Secondary signs during non-enhanced helical computed tomography in the diagnosis of ureteral stones

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ABSTRACT

Nonenhanced helical computed tomography (NHCT) is a well-accepted diagnostic method for examining patients with suspected ureterolithiasis. NHCT shows stones within the lumen of the ureter, and it can also be used to evaluate secondary signs associated with ureteral obstruction from stones. Secondary signs include the tissue rim sign, hydroureret, perirenal stranding, and renal density differences between affected and nonaffected kidneys. Identification of secondary signs can help diagnose ureteral stones and contributes to the evaluation of ureteral obstruction.

1. Introduction

Urinary lithiasis is a common condition that affects 4–20% of the world’s population.1–4 In recent years, the incidence of stone formation has gradually increased worldwide.5 Moreover, stones often recur, and each stone event is associated with significant metabolic and intervention-related morbidity. Most patients present with moderate to severe colic caused by the stone entering the ureter. Stones in the proximal (upper) ureter cause pain in the flank or anterior upper abdomen. When the stone reaches the distal third of the ureter, the patient experiences pain in the ipsilateral testicle or labia. A stone at the junction of the ureter and bladder often causes dysuria, urgency, and frequency, and may be mistaken for a lower urinary tract infection. Hematuria is the most frequent accompanying sign in cases of ureteral stones. Less frequently, patients may present with silent ureteral obstruction, unexplained persistent urinary infection, painless hematuria, and even the absence of hematuria. Various intra-abdominal pathologies may cause the same symptoms, including appendicitis, diverticulitis, duodenal ulcers, cholecystitis, pyelonephritis, renal infarct, gynecologic disorders, vascular aneurysms, pancreatitis, ureteral strictures, and intra-abdominal tumors.6,7 An accurate diagnosis with the proper tools is important for determining the appropriate treatment.

2. Diagnosis of ureteral stones

2.1. Conventional radiography

In patients with suspected ureteral colic, kidney-ureter-bladder (KUB) plain-film radiography and ultrasonography (US) may be the least expensive and most easily accessible modalities. Conventional KUB radiography is inadequate for diagnosis because radiolucent stones and even small radio-opaque stones in the kidney or ureter may not be visible. In addition, this method provides no information regarding possible obstruction.8

2.2. US

US plays an important role in the primary diagnosis of patients with suspected urolithiasis as well as during follow-up.8 US affords the advantages of low cost, easy and noninvasive use, no use of radiation, and high availability; however, it is not sensitive enough to detect stones and can only image the kidney and proximal ureter. In addition, US may not detect stones of smaller than 3 mm in diameter.10 The sensitivity and specificity of US for detecting ureteric calculi vary significantly at 19–93% and 95–97%, respectively.11–13

2.3. Intravenous urography

Intravenous urography (IVU) is widely used to evaluate patients with suspected ureteral stone disease. IVU can be used for both the morphologic and functional evaluations of ureteral stone disease.
This technique provides information regarding the existence, cause, location, and severity of an obstruction. However, the diagnostic accuracy of IVU is low. IVU may fail to detect radiolucent or small stones; poor opacification of the renal collecting system because of severe obstruction also results in the nondetection of stones. It is also difficult to detect nonurolithic pathologies using IVU. IVU exposes the patient to a risk of radiocontrast infusion and contrast-mediated acute renal injury and provides less information than does noncontrast computed tomography (CT).\(^6,14\)

### 2.4. NHCT

CT is a noninvasive technique that provides greater discrimination in terms of densities between different tissues than conventional radiography. Ready access to picture archives and communication systems (PACS) allows specialists to examine radiologic reports with imaging. NHCT can also be used to detect various additional renal and extrarenal pathologies.

Helical CT without contrast is the preferred imaging method in patients with suspected urolithiasis. It has several advantages over other imaging techniques, namely that it requires no radiocontrast material, it can visualize distal ureters, it can be used to detect radiolucent stones (i.e., uric acid stones), radio-opaque stones, and stones as small as 1–2 mm, and it can be used to detect hydronephrosis and intra-abdominal and renal disorders (other than stones) that may be causing the symptoms.

In patients presenting to an emergency department with flank pain, NHCT used for the diagnosis of ureteral stones showed a sensitivity of 98%, a specificity of 100%, a positive predictive value (PPV) of 100% and a negative predictive value (NPV) of 97%.\(^{15–17}\) NHCT can also be used to identify significant, additional, or alternative reasons for a patient's symptoms.\(^8\)

### 2.5. IVU versus NHCT

The direct cost of NHCT is higher than that of IVU in many countries, but it is nearly identical in other countries. Indirect costs are much lower for NHCT because it saves examination time, and, when immediately performed, initial abdominal (KUB) plain-film radiography and US are unnecessary.\(^{19,20}\) The sensitivity of IVU for detecting ureteral stones is 59.1%, the specificity is 100%, the false-positive rate is 0%, the false negative rate is 40.9%, the PPV is 100%, and the NPV is 37.2%. By contrast, the sensitivity of NHCT is 98.5%, the specificity is 100%, the false-positive rate is 0%, the false-negative rate is 1.5%, the PPV is 100%, and the NPV is 94.1%.\(^{21}\)

Two important advantages of NHCT over IVU are a short duration of the examination and the absence of contrast medium administration.\(^{19,22}\) NHCT can be used to detect a stone as well as to observe secondary signs of various renal and extrarenal pathologies associated with stones.\(^{18}\) If it is available, NHCT is a better alternative than IVU because it has a higher diagnostic accuracy and is more effective, faster, and less risky than IVU.\(^{18,23,24}\)

### 3. Secondary signs of NHCT

NHCT reveals urinary tract calculi and also secondary signs associated with ureteral stones.\(^{25–27}\) Secondary signs are indicators of ureteral duct obstruction. A stone might not be easily identified because of its small size, low attenuation, recent passage, or respiratory movement during the examination. In addition, the identification of stones may be difficult in patients with phleboliths along the course of the ureter. Detection of secondary signs associated with ureteral stones may assist in making a diagnosis and provide data regarding the degree of ureteral obstruction. Secondary signs include a tissue rim sign, hydroureter, perirenal stranding, and renal density differences between affected and nonaffected kidneys.

The tissue rim sign is an area of soft-tissue attenuation surrounding a suspected ureteral calculus that appears calcified. Hydroureter occurs when unilateral ureteral dilation is present at a specific level and is observed as a continuation of the proximally dilated ureter to the renal pelvis. Perinephric fat stranding is defined as increased density or stranding in the surrounding perirenal adipose tissue as a result of inflammation secondary to ureteral stones.\(^{26,27}\) Renal density differences are asymmetrical density decreases in Hounsfield (HF) units between the affected and nonaffected kidneys.\(^{29–33}\)

Secondary CT signs of ureteral obstruction are helpful in diagnosing ureteral stones. When no stone is detected in the presence of secondary signs, previously passed stones, pyelonephritis, and causes of obstruction other than stones should be considered.

#### 3.1. Tissue rim sign

The tissue rim sign is defined as the visualization of annular soft tissue immediately adjacent to the segment of the ureter surrounding a stone.\(^{26,34,35}\) The tissue rim sign occurs as a result of inflammation and edema in the ureteral wall surrounding the stone (Fig. 1). It is highly specific for distinguishing ureteral stones from phleboliths. A soft-tissue rim sign around a calcific focus is an important indicator of a ureteric stone, whereas a comet-tail sign around a calcific focus suggests a phlebolith, a radiologic mimic of a ureteric stone.\(^{34}\) Tissue rim signs are detected in 34–76% of patients with ureteral stones.\(^{36}\) It is also useful for diagnosing urolithiasis in patients with renal colic. Visualization of the soft-tissue rim sign is dependent on the stone size; Heneghan et al\(^{32}\) determined that the rim sign is generally present with smaller stones (mean size, 4.3 mm) rather than larger stones (mean size, 6.3 mm). This difference was statistically significant (\(p < 0.001\)) and 90% of stones that measured 4 mm or smaller exhibited a rim sign, whereas stones that measured 5 mm or larger did not. It was postulated that larger calculi generally cause thinning of the ureteral wall to a greater degree than smaller stones, making the ureteral wall more difficult to detect. No statistically significant difference in location of the stone or degree of obstruction was shown for the rim sign.\(^{27}\)

Most ureteral calculi are of sufficiently high attenuation to be readily apparent on non-enhanced CT. Occasionally, it may be difficult to differentiate a ureteral calculus from a phlebolith. This

![Fig. 1. Ureteral wall thickening (the tissue rim sign) secondary to a stone in the left middle ureter of a 48-year-old woman.](image-url)
problem typically occurs in patients who are elderly, those who have minimal retroperitoneal fat, and those who have non-obstructing calculi. If a soft-tissue rim sign is present, it can be used to differentiate ureteral calculi from pelvic phleboliths in patients suspected of having ureteral colic.\textsuperscript{37–41} The tissue rim sign is visible in 76% of ureteric calculi but in only 2% of phleboliths. Smith et al\textsuperscript{42} calculated an odds ratio of 31:1 when comparing the frequency of occurrence of a soft-tissue rim sign with calculus and that of the same sign with phleboliths. Results of another study by Kawashima et al\textsuperscript{43} showed that 50% of ureteral stones manifested a rim sign, 34% of stones were indeterminate for a rim sign, and 16% of stones did not manifest a rim sign. Therefore, a positive soft-tissue rim sign is helpful in diagnosing ureterolithiasis. However, a negative soft-tissue rim sign does not preclude such a diagnosis because it is absent in some patients with ureterolithiasis.

3.2. Proximal ureteral dilatation

Hydroureter occurs when unilateral ureteral dilatation is present at a specific level. When ureteral dilatation is present, it is typically readily identified, although continuity with the renal pelvis should be verified to avoid mistaking a thrombosed or enlarged gonadal vein for the ureter. Evaluating hydroureter is more reliable than observing renal pelvic dilatation because the latter may be simulated by a large normal pelvis or an extrarenal pelvis. Ureteral dilatation may be found in the presence of a stone, as well as for a short time after the stone has passed, or as a result of other conditions associated with flank pain such as a renal infection.

Hydroureter, which is the most common secondary sign of ureteral stones, was detected with CT in 64–90% of patients.\textsuperscript{44}

3.3. Perinephric stranding

Perinephric stranding is defined as increased density or stranding in surrounding perirenal adipose tissues (Fig. 2). It can result from inflammation or increased lymphatic pressure secondary to ureteral stones.\textsuperscript{28,29} It was observed in 36–82% of adult patients\textsuperscript{45} and at a lower rate in a pediatric population.\textsuperscript{46}

3.4. Decreased renal density

In stone disease, decreased renal density may be observed secondary to an obstruction. Renal density differences were evaluated as asymmetrical density decreases in HF units between the affected and nonaffected kidneys.\textsuperscript{29–31} Renal parenchymal density was measured in the upper, middle, and lower portions of each kidney, and a mean value was calculated. The difference between the mean values of the affected and nonaffected kidneys was used to predict the presence of an acutely obstructing ureteral stone. Studies suggested that a renal parenchymal density difference of 5 HU or more can be useful as a secondary sign to differentiate an acutely obstructed kidney from a nonobstructed one. In a minority of patients with a ureteral stone in whom the renal parenchymal density difference is fewer than 5 HU, combining other secondary signs may be helpful for a diagnosis. This difference was detected in 24–95% of patients.\textsuperscript{47} Furthermore, an attenuation difference has the advantage of being an objective, measurement-based indicator. Goldman\textsuperscript{33} reported that an attenuation difference between kidneys of 5.0 H or higher showed 61% sensitivity, 100% specificity, 100% PPV, 69% NPV, and 79% accuracy for diagnosing ureterolithiasis.

4. Value of secondary signs

The sensitivities of secondary signs in predicting the presence of an acute obstructing ureteral stone are 90% for hydroureter, 82% for perinephric stranding, 77% for the tissue rim sign, and 89% for a parenchymal density difference. Specificities of secondary signs are 93% for hydroureter, 93% for perinephric stranding, 92% for the tissue rim sign, and 100% for a parenchymal density difference.\textsuperscript{37,42,45} The odds ratio for the frequency of the tissue-rim sign with stones versus the tissue-rim sign with phleboliths is 31:1.\textsuperscript{42}

When using unenhanced CT for diagnosing acute flank pain, if a ureteral stone is not observed or an indeterminate but suspicious calcification is observed, then secondary signs of obstruction are important for a diagnosis. Comparing the perireteric area on the opposite side facilitates a diagnosis. A single secondary sign might not be present in every case of a ureteral stone, but a combined effect of multiple secondary signs may significantly increase the detection rate of a radiologic diagnosis of a ureteral stone on NHCT when evaluating patients with acute flank pain.

5. Conclusions

NHCT is the most effective available tool for diagnosing urinary stone disease. NHCT reveals stones within the lumen of the ureter and also permits evaluation of secondary signs associated with ureteral obstruction from stones. These secondary signs include the tissue rim sign, hydroureter, perireteral stranding, and renal density differences between the affected and nonaffected kidneys. Identification of secondary signs supports the diagnosis of ureteral stones and contributes to the evaluation of a ureteral obstruction.

Conflicts of interest statement

The author declares that he has no financial or non-financial conflicts of interest related to the subject matter or materials discussed in the manuscript.

References


Fig. 2. Left perinephritic edema and fat stranding secondary to a ureteral stone in a 55-year-old man. In addition, ipsilateral hydronephrosis can be observed.


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