Sonography First for Acute Flank Pain?

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Invited paper

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The Sound Judgment Series consists of invited articles highlighting the clinical value of using ultrasound first in specific clinical diagnoses where ultrasound has shown comparative or superior value. The series is meant to serve as an educational tool for medical and sonography students and clinical practitioners and may help integrate ultrasound into clinical practice.

As part of the Sound Judgment Series, this article describes the case of a patient presenting with acute flank pain and a classic clinical picture of a first episode of renal colic. The epidemiologic characteristics, pathophysiologic characteristics, risk factors, and initial assessment of patients with renal colic are briefly discussed. Imaging options are discussed, with emphasis on sonography and computed tomography (CT). Although CT is typically a first-line test in the United States and is very accurate, there is increasing awareness of the radiation risk associated with CT scanning. Sonography may directly visualize kidney stones and/or evidence of ureteral obstruction and may obviate the need for CT scanning. Sonography is typically the first-line test in Europe, even in a first episode of kidney stones. We submit that sonography as an initial imaging modality in suspected kidney stones should be considered more often, particularly in younger and female patients with classic symptoms on first presentation and in patients with symptoms consistent with their prior episodes of renal colic, reserving CT for patients in whom symptoms do not resolve or there is a suspicion of alternative diagnoses. Decisions about imaging may offer an opportunity for shared decision making about what initial imaging modality to use.

Clinical Case

A 28-year-old woman presents to the emergency department (ED) at 4 AM with acute onset of left flank pain. The pain is sharp and severe ("as bad as labor pains") and awakened her abruptly from sleep 2 hours previously. She has nausea and has vomited once. She had been in good health before this episode and has no fever, no vaginal bleeding or discharge, and no urinary symptoms. She is sexually active with one partner, and her last menstrual period was normal 2 weeks previously. She is taking oral contraceptive pills but no other medications. She has a family history of kidney stones but has never had one herself. She has no surgical history, has never been pregnant, and does not have a history of pelvic pain.

On physical examination, she appears uncomfortable and is writhing slightly on the stretcher. The following vital signs were obtained: temperature, 98.4°F (oral); heart rate, 97 beats per minute; blood pressure, 135/85 mm Hg; and respiratory rate, 12 breaths per minute. Her abdominopelvic examination is benign, with no distension, no abdominal, pelvic, or adnexal tenderness, and no reproducible tenderness of the abdomen or flank. Urinalysis results are positive for microscopic blood and negative for leukocyte esterase or pregnancy.

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Abbreviations
CT, computed tomography; ED, emergency department

What is the most likely diagnosis? What diagnostic studies (if any) should be performed?

The above scenario is a classic presentation of renal colic. Kidney stones are a common and increasing problem in the United States and worldwide.[1] Recent data show that the prevalence of symptomatic kidney stones in the United States has risen from 5.2% in the early 1990s to greater than 8% in 2012, a 71% increase occurring across all age groups and ethnicities.[2,3] Although rarely life threatening, kidney stones may cause considerable pain, frequently resulting in an ED visit. In the United States, there were more than 600,000 ED visits for renal colic in 2000, and kidney stones are estimated to account for greater than $2 billion in annual health care expenditures.[4] Although most kidney stones are small (<6 mm) and pass spontaneously, a subset of stones (usually the larger ones) will require urologic intervention. The use of diagnostic imaging modalities in the workup of suspected renal colic is highly variable.[5]

Pathophysiologic Characteristics and Risk Factors

About 75% of kidney stones contain calcium, typically in the form of calcium oxalate alone or mixed with calcium phosphate and are, therefore, highly radiopaque. Struvite (magnesium ammonium phosphate) stones are present in 10% to 15% of cases and may develop into staghorn calculi. Uric acid stones account for 6%, and cysteine stones constitute 1% to 2%.[6] Uric acid stones are not visible on plain radiography but are visible on CT or sonography. Patients treated with indinavir for human immunodeficiency virus may form stones when the drug crystallizes in the urine; it is important to recognize this clinical scenario because such renal calculi will not be visible on CT or plain radiography but can be seen on sonography.

Kidney stones occur about twice as frequently in men and have strong associations with the family history as well as geographic patterns.[1,7] Diet (specifically beverage consumption) and environmental factors such as temperature and sunlight (which may affect hydration status) are often implicated in geographic patterns.[8] Obesity has recently been shown to be associated with kidney stone formation and may be a contributing factor to the increased incidence of renal calculi.[9]

History, Physical Examination, and Point-of-Care Urine Testing

Patients with renal colic classically present with acute, severe flank pain, nausea, and hematuria (typically microscopic). This clinical presentation may be adequate for accurate diagnosis in most patients. One study reported sensitivity of 89% and specificity of 99% for discerning which patients with acute abdominal pain had renal colic.[10] Some degree of hematuria occurs in about 85% of all symptomatic kidney stones.[7,11] However, hematuria is a nonspecific finding, and the absence of hematuria does not entirely exclude renal colic as a cause of abdominal, pelvic, or flank pain.[11]

Imaging

Reasons to perform imaging include the following: (1) confirmation of the diagnosis and exclusion of other diseases that might cause similar symptoms, (2) determination of the size and location of stones, which have implications for both management and prognosis,[12] and (3) exclusion of obstruction or hydronephrosis, which has implications for patient treatment, especially in the setting of renal insufficiency. Concerns about liability ("defensive medicine"), as well as patient expectations, availability of technology, and financial incentives may influence whether imaging is requested as well.[13] Nearly all stones that are less than 5 mm in their maximum dimension will pass spontaneously, whereas stones larger than 5 mm are more likely to require intervention.[7,14] The stone location (with more proximal stones being less likely to pass) also plays a role in the prognosis.[14,15]

Computed Tomography

Since the landmark article by Smith et al[16] in 1996, CT has rapidly become the reference standard for the diagnosis of kidney stones. In 2004, the *New England Journal of Medicine* dubbed non–contrast-enhanced helical CT of the abdomen and pelvis the "best imaging study to confirm the diagnosis of a urinary stone in a patient with acute flank pain."[7] The American College of Radiology has given CT a rating of 8 (up to a possible 9, with 7–9 being "usually appropriate") in their appropriateness criteria recommendation for "acute-onset flank pain–suspicion of stone disease."[16]

The sensitivity and specificity of CT for diagnosing kidney stones have been reported as 95% to 96% and 98% to 100%, respectively, with overall accuracy of 98%.[16,17] The only stones that CT typically does not detect are completely radiolucent stones, such as stones secondary to indinavir therapy, an antiretroviral agent. Computed tomography can determine both the size and location of stones, the primary predictors of whether a ureteral stone will pass primarily without intervention. Ureteral stones that are 5 mm or smaller in maximum diameter and/or distally located are much more likely to pass.[14] However, CT measurement of the maximum stone diameter does not always correlate well with the actual stone size, often overestimating the maximum diameter by 1 mm or more.[18]

In addition to delineating the stone size and location, CT may reveal alternative diagnoses that present similarly to renal colic. Several studies have reported that alternative diagnoses may be found in 10% to 14% of patients undergoing imaging using renal stone protocol CT.[19,20] In particular, the use of CT in patients with a "first diagnosis" of kidney stones has been advocated to avoid missing any important alternative diagnoses, an approach that is advocated by many clinicians.[21] However, many of the studies of alternative findings have been limited by a retrospective modality, lack of clinical follow-up, and overemphasis on CT findings that may be important (eg, "mesenteric adenitis"). Recent work at our institution has found that some simple screening criteria (ie, CT in patients with flank pain and absence of pyuria) may reduce the incidence of clinically important alternative diagnoses to less than 3%.[22] Furthermore, alternative findings on CT are less likely to be present in a patient who has had a prior diagnosis of a kidney stone and presents in a similar fashion.

Although CT scanning has become the diagnostic test of choice for kidney stones, it is not without drawbacks, primarily exposure to ionizing radiation and cost. Another important consideration is the discovery of incidental findings on CT that, although at times may be helpful, may frequently lead to further testing and intervention that may be unnecessary and result in increased risk and cost.[23,24] Although the risk of malignancy from exposure to ionizing radiation has been debated, the most recent conclusions from the National Academy of Sciences support the "linear no-threshold model" (ie, that there is no threshold level of radiation that causes cancer and that increased exposure to ionizing radiation is linearly associated with the risk of malignancy), and recent epidemiologic data support this model.[25,26] It has been estimated that as many as 29,000 malignancies may ultimately result from CT scans performed in the United States in 2007 alone.[27] The lifetime risk of developing a malignancy from a single non–contrast-enhanced CT scan of the abdomen-pelvis (as is typically performed to diagnose renal colic) is estimated to range from 1 per 500 in a 20-year-old woman to 1 per 1330 in a 60-year-old man.[28]

Renal colic is estimated to recur in 50% of patients. These patients may present repeatedly to the ED and may, therefore, have numerous CT scans. In one series of CT scans performed for renal colic at a single institution over a 6-year period, 4% of patients had 3 or more CT scans for renal colic, with 1 patient undergoing 18 CT examinations, incurring an effective radiation exposure of between 20 and 154 mSv.[29] Although patients are more confident in the diagnosis physicians make when a CT examination is performed, they consistently underestimate the radiation dose and risk of future malignancy and may be unaware of prior CT examinations that they have had.[30] Patients are unlikely to receive any information at all about the risks of CT when it is ordered, in part due to time constraints but also because practitioners of various medical specialties may not understand the risks well themselves.[31]

Despite a 10-fold rise in the use of CT for diagnosis of kidney stones from 1996 to 2007, one study found no change in the frequency of kidney stone diagnosis, frequency of alternative diagnoses, or admissions for kidney stones.[32] Another study looking at the introduction of non–contrast-enhanced CT for kidney stone diagnosis also found an increase in imaging with "little affect on acute care of patients in the ED," specifically, no change in admission or revisit rates.[33]

Recently, CT protocols as well as algorithms such as adaptive statistical iterative reconstruction have been developed that may substantially lower the radiation dose without sacrificing clinical accuracy. In nonobese patients (body mass index <30 kg/m^2), low-dose CT has been shown to be 100% sensitive for detecting kidney stones that are larger than 3 mm and 86% sensitive for stones that are smaller than 3 mm.[34] Other studies from Europe and Asia have confirmed that low-dose CT is accurate in detecting larger (ie, >2 mm) stones in nonobese patients.[35,36] However, we are unaware of any clinical studies using low-dose CT protocols for diagnosis of renal colic in the United States.[37,38] A concern often raised regarding low-dose CT protocols is that although large kidney stones may not be missed, other clinically relevant pathologic conditions may not be detected. Although a large-enough definitive study of low-dose CT in renal colic has not been performed, a recent study showed that low-dose CT was not inferior to regular-dose CT in the diagnosis of appendicitis.[39]

Sonography

Sonography is a widely available imaging modality that does not expose the patient to ionizing radiation and may diagnose kidney stones through direct visualization or by showing secondary signs of ureteral obstruction. The sensitivity of sonography for detecting kidney stones has been variably reported to be between 12% and 98%.[40–43] This wide variation is likely due to both operator dependency as well as discrepancies in the literature between direct visualization of stones versus secondary signs that are treated as diagnostic.

Sonography is highly effective in showing large stones (>5 mm) but poor at visualizing stones smaller than 3 mm.[41,44] Additionally, although sonography can detect stones located at the ureteropelvic junction or distally at the ureterovesical junction (Figure 1 and Video 1), stones located in the mid ureter (Figure 2) are typically obscured by overlying bowel gas. In women, the endovaginal approach may be useful to identify stones at the ureterovesical junction (Figure 3). Stones on sonography are hyperechoic and show posterior shadowing depending on their size and the transducer frequency (Figure 4 and Video 2), unless spatial compounding is used, in which case distal shadowing may not be observed. It may be difficult to distinguish small stones from vascular calcifications. On color Doppler imaging, a "twinkling" artifact (Figure 4 and Video 3), a comet tail of aliasing colors posterior to the stone, may be observed.[45,46] This artifact is thought to be related to the interaction of Doppler sound waves on the rough surface of the stone.[47]

Sonography is reported to have overall sensitivity between 73% to 100% for obstruction of the collecting sytem.[40,44] Signs of obstruction include hydronephrosis, hydroureter, and decreased or absent ureteral jets on the affected side. Hydronephrosis may range from mild pelvicaliectasis to severe hydronephrosis with cortical thinning and is typically graded on a scale from 1 to 3 corresponding to mild, moderate, and severe hydronephrosis (Figures 2A, 3A, and 4A and Video 4). Accompanying hydroureter may also be seen (Figure 2 and Video 5). Severe hydronephrosis

Figure 1. Ureterovesical junction and bladder calculi. This 48-year-old man presented with recurrent episodes of renal colic. Sagittal image of the bladder shows an echogenic renal calculus at the ureterovesical junction (white arrow) as well as mild dilatation of the proximal ureter. Note two mobile echogenic shadowing calculi within the bladder lumen.

Figure 2. Midureteral calculus. **A**, Sagittal image of the right kidney shows moderate hydronephrosis and dilatation of the proximal ureter in this 24-year-old woman presenting with right flank pain. **B**, More distal image shows an echogenic shadowing calculus in the mid ureter with dilatation of the proximal ureter.

A

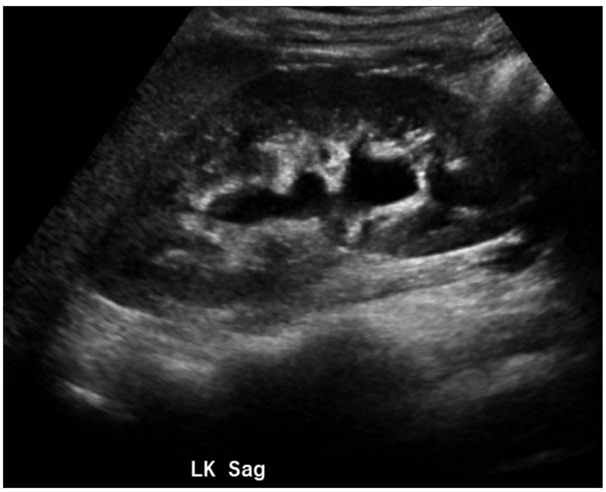
B

takes time to develop, and its presence indicates a more chronic condition than acute renal colic. Patients with larger stones (less likely to pass spontaneously) are more likely to show moderate or severe hydronephrosis on sonography.[48] Questions remain about what role the presence or absence of hydronephrosis alone may play in the evaluation and treatment of a patient with suspected renal colic. Although the presence of hydronephrosis in a patient with classic symptoms is fairly definitive for a ureteral stone, visualizing the actual stone and determining its size and location may be important for follow-up after the acute event. In the setting of renal failure or signs of infection in a patient with presumed renal calculi, the presence of hydronephrosis may prompt immediate intervention.

Ureteral jets occur from the periodic contraction of the ureters and may be seen on gray-scale imaging but are much more easily visible on color Doppler imaging (Figure 5 and Video 6). An average healthy person has close to 3 ureteral jets per minute, whereas those with ureteral obstruction will have decreased or absent jets.[49] Absence of the ureteral jet suggests complete obstruction (provided that the contralateral jet is observed) but does not exclude partial obstruction of the collecting system (Figure 4).

Figure 3. Left ureterovesical junction calculus. **A**, Sagittal image shows moderate dilatation of the left intrarenal collecting system in this 26-year-old women who presented with left flank pain during the late second trimester of pregnancy. The right kidney was normal. **B**, Endovaginal image of the left ureterovesical junction shows a left ureterovesical junction stone and dilatation of the distal ureter (calipers).

A



B

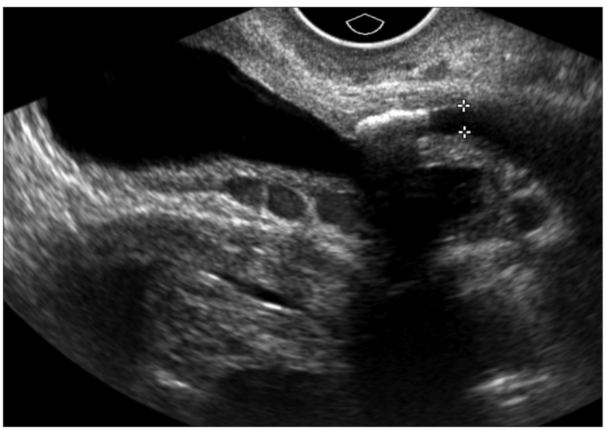
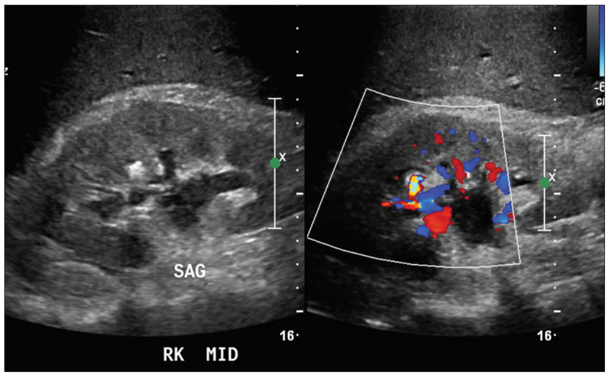
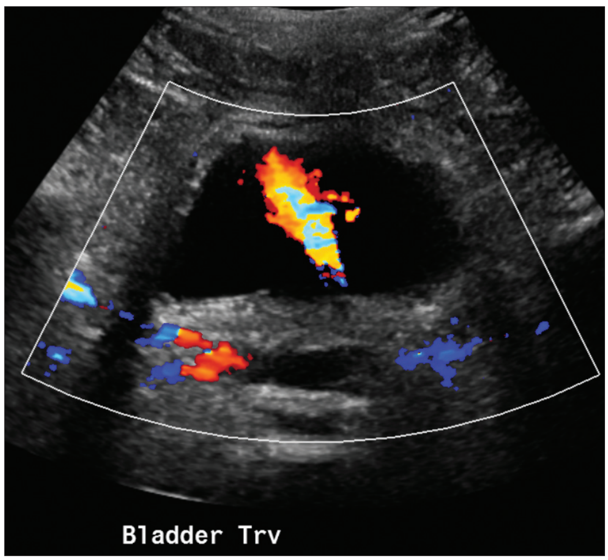


Figure 4. Right hydronephrosis and renal calculi. **A**, Split-screen gray-scale and color Doppler sagittal images of the right kidney show mild to moderate hydronephrosis as well as an echogenic nonobstructing renal calculus at the mid pole. Note the twinkling comet tail artifact deep to the calculus on the color Doppler image. **B**, Color Doppler transverse image of the bladder reveals a left but not a right ureteral jet indicative of more proximal obstruction of the right collecting system.

A



B



Sonography may also be used to investigate other conditions that may mimic kidney stones such as subcapsular hematomas (Figure 6), renal abscesses, pyelonephritis (Figure 7), and other causes of acute hydronephrosis such as tumors and blood clots. In female patients, ovarian torsion and hemorrhagic cysts may have a similar clinical presentation, with acute onset of lateralized pain that radiates to the flank or back and associated nausea and vomiting. Similarly, appendicitis may be diagnosed as a cause of flank pain on sonography, although CT is more sensitive for this diagnosis than sonography.

Plain radiography

Kidney-ureter-bladder plain radiography is occasionally used for diagnosis and follow-up. It will typically show larger calcium-containing stones but may miss smaller stones and will not show uric acid or indinavir stones. Accuracy and sensitivity are limited by a large patient body habitus and patient motion. Phleboliths and other calcifications may be mistaken for stones, limiting specificity. Kidney-ureter-bladder radiography has been reported to have sensitivity between 45% and 69% and specificity between 71% and 82%.[50,51] Urologists often choose to monitor the progression of stones with kidney-ureter-bladder radiography because it is less expansive, exposes the patient to less radiation, and may be obtained in the office setting[12] in comparison to serial CT scans. Kidney-ureter-bladder radiography, in combination with other modalities such as sonography, has been reported to achieve clinical accuracy close to that of non–contrast-enhanced CT in follow-up of renal calculi.[52] However, the radiation dose from kidney-ureter-bladder radiography is often close to 1 mSv (about 20 times that of a chest radiograph), and low- or ultra–low-dose CT protocols may offer better diagnostic images than kidney-ureter-bladder radiography with similar radiation exposure.

Clinical Scenario: Why Not Sonography First?

In the case of the 28-year-old woman described at the beginning of this article, there are multiple potential diagnostic approaches. The patient could undergo CT, retroperitoneal sonography, plain radiography, some combination of imaging, or no imaging at all. A similar patient presenting to a dozen different EDs in the United States or Europe might get worked up a dozen different ways. Published data on imaging trends, recommendations for "first" diagnosis of renal colic in a patient without a personal history of renal colic or known kidney stones, and published "appropriateness criteria" all point to the use of CT as the initial and definitive test (particularly in the United States) for establishing the diagnosis of renal colic and excluding other diagnoses.

Figure 5. Normal ureteral jets. Bilateral ureteral jets are apparent on this color Doppler image from an asymptomatic patient.

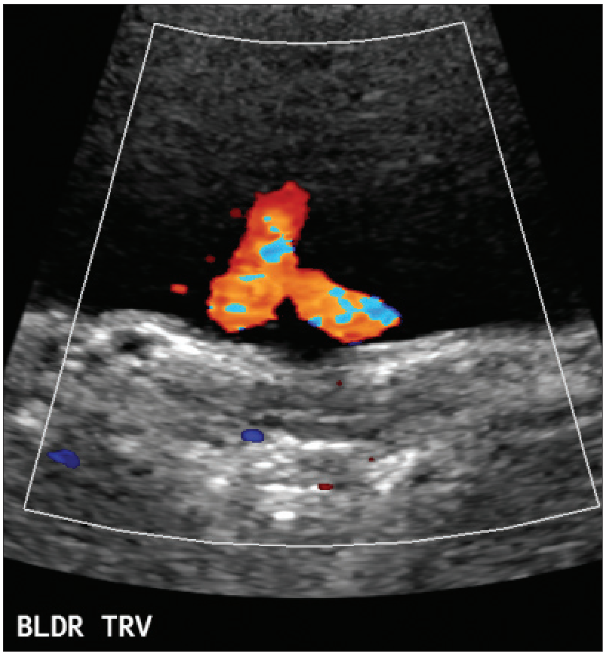


Figure 6. Subcapsular hematoma. This 36-year-old woman presented with right flank pain after trauma. Sagittal gray-scale image of the right kidney shows an anechoic fluid collection compressing the renal cortex (note straightening of the cortical contour), consistent with a subcapsular hematoma.

However, the size and location of renal stones as well as the presence or absence of obstruction of the collecting system can often be established with sonography without the cost and radiation exposure of a non–contrast-enhanced CT scan. Thus, as concerns regarding the risks of radiation exposure and health care costs increase, many physicians are reconsidering the role of sonography as the first-line imaging modality of choice in the workup of suspected renal colic.[53] Even if the stone is not directly visualized, the presence of secondary signs such as hydronephrosis and decreased, absent, or persistent ureteral jets, particularly in a patient with characteristic symptoms and urinalysis results, may effectively confirm the diagnosis (Figure 4).

Such an "ultrasound-first" approach is more frequently advocated in Europe. In 2011, the European Association of Urology Urolithiasis Guideline Panel published recommendations stating that for the diagnosis of renal colic, sonography "… should be used as the primary procedure. It is a safe (no risk of radiation), reproducible and inexpensive method of urinary stone detection." Thus, in many European hospitals, CT is not the first-line imaging test for suspected renal colic. However, on the western side of the Atlantic, CT is often the first test done, even in repeated bouts of renal colic, perhaps related to concerns regarding the accuracy of sonography and likely related to the ease of obtaining a non–contrast-enhanced CT examination in the ED setting.[54,55] Studies in the United States note the decreased sensitivity of sonography both for diagnosis as well as identification of other causes of the patient's symptoms in comparison to CT,[41,43] whereas European and Asian studies tend to emphasize the clinical utility of sonography, often in combination with lower-radiation studies such as kidney-ureter-bladder radiography and low-dose CT.[40,52]

Figure 7. Pyelonephritis. This 24-year-old woman presented with acute right flank pain. Sagittal gray-scale image reveals that the right renal cortex is thickened and heterogeneous with blurring of the cortical sinus definition, consistent with acute pyelonephritis. There is no evidence of hydronephrosis or renal calculi. The patient had pyuria, and the urine culture grew *Escherichia coli*.

Computed tomography is clearly the "best imaging study"[7] for suspected renal colic if diagnostic certainty is the primary concern. Recently, however, there has been increased interest in "patient-centered" medicine: asking the questions, "What are my options, and what are the benefits and harms of those options?"[56,57] Considering the diagnosis of renal colic from this perspective, is the small but real risk of life-threatening consequences later in life due to radiation exposure from a CT scan worth it to the patient if the diagnosis of a non–life-threatening condition such as a kidney stone is nearly certain from the symptoms, urinalysis, and sonography? Different patients may answer this question differently, just as there is likely to be variability on the part of providers in terms of tolerance for uncertainty and risk. However, if the patient and provider clearly understand the risks of doing a test as well as the risks of not doing the test, they may be able to find a mutually agreeable approach.

Approaching patient care in this manner requires more knowledge, effort, and time on the part of both providers and patients, and the fast pace and time constraints of emergency medicine in most American EDs work against this approach.[55] In addition, there may be additional downsides to increasing patients' involvement in decisions about their medical care.[58] However, in February 2012, Stephen Swensen, MD, director for quality at the Mayo Clinic, published an article entitled "Patient-Centered Imaging,"[13] which discussed the overuse of imaging, calling for a "multi-stakeholder Imaging Leadership Coalition" and decision support that incorporates "point-of-order shared decision making" Renal colic, a non–life-threatening diagnosis with many potential algorithms for establishing the diagnosis (not all of which are benign), may represent an ideal opportunity for incorporation of shared decision making.

Sonography should be considered the first-line imaging test of choice for assessment of renal colic in children and pregnant patients. However, clinicians should also strongly consider sonography first in younger adults, non-pregnant female patients of reproductive age, and other patients with frequent or repeated ED visits due to renal colic or known renal calculi by weighing the risks of radiation exposure as well as health care costs. Perhaps non–contrast-enhanced CT should be reserved for patients in whom sonography is not revealing or for patients with persistent symptoms, renal failure, or concern for infection to determine whether intervention is necessary. In an ideal scenario, the patient should be involved in decision making about imaging and understand the risks, inclusive of the diagnostic uncertainty of different approaches. Although communication with patients is always important, it may be particularly relevant when a test for a non–life-threatening diagnosis has potential risk. Regardless of the diagnostic approach that is chosen, understanding the strengths and limitations of imaging options, including associated long-term risks, will make us better clinicians and imagers.

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