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# TRENDS IN IMAGING FOR SUSPECTED URINARY STONES IN THE EMERGENCY DEPARTMENT

Emergency Medicine

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KEYWORDS

## INTRODUCTION

Urolithiasis is a multi-factorial recurrent disease that presents a critical health concern globally.[1] It is the third most common urological disease affecting both males and females, with reported higher incidences in the Middle East, Scandinavian countries, the United States, Central Europe, Mediterranean countries, and the British Isles.[2,3] Epidemiologically, prevalence ranges from 1% to 20% worldwide (7-13% in North America, 5-9% in Europe, and 1-5% in Asia). In the UAE also, the incidence and prevalence of urolithiasis were documented to be rising due to its high temperature and semi-arid climate. The recurrence rate of urolithiasis is reported to be 6%–17% after 1 year, 21%–53% after 3–5 years, and the lifetime risk of recurrence is estimated to be 60%–80%.[4]

Urolithiasis is a complex process involving various intrinsic risk factors (such as age, sex, and heredity) and extrinsic risk factors (such as geography, climate, oxalate-rich foods, mineral composition, and water intake). Urinary tract stones are classified based on composition as calcium oxalate or phosphate (80%), magnesium ammonium phosphate (10–15%), struvite (10%), and uric acid (9%). Other uncommon types of stones are drug-induced (2%) and caused mostly by protease inhibitors used for the treatment of HIV (atazanavir and indinavir) and sulfadiazine.[5] Calculus formation is a cascade of biochemical disturbances in urine that stimulate crystal nucleation, growth, aggregation, and retention .[6] Several theories suggests that the stone's crystals supersaturate the urine due to their high concentration and begin to collect and crystallise within the kidney's parenchyma, forming calculi. These crystals will aggregate and grow in size, with the potential to migrate into the ureter and cause symptoms.[7,8]

Patients with urolithiasis may have excruciating pain, which varies according to the patient's position and the location of the stone. The most common site for the development of urolithiasis is at the distal nephron, close to the urinary papilla, causing sudden, colicky pain in the flank radiating to the hypochondrium.[9,10] Stones lodged at the ureterovesical junction cause urination urgency, suprapubic discomfort, and pain radiating into the groin and genitals As stones pass through the ureter, acute flank pain can develops due to prostaglandin release because of increased luminal tension and hydronephrosis. Associated symptoms include hematuria (90% microscopic on urine analysis), nausea, vomiting, and fever. Patients with acute sepsis as a result of an obstructing calculus require prompt drainage and appropriate antibiotic therapy.[11,12] Thus, appropriate management of urolithiasis has a substantial impact on the patient's quality of life. Imaging in urolithiasis plays a vital role in giving a better understanding of the disease and aiding in diagnosis and management. In this review article, we will discuss the current imaging modalities for management of patients with suspected urinary stones.

### Imaging Modalities

Patients with obstructing stones presenting to the emergency department undergo abdominal imaging for diagnosis and location of the stone.[13] Imaging modalities with high sensitivity provides clinician in differentiation from other diseases, assessment of complications, and appropriateness of potential therapies.[14] There are a variety of imaging modalities available, including computed tomography (CT), ultrasonography, kidney-ureter-bladder (KUB) radiography, and MRI. The sensitivity, specificity, dose of ionising radiation, and relative costs vary between modalities.[15,16] The American Urological Association (AUA) currently recommends computed tomography (CT) as the preferred initial imaging study for suspected urinary stone disease. However, consensus among representatives from the American College of Emergency Physicians, American College of Radiology, and AUA supports ultrasonography for the initial evaluation of suspected uncomplicated urinary stone disease (Table 1).[17,18,19,20] The choice of imaging modality depends on patient parameters such as patient preference, clinical status, and symptom load, as well as stone volume and location.

### Computerized Tomography

CT is preferred in emergency department due to its high sensitivity and specificity (>95% and >96%, respectively) for the detection of stones, easy availability, faster acquisition, and ability to detect extra-urinary pathologies.[21] Different approaches to CT scanning with no contrast or differing amounts of contrast and variable imaging timings have been developed. In emergency department, non-contrast CT (NCCT) is used in patients with urolithiasis for fast diagnosis. Urinary stones absorb considerably more radiation because of their different composition compared with renal structures and are readily identifiable without the need for contrast. Almost all stones can be visualized using CT with the exception of radiolucent stones formed by protease inhibitors such as Indinavir.[22] The attenuation value for calcium stones is significantly more(1700–2800 HU for calcium oxalate stones and 1200–1600 for calcium phosphate stones) than pure uric acid stones (200 and 450 HU). Other mixed types of stones mixed-types, have a wide range of attenuation values ranging from 600 HU to 2800 HU.[23,24] Evidence suggests that the dual-energy CT (DECT) method based on the internal urinary stone attenuation distribution can classify urinary stones into uric acid and non-uric acid stones with high accuracy, which will be very helpful to the treating surgeon in selecting the optimal modality of treatment. Ilyas M. et al. established 100% sensitivity and specificity of DECT using the 3rd generation CT scanners in the determination of urinary calculi composition. It was found to be 100% sensitive and specific for differentiating UA stones from non-UA stones.[25]

Tasian GE et al. (2014) determined the high prevalence (41% to 79%) of the use of CT as the initial imaging study for children with nephrolithiasis.[26] The potential effects of the radiation exposure from CT examinations is a crucial concern.[27] Patients with urolithiasis are often subject to multiple CT examinations during their lifetime, which can result in a substantial cumulative dose.[28] Recent efforts have focused on CT dose modification to prevent unwanted health hazards. Low-dose CT protocols use low tube currents, which lower organ-specific radiation by 59% compared with standard CT with no loss of image quality.[29] Niemann T et al. (2008) reported the sensitivity and specificity of low-dose CT for the diagnosis of urolithiasis to be 0.966 (95% CI, 0.950–0.978) and 0.949 (95% CI, 0.920–0.970), respectively.[30] Raskin D. et al. (2021) also confirmed that a modified non-contrast very low-dose computed tomography protocol delivering an effective radiation dose of about 1 mSv is applicable for confirmation of the presence and location of stones that are 4 mm or greater in size.[31] Mussmann B. et al. (2021) determined that dual energy computed tomography using fast kV switching may potentially be developed as a low-dose clinical tool as the composition of stones was correctly identified by it (83% absolute agreement; $k = 0.69$).[32]

### Ultrasound

Ultrasound (US) is an excellent, low-cost imaging modality used for the diagnosis and management of urolithiasis. It has the advantages of being noninvasive, portable, ubiquitous, and especially useful in pregnant women and paediatric patients when minimising radiation exposure is critical.[33] Edmonds ML et al (2010) determined the rate of urologic intervention within 90 days of their initial emergency department (ED) visit was significantly lower in those with normal results on US ($p < 0.001$) than in those with abnormal results on US.[34] However, studies have reported the moderate sensitivity and specificity of US for detecting urinary stones as 24%–81% and 83%–100%, respectively.[35] Ahmed F et al (2018 ) found that NCCT detected 276 (97.2%) stones, while US could identify 213 (75.5%)

stones with overall sensitivity and specificity of US were 75.4% and 16.7%, respectively.[36] Riaz M et al. (2022) determined that trans-abdominal ultrasound detected urolithiasis in 80.76% of the patients who had CT KUB, with sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy in urolithiasis calculated to be 68.3%, 66.7%, 89.6%, 33.33%, and 67.95%, respectively.[37]

Secondary signs of obstruction, such as hydronephrosis, ureteral dilation, and peri-renal fluid, are very well detected in the US. Ather MH et al (2004) established sensitivity and specificity of US for renal stones to be 81% and 100% and for hydronephrosis, 93% and 100%, respectively. Its sensitivity to pick ureteric stone (46%) and to identify hydroureter (50%) was found to be low.[38] Inaccuracy in determining stone size and poor detection in patients with a high BMI are other reported limitations of ultrasonography.[39] Alnour MM et al (20190 indicated that presence of urolithiasis in smallest valid of size (  5mm) is better detected by ultrasound while the presence of urolithiasis in (>5mm) is better detected by computed tomography.[40] However, Alahmadi AE et al. (2020) revealed a strong compatibility between US and CT with no significant difference in measuring the size of urinary stones (73.7% in stones <10 mm, 66.7% in stones 11–20 mm, and 50% in stones >21 mm) ($P < 0.001$).[41]

The color Doppler adds additional value over gray-scale US alone in the detection and overall accuracy of diagnosis for renal and ureteral stones. Bacha R et al (2019) established sensitivity and specificity of the gray-scale ultrasound criteria in the detection of urinary stones was 96.1% and 57.9%, respectively, while the sensitivity and specificity of the color Doppler twinkling artifact in the detection of urinary stones was 100.0% and 97.4%, respectively.[42] Zhang A et al (2021) indicated that colour Doppler ultrasound twinkling artefacts can predict the chemical components of urinary stones, which can be used as a criterion for clinical diagnosis.[43]

### Plain Radiography

Plain abdominal radiography of the kidneys, ureter, and bladder (KUB) is a reasonable investigation in patients with a history of radiopaque urinary stones. It is not sensitive for the detection of urinary tract stones because some urinary tract stones are radiolucent, and radiopaque stones that are obscured by bowel content projecting over the urinary tract go undetected.[44] The sensitivity and specificity of standard KUB radiography is estimated to be 57% and 76%, respectively.[45] Wang SC et al. (2004) reported that the prediction of stone component based on stone morphology on plain abdominal film has an overall accuracy of 27.4%.[46]The efficacy of plain radiography improves when combined with ultrsound. Kanno T et al(2017) found that ultrasonography and plain radiography detected at least 1 stone in 882 and 488 kidneys, yielding a sensitivity of 88.7% and 49.1% and a specificity of 68.3% and 99.1%, respectively.[47]

Recent advancements with computer-aided diagnosis (CAD) of a plain X-ray may be a promising method to detect radio-opaque urinary tract stones with satisfactory sensitivity. Kobayashi M et al (2021) reported the sensitivity and positive predictive value were 0.872 and 0.662, respectively for CAD model.[48]

Even though a multidetector CT scan remains the gold standard in the diagnosis of urolithiasis, a KUB radiograph has remained part of the protocol for most clinicians even after a non-contrast helical CT scan is carried out when medical expulsive therapy is attempted.[49] Khaled AA et al (2022) also indicated that the CT-scout film with an optimal HU cut-off value, when utilized together, can further aid clinicians in deciding the plan of management for patients with urolithiasis.[50]

### MRI

Abdominopelvic MRI is a nonradiation-based imaging modality that provides a comprehensive exam of all the soft tissues of the abdomen and pelvis. Magnetic resonance urography (MRU) is not commonly used in dignosis of urolithiasis and is often reserved for pregnant women and children when information about anatomic details of the pelvicaliceal systems, ureters, and excretory function of the kidney is needed with a preference for avoiding ionizing radiation.[51,52]

Ibrahim ES et al (2016) reported that MRI has the potential for imaging kidney stones, especially medium-to-large stones (mean ± SD =9 ±4 mm) with sufficient background contrast. [53]Moderate quality evidence from one study of 159 adults showed that the MRI has a sensitivity and specificity respectively of 72% and 100%.[54] EL-Sheikh HEet al (2022) indicated that MRI has a low sensitivity when it comes to stone identification (69.4 percent ) but MRI is more sensitive and specific in detecting and measuring these secondary effects.[55]

### Trends For Imaging For Diagnosis Of Urolithiasis In Emergency Department

Studies analysing the pattern of use of imaging modalities for diagnosis of urolithiasis in emergency departments are summarised in Table 2.[56-62] CT has become the dominant imaging modality used in the ED for the evaluation of patients with acute flank pain and clinical suspicion of urolithiasis. With the consideration of the risks of radiation exposure associated with the use of CT, the practise of using ultrasound is also relatively increasing. Chang HC et al, 2021 reported Ultrasound use for the evaluation of renal colic has increased from 2.7% to 6.9%, while computerized tomography rates have remained stable at 85.8%. For pediatric patients also, increased use of US is seen.[56] Barrick L et al (2020) also reported fewer CT procedures were performed at later visits compared with the first ($P < 0.05$), and US was used more during second or later visits than the first ($P < 0.05$).[62] More recent studies are required to determine whether practice patterns have changed.

## CONCLUSION

In the emergency department, CT is the preferred imaging modality used for the diagnosis of urolithiasis. However, concerns regarding radiation exposure have raised interest in using ultrasound in the emergency department for the initial imaging of suspected urinary stones.

**Table 1: Guidelines for imaging of urolithiasis**

| Year | Association/Society | Recommendation |
|---|---|---|
| 2023 | American College of Radiology | For Acute onset flank pain- CT abdomen and pelvis without IV contrast<br>Acute onset flank pain in Pregnant patient- US kidneys and bladder retroperitoneal<br>CT without contrast is inconclusive for the presence of stones- MRU without and with IV contrast |
| 2023 | European Association of Urology (EAU) | For acute flank pain- US<br>For assessment of urinary tract anatomy before stone removal- contrast imaging<br>imaging in children- US, KUB X-ray or low-dose NCCT |
| 2019 | American Urology Association (AUA) | For acute flank pain- Noncontrast computed tomography<br>In children before PCNL procedure- Noncontrast computed tomography |
| 2019 | National Institute for Health and Care Excellence (NICE ) | CT should be the gold standard method for diagnosing renal colic |

**Table 2: Trends For Imaging In Emergency Department**

| Study | Details | Outcomes |
|---|---|---|
| Chang HC et al, 2021 | Reviewed adult patients newly diagnosed with nephrolithiasis in U.S. emergency departments between 2007 and 2015 | The ultrasound-only rate increased from 2.7% to 6.9%, while the computerized tomography-only rate remained stable at 85.8%. |
| Barrick L et al, 2020 | Examined computed tomography (CT) and ultrasound (US) utilization trends in incident and prevalent pediatric emergency department (ED) urolithiasis patients | CT was performed in 35.7% of patients initially while Ultrasound was performed in 32.2% of patients. Fewer CT procedures were performed at later visits compared with the first ($P < 0.05$), and US was used more during second or later visits than the first ($P < 0.05$). |
| Moore CL et al,2019 | A three-step modified Delphi process was done to seek consensus on optimal imaging in 29 specific clinical scenarios. | CT was recommended in 7 scenarios (24%), with ultrasound in 9 (31%) and no further imaging needed in 12 (45%) |

| | | |
|---|---|---|
| Mills L et al,2018 | Reviewed the evidence for using ultrasound in emergency department to evaluate patients with suspected urolithiasis. | Ultrasound is moderately sensitive and specific in making the diagnosis of urolithiasis |
| Johnson EK et al, 2014 | Determined imaging practices for patients younger than 18 years presented to emergency departments with suspected urolithiasis | Of the patients 9,773 (87%) underwent computerized tomography alone |
| Fwu CW et al, 2013 | Analysed national trends in rates of emergency department visits and use of imaging using the National Hospital Ambulatory Medical Care Survey | The use of computed tomography in urolithiasis patients more than tripled, from 21 to 71%. |
| Hyams ES et al 2011 | Characterized the use of conventional radiography , ultrasound and computerized tomography in the emergency department evaluation of patients with acute flank pain | Between 2000 and 2008 there was a significant increase in computerized tomography use for the emergency evaluation of patients with flank pain |

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