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Noncontrast helical CT for ureteral stones

Abstract Noncontrast helical computed tomography (CT) has recently been found to be superior to excretory urography (IVU) in the evaluation of patients with suspected ureterolithiasis. Noncontrast helical CT does not require the use of intravenous contrast material with its associated cost and risk of adverse reactions and can be completed within 5 min, in most cases. Noncontrast CT often detects extraurinary pathology responsible for the patient's symptoms. CT is also more sensitive than IVU in detecting the calculus, regardless of its size, location, and chemical composition. However, confidently differentiating ureteral calculi from phleboliths along the course of the ureter may, at times, be difficult. The "tissue-rim" sign, a rim of soft tissue attenuation around the suspicious calcification, is helpful in making this distinction. Noncontrast CT does not provide physiological information about renal function and the degree of obstruction. A pilot study has suggested a proportional relationship between the extent of perinephric edema and the degree of obstruction. The cost of the examination and the radiation dose delivered to the patient may be higher with CT. Despite these limitations, noncontrast helical CT has quickly become the imaging study of choice in evaluating patients with acute flank pain.

Acute flank pain is a common clinical problem. However, the diagnosis of ureterolithiasis may not be apparent on the basis of history, physical examination, and laboratory values. Many patients with acute flank pain, therefore, undergo imaging studies to determine if ureteral obstruction is present. Urologists have traditionally used excretory urography (IVU) to diagnose ureteral calculi in these patients. The excretory urogram provides direct information about the presence, size, and location of any ureteral calculus and about renal function and the degree of ureteral obstruction. Recently, however, several reports in the radiological literature have indicated that noncontrast helical computed tomography (CT) is more effective in the detection of ureteral calculi and may also reveal unsuspected pathology in the abdomen or pelvis responsible for the patient's symptoms [1–5]. This article reviews the methodology of noncontrast helical CT and details its advantages and pitfalls over IVU in the evaluation of patients with suspected ureterolithiasis.

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Methods

No published data exist, regarding the optimal CT parameters to use when evaluating patients with acute flank pain. Helical data acquisition is preferred over conventional incremental acquisition in order to avoid missing small ureteral calculi due to respiratory misregistration. The examination is carried out without intravenous or enteric contrast material. Data are acquired from the top of the kidneys (usually at the level of T12) to the symphysis pubis during two or three breath holds. At our institution, a collimation of 5 mm and a pitch of 1.6 are used with success, although thicker collimation (up to 10 mm) and a pitch ranging from 1.0 to 2.0 may also be satisfactory. Calcifications along the course of the ureter may be further evaluated using retrospective reconstructions in 1-mm to 3-mm increments through a limited region containing the suspicious calcification.

CT signs of ureteral calculi

The primary sign of ureterolithiasis on noncontrast helical CT is the identification of a calcification within the lumen of the ureter or at the ureterovesical junction [2]. However, in some patients with ureteral stone disease, a calculus may not be identified on CT because of small stone size, volume averaging, or respiratory misregistration. The calculus may also be difficult to distinguish from phleboliths or arterial calcifications. Several secondary signs have been described to aid in the diagnosis of ureterolithiasis in difficult cases [1–5]. These signs include dilatation of the collecting system and ureter, perinephric edema, and nephromegaly on the symptomatic side. Perinephric edema consists of stranding of the perinephric fat, perinephric fluid collections, and/or thickening of the renal fascia [6]. Nephromegaly is defined as increased renal cortical thickness at the level of the renal hilum. The urinary tract contralateral to the suspicious calcification serves as an intrinsic control.

The sensitivity and specificity of each secondary sign are, respectively: dilatation of the collecting system, 83% and 94%; dilatation of the ureter, 90% and 93%; perinephric edema, 82% and 93%; and nephromegaly 71% and 89% [4]. The presence of both unilateral dilatation of the ureter and unilateral or asymmetric perinephric edema has a positive predictive value of 99% [4] for ureteral stone disease. The absence of both perinephric edema and dilatation of the ureter has a negative predictive value of 95% [4].

Advantages of noncontrast helical CT

Noncontrast helical CT has quickly become the examination of choice among radiologists for the evaluation of patients with acute flank pain and suspected ureterolithiasis. There are a number of advantages in using noncontrast helical CT instead of IVU. CT is more accurate than excretory urography and has a reported sensitivity of 97%, specificity of 96%, positive predictive value of 96%, negative predictive value of 97%, and accuracy of 97% [3]. CT is able to detect calculi regardless of their chemical composition, because all calculi have Hounsfield units greater than 200, including uric acid calculi. CT defines the size and location of any ureteral calculi accurately, even calculi at the ureterovesical junction that are sometimes difficult to appreciate with IVU. Noncontrast helical CT is carried out without intravenous or enteric contrast material, which reduces cost, examination time, and particularly eliminates the risk of allergic reactions and nephrotoxicity. Also, because no contrast material is used, the examination does not interfere with the performance of subsequent imaging studies. Another advantage of noncontrast helical CT is the short examination time. The information is acquired in about 5 min, in most cases, whereas excretory urograms may be carried out for hours in cases of high-grade obstruction before the exact point of obstruction is defined. In addition, noncontrast helical CT surveys the entire abdomen and pelvis, not only the urinary tract and may, therefore, reveal unsuspected pathology responsible for the patient's symptoms [1–5]. About one-fourth of patients with acute flank pain will have an alternate diagnosis, such as appendicitis, diverticulitis, cholecystitis, ruptured abdominal aortic aneurysm, ovarian torsion, pyelonephritis, renal infarction, etc.

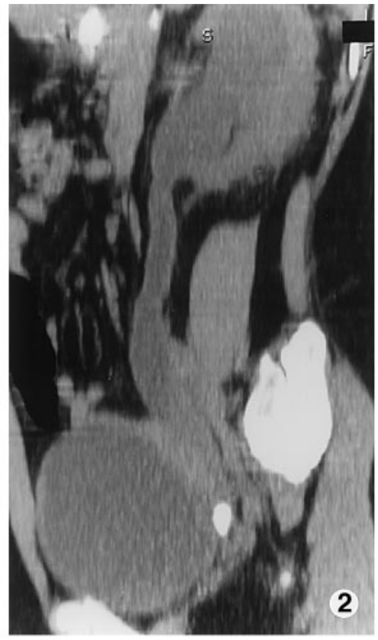
Pitfalls and solutions

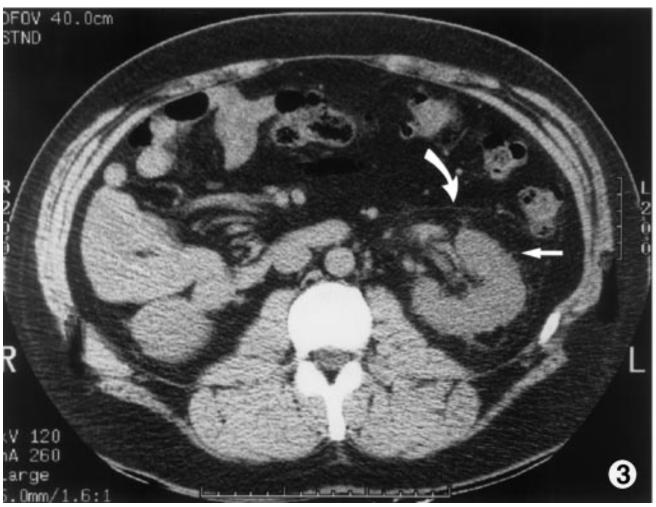
Calculus or phlebolith?

A major pitfall of noncontrast helical CT in the evaluation of patients with suspected ureterolithiasis is that it is often difficult to accurately identify the ureter amongst periureteral vessels and to differentiate with certainty ureteral calculi from phleboliths along the expected course of the ureter. This problem is compounded in the pelvis, where most phleboliths are located, and in thin patients with little retroperitoneal and intrapelvic fat. It is helpful to carefully follow the course of the ureter over serial sections and to determine how the ureter relates to the suspicious calcification. Thorough knowledge of the anatomy of the retroperitoneum and pelvis and of the structures lying in the expected course of the ureters is, therefore, essential for correct interpretation of these examinations.

The "tissue-rim" sign, a circumferential rim of soft tissue attenuation around a calcification (Fig. 1), has been found to be invaluable in the difficult distinction between calculus and phlebolith [2, 4, 7, 8]. When a fat plane exists around a suspicious calcification, finding a circumferential rim of soft tissue around the calcification accurately predicts that it represents a calculus (sensitivity 50–77%, specificity 92–100%) [4, 7, 8]. The odds ratio, comparing the frequency of the "tissue-rim" sign with calculi versus the frequency with phleboliths, has been reported to be between 31:1 and 41:1. When the suspicious calcification is in the region of the ureterovesical junction and is therefore surrounded by fluid-attenuation urine or when no fat plane exists around the calcification, the "tissue-rim" sign is indeterminate. In such cases, careful inspection for the secondary CT findings is necessary. The "tissue-rim" sign is best documented on fine collimation scans (1-mm to 3-mm) through the region containing the suspicious calcification. The rim of soft tissue is thought to represent the edematous wall of the ureter around the calculus. This sign is less common with larger calculi (> 5 mm), and may be explained by the stretching of the ureteral wall by larger calculi [7, 8].

Some authors have suggested the reconstruction of the axial images along a curved, oblique coronal plane paralleling the course of the ureters, a technique called curved planar reformatting (CPR) [5]. The CPR views are useful in determining whether a pelvic calcification represents an ureteral calculus or a phlebolith in a pelvic vein and are essential in making the correct diagnosis in some patients. By displaying the anatomy in a manner similar to the excretory urogram, CPR images also allow enhanced communication with emergency physicians and urologists (Fig. 2). The reconstructions are carried out at a dedicated workstation by a technologist or radiologist familiar with the software. Overall, the steps for creating and filming the reformatted images take about 30 min. Therefore, because the technique requires an investment in time and equipment, it is only recommended for selected cases.





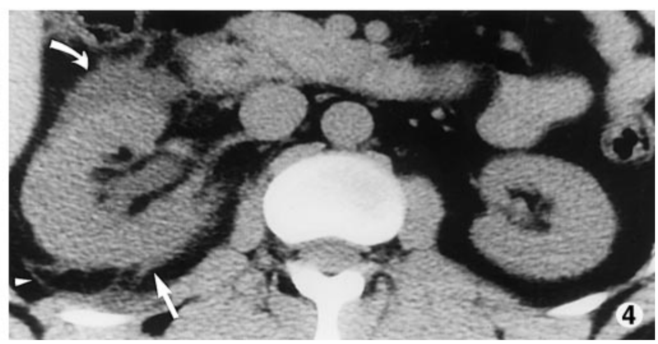


Fig. 1 Axial noncontrast helical computed-tomography image shows a rim of soft tissue (*arrowheads*) around a calculus in the mid right ureter (positive "tissue-rim" sign)

Fig. 2 Sagittal curved planar reformatted computed-tomography image of the right urinary tract. A calculus is present at the right ureterovesical junction. Note the prominent dilatation of the right ureter and collecting system and the perinephric edema

Fig. 3 Axial noncontrast helical computed-tomography image at the level of the left renal hilum shows limited perinephric edema. Note the mild thickening of the renal fascia (*curved arrow*) and the several thin strands in the perinephric space (*straight arrow*)

Fig. 4 Axial noncontrast helical computed-tomography image at the level of the right renal hilum shows extensive perinephric edema. Note the large perinephric fluid collection anterior to the kidney (*curved arrow*), the thick perinephric strands (*straight arrow*), and the moderate thickening of the renal fascia posteriorly (*arrowhead*)

We also noted that phleboliths, but not ureteral calculi, are often accompanied by a tail of soft tissue attenuation of varying length, the so-called "tail sign". The true usefulness of this finding requires further investigation.

When the calcification remains indeterminate after careful analysis, one must rely on the secondary signs of ureteral obstruction to make the correct diagnosis. However, secondary signs may still be present in patients who have recently passed a calculus or may be absent when a calculus is not causing any obstruction. In order to make a definitive diagnosis in these few cases, it may be necessary to repeat the CT after intravenous contrast is administered or to perform an excretory urogram.

Degree of ureteral obstruction

The most important parameters that determine management in patients with acute ureterolithiasis are the size and location of the calculus, because these findings predict the likelihood of spontaneous passage. Infection of the collecting system and ureter above an obstructing calculus is another important variable in the management of these patients. Urologists are also interested in the degree of obstruction associated with the ureteral calculus, as prolonged high-grade obstruction may eventually impair renal function and require surgical intervention.

This functional information is readily available with IVU; the time needed to opacify the ureter to the point of obstruction is proportional to the degree of obstruction. Noncontrast CT does not provide such direct functional information. A pilot study has suggested that a proportional relationship exists between the extent of perinephric edema on noncontrast helical CT and the degree of ureteral obstruction [6]. The extent of perinephric edema is assessed subjectively on CT by evaluating the severity of perinephric stranding, the presence and size of perinephric fluid collections, and the degree of thickening of the renal fascia. A calculus not associated with edematous changes in the perinephric space will not be likely to cause perceptible obstruction of the urinary system with IVU. When limited perinephric edema is found on the side of a ureteral calculus, a low-grade obstruction is likely to be found with IVU. However, extensive perinephric edema accurately predicts that the calculus is causing high-grade obstruction (Figs. 3, 4).

The anatomical changes that occur in the perinephric space in the presence of a ureteral calculus are thought to result from the physiological adaptations of the kidney subjected to acute obstruction. When acutely obstructed, the kidney responds to the increased pressure within the ureter with resorption of urine through several pathways (pyelolymphatic, pyelosinus, pyelotubular, and pyelovenous backflow mechanisms). The perinephric edema probably represents resorbed urine infiltrating the perinephric space along the bridging septae of Kunin. The presence of fluid in the perinephric space has also been observed in acutely obstructed kidneys imaged with magnetic resonance (MR) urography [9].

Cost and radiation dose

The cost of a CT scan is higher than that of an IVU. However, at most institutions in which noncontrast CT has replaced IVU as the initial imaging study performed for acute flank pain, noncontrast helical CT is billed as a "limited CT" and its cost has been adjusted to approximate that of the urogram. The radiation dose delivered to the patient is usually higher with CT than with IVU, depending on the number of films obtained during urography. The skin dose of an abdominal CT scan is about 3–5 rad. The skin dose of each abdominal radiograph is about 0.25–0.30 rad.

Image interpretation

The following algorithm may be used when interpreting noncontrast helical CT in patients with acute flank pain and suspected ureterolithiasis [4].

If a ureteral calculus is present on the symptomatic side, no further imaging study is necessary. The diagnosis is further substantiated when secondary signs of ureteral obstruction are present on the side of the calculus. The degree of obstruction may be estimated by assessing the extent of perinephric edema associated with the calculus.

If no ureteral calculus is demonstrated, but both dilatation of the ureter and perinephric edema are present, the patient either has a calculus too small to be resolved by CT or has recently passed a calculus. In the context of fever and leukocytosis, infection must be a consideration.

If a suspicious calcification is present on the symptomatic side, but it is unclear whether it represents a ureteral calculus or a phlebolith, the CT is evaluated for the presence of a "tissue-rim" sign. If a rim of soft tissue is present around the calcification, it most likely represents a calculus. Otherwise, the calcification is indeterminate. In such cases, curved planar reformatted (CPR) views may help define the relationship of the calcification to the ureter.

When perinephric edema is the only abnormality and CT does not reveal a ureteral calculus or dilatation of the ureter, alternate diagnosis must be considered, such as pyelonephritis, renal vein thrombosis, and renal infarction. In these cases, contrast-enhanced CT or IVU may reveal the true nature of the problem [4, 10].

Conclusion

Noncontrast helical CT is very effective in the evaluation of patients with acute flank pain and suspected ureterolithiasis. Because of its many advantages over IVU, it has become the imaging study of choice in this setting. The potential pitfalls of noncontrast helical CT can be overcome by understanding the CT signs of ureteral stone disease and applying the interpretation algorithm outlined in this review.

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