **"I assumed that my 70-year-old patient was tachycardic because of the pain from her kidney stone. She was 99.9°F orally so I didn't bother to check a rectal temperature. I was surprised to learn that she returned with urosepsis."**
   Elderly febrile patients should be admitted and urology consulted. Although pain can cause tachycardia, a further workup should be initiated. Elderly patients with fever can develop altered mental status and hypotension and decompensate quickly.

5. **"The 22-year-old male patient reported that his lower back pain was similar to his previous renal colic episodes. After we administered morphine and ketorolac, his pain resolved and we discharged him with urology follow-up. I didn't even think to examine his testicles and was surprised to learn he actually had testicular torsion."**
   A complete genital examination should be performed in patients with symptoms suggestive of renal colic. Testicular or ovarian torsion can present very similarly. Epididymitis, acute cervicitis, or pelvic inflammatory disease can also be confused with kidney stones. Remember to conduct a complete history and physical examination even if patients report similar symptoms previously and that opioids were curative.

phy should be used as a first study. Many radio-opaque stones can be identified with a simple abdominal flat-plate or KUB film. The IVP is rarely used in children. If no stone is identified but symptoms persist, a spiral CT scan is indicated.

Controversies/Cutting Edge

Intravenous Contrast In The Management Of Flank Pain

Contrast may be used in the identification of pyelonephritis or in renal or vascular conditions (tumor, mass, or cysts). The contrast is used to document stone density, location in the ureter, or other extrarenal urinary etiologies. It should be considered in the presence of secondary signs on CT without evidence of a stone.

The Cumulative Effect Of Repeat Computed Tomography Scans

Many kidney stone patients are young and undergo multiple examinations through their disease progression. A study of 356 patient encounters revealed a mean number of 2.5 scans per patient, with 10% having 5 or more scans during the study period of 10 months.[55] This study also concluded that many emergency clinicians rely on the diagnostic value of CT scans but with a limited familiarity with the potential hazards of CT-related radiation exposures. According to a 2001 report from the International Commission on Radiological Protection, a single abdominal/pelvic CT scan for suspected renal colic exposes the patient to 15 mSv.[56] Most of the data for human cancer rates caused by radiation are based on data for people exposed to the Hiroshima or Nagasaki atomic bombs or other nuclear events. It

Risk Management Pitfalls For Renal Calculi (continued from page 12)

6. **"I ordered an analysis of the stone composition, 24-hour urine collections (volume, pH, urinary substrates), and a full electrolyte panel for my 30-year-old patient who presented with renal colic for the first time."**
   A detailed metabolic evaluation is not cost-effective and is rarely indicated in the acute setting. An assessment of renal function (blood urea nitrogen and creatinine) is warranted, but further laboratory testing should be done only if indicated.

7. **"The majority of stones are calcium-based, so I just ordered a KUB to rule out urolithiasis."**
   While 70% to 75% of all stones are calcareous and radio-opaque, only 60% are visible on plain films. KUBs have a sensitivity of 45% to 59% and specificity of 77% in detecting urinary tract calculi. Thus, utilizing KUBs alone is insufficient to diagnose renal colic; KUBs should always be paired with another imaging modality.

8. **"A 12-week pregnant woman presented with severe right flank pain which radiated to her right lower quadrant with right costovertebral angle tenderness. It probably was renal colic, but because of the potential morbidity, I obtained a CT to make sure it wasn't appendicitis."**
   Ultrasonography is the modality of choice in pregnant patients and children. The calculus itself can be seen or secondary signs of the stone such as hydronephrosis can often be visualized. Ultrasound has a reported sensitivity of 98% and a specificity of 100%, although it is dependent on the skill of the operator, adequacy of the equipment, and patient body habitus. A CT might be unavoidable for this patient; however, other modalities should be explored first.

9. **"My 60-kg patient with renal colic still had pain after 6 mg of morphine. I administered another 6 mg, but then she developed respiratory depression and had to be bagged."**
   Non-steroidal anti-inflammatory drugs relieve acute renal colic pain through prostaglandin-mediated pathways and decreased ureteral contractility. In addition, NSAIDs cause fewer adverse effects than opioids. A combination of morphine and ketorolac offers superior pain relief than either drug alone.

10. **"I thought his 7-mm stone would pass spontaneously and didn't think he needed urology follow-up."**
    Most ureteral calculi smaller than 5 mm will pass spontaneously, typically within 4 weeks from symptom onset. Larger stones will take longer to pass. Stones larger than 7 mm usually require surgical intervention, so emergent urologic consultation is needed.

is unknown whether such data can be extrapolated to patients undergoing CT, but consideration should be given to the cumulative radiation dose of patients undergoing multiple CTs.

While CT is proven the better study in terms of diagnostic accuracy (calculus and/or secondary signs) and the identification of other diagnoses, the availability of CT in all institutions as well as the amount of radiation exposure to patients are valid concerns. Two paths have been suggested: (1) using KUB/ultrasound followed by CT if the results are negative, and (2) using CT only if there is strong suspicion of a major colic event.[35]

Stones That Cannot Be Detected By Computed Tomography

Crystal deposits formed as a result of pure protease inhibitors such as indinavir are not visible on CT scans. A small but well-designed 3-month study of 6 patients taking 2400 mg of indinavir reported that the calculi formed from indinavir had an attenuation that is the same or slightly higher than that of soft tissue, rendering it undetectable or barely detectable on unenhanced CT.[58] A patient with a history of use of this drug who presents with acute symptoms and secondary signs of obstruction should have a presumed diagnosis of a drug-induced stone and be managed accordingly.

Medical Expulsive Therapy

Several drugs have been suggested to enhance the spontaneous passage of ureteral calculi. These include calcium-channel blockers, steroids, and alpha-adrenergic blockers. A 2005 prospective randomized study of 210 patients compared a corticosteroid in combination with phloroglucinol, tamsulosin, or

Time- And Cost-Effective Strategies For Renal Calculi

Recommend a low-salt, low-protein diet for patients with calcium stones.
If a specific etiology of calcium calculi can be identified (ie, hyperparathyroidism, hypercalcemia of malignancy, sarcoidosis, or increased calcium absorption from the gut), it can be addressed directly to prevent stone formation. However, if the cause is idiopathic, a low-salt, low-protein diet is preferred to a low-calcium diet.

Patients with atypical symptoms often undergo unnecessary additional testing, increasing their length of stay and healthcare costs.
Women, patients with atypical symptoms (such as the lack of nausea and vomiting, radiation of pain, and urinary symptoms), and patients without hematuria were found to have increased length of stays, undergoing many additional tests. Understanding that not all renal stones cause urinary symptoms and hematuria could reduce the need for additional tests and costs.

A comprehensive metabolic evaluation is not cost-effective for all patients with urolithiasis.
While not cost-effective for all patients with urolithiasis, a comprehensive metabolic evaluation should be considered for those patients with multiple recurrences, in pediatric patients, or in patients with significant risk factors. One international guideline recommended that every child with a urinary stone have a full outpatient metabolic workup.[54] The workup should include a family and patient history, analysis of stone composition, 24-hour urine collections, and a full electrolyte panel.

If a patient with recurring renal colic has a known radio-opaque stone, utilize KUB in acute episodes to show the progression of the stone through the urinary tract.
This method will save the patient from further CT radiation and reduce healthcare costs. Unfortunately, it is only applicable in patients with radio-opaque calculi. If the KUB is not diagnostic, a more sensitive imaging modality should be utilized.

High-dose IV fluids are often suggested to improve outcomes in patients with acute renal colic. However, a prospective trial found no difference in the IV hydration cohort's pain scale at 6 hours.[49]
In the nonacute setting, urinary dilution can be achieved by the addition of 1-2 liters per day orally, which reduces crystallization of calcium salts and supersaturations, thereby preventing recurrences.

Costs and ED lengths of stay that were found to be higher with stones larger than 5 mm were attributed to persistent pain, longer time period to achieve pain control, and complications.[57]
Appropriate weight-based medication dosing should be administered early to hasten resolution of symptoms. Urologists should be consulted to ensure prompt follow-up for patients with renal calculi larger than 5 mm to facilitate curative surgical manipulation.

nifedipine and found that tamsulosin and a corticosteroid was the most efficacious combination. This combination resulted in stones being passed more quickly and a reduced need for analgesics.[59]

Steroids are always a controversial issue. True, steroids could reduce inflammation in the urinary tract caused by a kidney stone, but are the steroids a necessary component in medical expulsive therapy (MET)? Singh et al conducted a meta-analysis of 16 studies using alpha-antagonists and 9 studies using a calcium-channel blocker for MET and found that both drugs augmented stone expulsion rates.[60] A subgroup analysis of these trials, using adjunct medications such as steroids and antibiotics, yields a similar improvement in expulsion rates.[60] This meta-analysis seems to suggest that calcium-channel blockers or alpha-antagonists, used alone, improve expulsion rates and medications like steroids may be useful as an adjunct therapy.

The Economic Impact Of Patients With Kidney Stones In The Emergency Department

Costs and ED lengths of stay were found to be higher with stones larger than 5 mm. A retrospective review of 574 patients in a 36,000-volume ED concluded that this likely reflected the recalcitrant nature of the pain, longer time to achieve pain control, and complications.[61] On average, the time for CT was 5-15 minutes versus KUB/ultrasound which required 20-40 minutes.[62] The indirect costs of managing these patients is higher for those receiving IVP due to room-occupation time, preparation time for contrast, and potential management of contrast-induced complications. Protocols that include the KUB/ultrasound combination are cheaper, though time-to-diagnosis is longer than that with CT alone.

Disposition

Some kidney stone patients may require admission to the hospital. **(See Table 6.)** For the remainder of patients, clear and specific discharge instructions are essential. Patients should be advised to follow up with a urologist. Although it is not the primary responsibility of the emergency clinician to determine the cause of a patient's stones or to initiate preventive measures during acute renal colic, the patient should be educated on the availability of preventive testing and treatments.

Table 5. Pediatric Population And Stones

Pediatric Considerations

- Urine cultures suggested
- Risk factors and metabolic workup are critical
- Only 5% of stones escape detection by noncontrast CT
- Ultrasound fails to identify stones in more than 40% of cases
- More likely to have spontaneous passage

Summary

Renal colic is one of the most severe pain syndromes commonly diagnosed and managed in the ED. While the morbidity and mortality of urolithiasis is relatively low in comparison to other conditions, these patients need to be assessed quickly for potential life-threatening mimics. In addition, they need to receive appropriate control of nausea and vomiting as well as appropriate and judicious use of analgesics. Patients who have good pain control with fluids and analgesics may be managed clinically, and imaging may not be necessary. Patients with persistent pain, concern for infection, or questionable clinical presentation should be imaged to enhance the diagnostic certainty and to rule out other etiologies of flank pain. While there is some controversy regarding the algorithm, patients may be evaluated with the KUB followed by ultrasound imaging; however, if available, CT is considered a better alternative due to its diagnostic accuracy, speed, and ability to identify alternate diagnoses. In the absence of a large stone, complete obstruction, renal failure, or sepsis, many of these patients may safely await spontaneous passage of the calculi.

Additional Resources

- American Urological Association Foundation: www.auafoundation.org, www.urologyhealth.org
- National Kidney Foundation: www.kidney.org
- Oxalosis and Hyperoxaluria Foundation: www.ohf.org
- International Kidney Stone Institute: www.iksi.org
- National Institute of Diabetes and Digestive and Kidney Disease (NIDDK) Information Clearinghouse: www.kidney.niddk.nih.gov

Table 6. Indications For Admission And/Or Intervention

- Obstruction in the presence of infection
- Urosepsis
- Intractable pain with refractory nausea and/or vomiting
- Impending renal failure
- Severe volume depletion
- Obstruction in solitary or transplanted kidney and complete obstruction
- Bilateral obstructions
- Urinary extravasation

Case Conclusions

The reason your chairman wanted to see you is because less than 24 hours later, the patient you discharged came back to the ED in severe pain, febrile, vomiting, and very displeased that he had to return. A nonenhanced abdomen and pelvic CT revealed a 6-mm right ureteral stone with significant hydroureter and hydronephrosis. He was subsequently admitted to the urology service for hydration, pain management, and definitive treatment. The chairman reminded you that urine negative for blood does not rule out the presence of a calculus.

The HIV patient with back pain was medicated with ketorolac, promethazine, and IV fluids. Her labs noted a WBC count of 12, with a urinalysis positive for leukocytes and RBCs (3 per hpf). Her CT demonstrated some periureteral stranding and mild hydroureter but no evidence of a stone. Further investigation revealed that she was on indinavir, and she was properly treated for a drug-induced stone.

When you checked on the patient with abdominal pain whom you had signed out to a colleague, you found that she improved greatly with the morphine and had a fairly unremarkable KUB. A sono tech was called in, but the second physician had become busy and did not have an opportunity to reexamine her. Later, in the ultrasound suite, the patient complained of worsening abdominal and flank pain. The astute sono tech scanned her aorta and she was found to have an AAA.

References

Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available.

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CME Questions

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1. All of the following are true regarding renal calculus patients, EXCEPT:
- a. It is more common in women
- b. It is a recurrent condition
- c. It can occur in the absence of hematuria
- d. Calculi are most often radio-opaque

2. Risk factors for calculi formation include:
- a. Diabetes mellitus
- b. Living in hot/dry climates
- c. Family history
- d. Decreased liquid intake and urine output
- e. All of the above

3. The pain of renal and ureteral calculi is thought to:
- a. Be related to the obstruction of a hollow viscus
- b. Radiate to the groin or genital organs
- c. Be severe in nature
- d. Be associated with nausea and vomiting
- e. All of the above

4. All of the following have been described as common locations of calculi EXCEPT:
- a. Uteropelvic junction
- b. Level of iliac vessels
- c. Ureterovesical junction
- d. Right kidney

5. Which condition(s) may mimic renal colic?
- a. Ruptured AAA
- b. Appendicitis
- c. Renal infarction
- d. Ectopic pregnancy
- e. All of the above

6. What percentage of kidney stones is radio-opaque (approximately)?
- a. 10%
- b. 20%
- c. 50%
- d. 75%

7. The evaluation of pregnant patients with suspected colic includes:
- a. MRI
- b. IVP
- c. Ultrasound
- d. Quantitative b-HCG

8. All of the following are true statements regarding ultrasound use in patients with renal colic EXCEPT:
- a. It should be used in pediatric patients
- b. It is a rapid study
- c. It is a very specific and sensitive test
- d. It is useful for diagnosing alternate pathologies in all cases

9. Secondary signs of calculus disease include all of the following except:
- a. Perinephric stranding
- b. Ureteral dilatation
- c. Ureteral rim sign
- d. Perinephric fluid
- e. Hydronephrosis

10. Patients with the following should be admitted, EXCEPT:
- a. Calculi with UTI
- b. Calculi with intractable pain
- c. Calculi with intractable vomiting
- d. Calculi > 3 mm
- e. Bilateral obstructions

In This Month's *Pediatric Emergency Medicine Practice*

Difficulty Breathing In Infants And Young Children: An Update

by Ari Cohen, MD, FAAP
Chief, Pediatric Emergency Services, Massachusetts General Hospital, Boston, MA

Pediatric respiratory distress is a common and troubling presenting complaint to the emergency department (ED). Although many respiratory illnesses are due to upper respiratory tract infections, which are self-limited and need only parental reassurance, the emergency clinician must constantly be alert and prepared for the few children with an underlying condition that can progress to respiratory compromise or failure. Emergency clinicians must utilize clues from both the history and physical examination to uncover the cause of the distress and then employ the most up-to-date modalities to prevent the child's deterioration. Although uncommon, respiratory failure can rapidly ensue in some instances and cause cardiopulmonary arrest. Respiratory failure is the most common cause of cardiac arrest in children. The unexpected and rapid respiratory collapse of the pediatric patient can most often be avoided by early recognition of the severity of illness and should prompt initiation of appropriate therapies.

This review discusses the most common pediatric respiratory emergencies and their management. A detailed discussion of the entire spectrum of respiratory illness in children is beyond the scope of this text. Rather, the review presents an updated, systematic approach to management with careful attention to the relevant existing evidence.

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Goals: Upon completion of this article, you should be able to: (1) demonstrate medical decision-making based on the strongest clinical evidence; (2) cost-effectively diagnose and treat the most critical ED presentations; and (3) describe the most common medicolegal pitfalls for each topic covered.

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