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**Abstract**

X-ray-based imaging modalities of plain films and computerized tomography (CT) are the common modalities used to detect urinary tract calculi. Plain films on their own have a low sensitivity and specificity for the detection of renal stones. Intravenous urograms (IVUs), which are obtained by intravenously injecting iodine-containing organic compounds prior to taking X-ray images, were the mainstay of radiological detection. Several problems were associated with the use of these iodinated compounds. The advent of helical CT has obviated their need in the majority of patients. CT scanning detects renal calculi with a high degree of accuracy. Exposure to ionizing radiation is a concern that needs to be addressed and dose-reduction measures should be employed whenever feasible.

**Keywords**

X-rays • Computerized tomography (CT) • Non-contrast computed tomography (NCCT) • Renal calculi • Diagnosis

**Introduction**

Imaging plays an integral part in the diagnosis and management of urinary tract calculi. This chapter will attempt to introduce the role of imaging using X-ray-based modalities.

**Imaging Modalities for Renal Tract Stones****Plain Abdominal Films**

Plain films are a good and low-cost way to image renal tract stones. This is because a large percentage of renal tract stones contain calcium and are therefore visible on plain films. Historically up to 90 % of the urinary stones are considered radio-opaque [1]. The actual detection rates, however, vary

greatly. The sensitivity of plain films for the detection of urinary stones ranges between 45 and 59 %, with specificity ranging between 71 and 77 % [1–4]. This low sensitivity is attributed to obscuration of the areas of interest by overlying bowel shadows and bony structures such as transverse processes of lumbar vertebrae. The low specificity, on the other hand, is attributed to non-urolithic opacities such as calcified gall stones, fecaliths, phleboliths, and calcified lymph nodes [1]. Surprisingly, there is little evidence that preparing the bowel prior to plain film adds significantly to the detection rates; therefore, bowel preparation is not recommended as a routine prerequisite for plain abdominal films (Fig. 33.1) [5].

Plain films, commonly labeled kidneys-ureters-bladder (KUB) X-rays, play a central role in the management of known radio-opaque stones. It is widely used for treatment planning and follow-up. The radio-opacity of a stone cannot always be ascertained from the scout film on non-contrast computed tomography (NCCT). While the Hounsfield units will give an indication as to whether the stone will be visible during percutaneous nephrolithotomy or ureteroscopy on the

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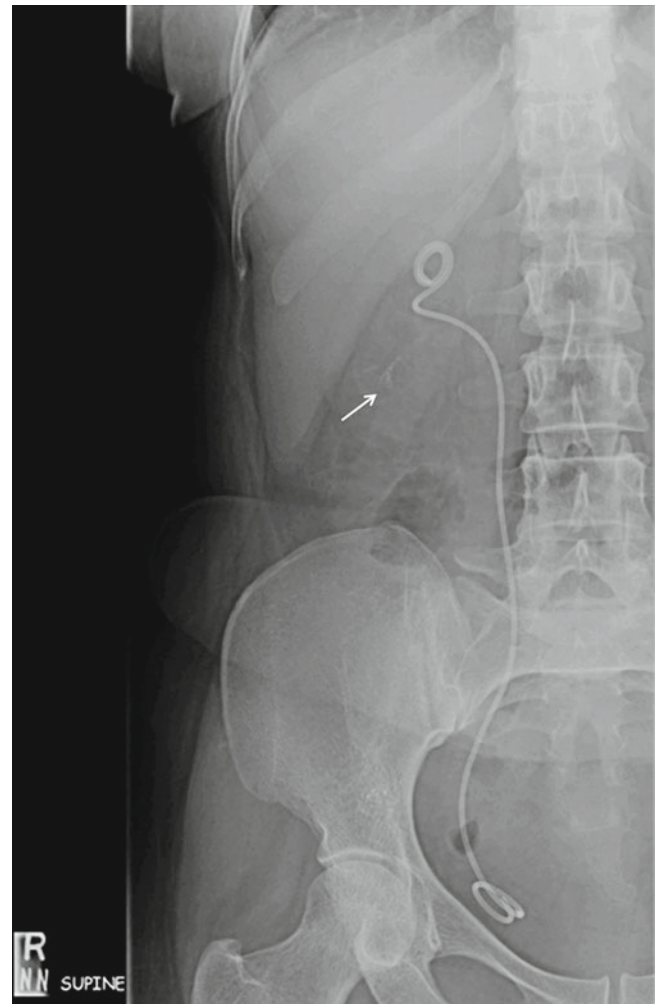


**Fig. 33.1** Plain supine abdominal film in a patient with renal colic. The multiple stones in the right renal area (*white arrow*) are difficult to visualize owing to significant amount of overlying bowel gas. Neither renal outline could be seen. Situations such as this are common and difficult to overcome. Additional imaging (usually with CT) is required to confirm the presence of stones

image intensifier, the surgeon is likely to ask for a KUB film for this assessment. The KUB X-ray is also used to assess the status of patients managed conservatively [6].

### Reducing Radiation Exposure When Multiple Follow-Up X-Rays Are Required Following SWL of Renal Stones

Patients usually require several X-ray examinations as part of their treatment, say with shockwave lithotripsy (SWL) or medical expulsion therapy. As the diagnosis has been established by earlier X-rays, and the stone burden already known, there is a rationale for carrying out a more focused study in an attempt to minimize radiation exposures. The most commonly applied strategy is the use of the so-called hemi-KUB. In this



**Fig. 33.2** Hemi-KUB. Post-lithotripsy follow-up. A right-sided double J stent is in place. Tiny residual calculi at the right lower pole (*arrow*). The required information regarding the position of the stent and the residual stone burden is obtained at a significant reduction in radiation dose

procedure, only one side of the abdomen is imaged. The coverage needs to extend across the midline a little over to the other side as the vesicoureteric junction is very close to the midline (the trigone being only 1.5" × 1.5" × 1.5" in a distended bladder and 1" × 1" × 1" otherwise). The reduction in radiation is less than 50 %, because of other considerations, but certainly the patient receives a reduced dose (Fig. 33.2) [7].

### Intravenous Urogram (IVU)

An intravenous urogram (IVU) is a series of X-ray images obtained after an intravenous injection of a water-soluble contrast agent that is preferentially excreted via the kidneys.

**Table 33.1** Risk factors for the development of contrast-mediated nephropathy (CMN)<sup>a</sup>

Prior renal impairment	Raised serum creatinine especially due to diabetic nephropathy
Dehydration	Especially in children and the elderly
Congestive cardiac failure	
Age	>70 years
Concurrent administration of nephron-toxic drugs	NSAIDs, etc.
Diabetes mellitus	Especially if taking biguanides (Metformin)

<sup>a</sup>Modified from European Society of Urogenital Radiology guidelines for avoiding CMN

The contrast agents most commonly used are organic iodides such as diatrizoate. These agents are broadly divided into high-osmolar agents with typical osmolality more than 1.5 osm/kg (e.g., diatrizoate), low-osmolar agents with typical osmolality of around 0.67 osm/kg (e.g., iohexol), and iso-osmolar agents with osmolality of 0.36 osm/kg (e.g., iotrolan). The cost and safety profile are inversely related, with the high-osmolar agents being the cheapest and the iso-osmolar agents being the safest. The general global trend has been to move toward the low- and iso-osmolar agents [8].

All of the aforementioned agents contain iodine in variable amounts. All agents are nephrotoxic to variable degrees, and all agents are associated with allergic reactions. The incidence of both nephrotoxicity and allergic reactions is highest with high-osmolar agents and lowest with iso-osmolar agents. The iso-osmolar agents are, however, very viscous and need special handling with contrast warmers, etc. to allow manageable injection profiles.

Nephrotoxicity of these agents is a major consideration, especially in patients whose renal function may be impaired by the underlying stone disease. Measures to reduce the risk of nephrotoxicity include identification of the patients at risk (Table 33.1), avoiding the use of high-osmolar agents, using the lowest dose (which would give the desired result) and adequate hydration prior to the administration of the contrast agent. The risk of renal damage is increased in those with pre-existing renal failure and those using nephrotoxic drugs concurrently. The use of so-called renal protective agents such as *N*-acetylcysteine is not established [9]. When a rise in serum creatinine occurs, it is transient and nephrotoxicity seldom results in end-stage renal failure in patients who had a previously normal serum creatinine.

A serum creatinine is not considered mandatory before an intravenous pyelography (IVP), though most often the urologist would have had this investigation done. It is therefore worthwhile looking at available serum creatinine reports and modifying protocol accordingly.

Patients with known atopy or reactive airways disease are at an increased risk of allergic reactions and may require

pretreatment with steroids. The risk of a fatal anaphylactoid reaction after the injection of a standard dose of low-osmolar contrast agent is estimated at 0.9/100,000 contrast administrations [10]. While iso-osmolar contrast solutions (often termed nonionic contrast) have a lower risk of mild to moderate reactions, the risk of fatal reactions is the same for both ionic and nonionic contrast [11]. The reaction may be immediate or delayed, sometimes after the patient has reached home.

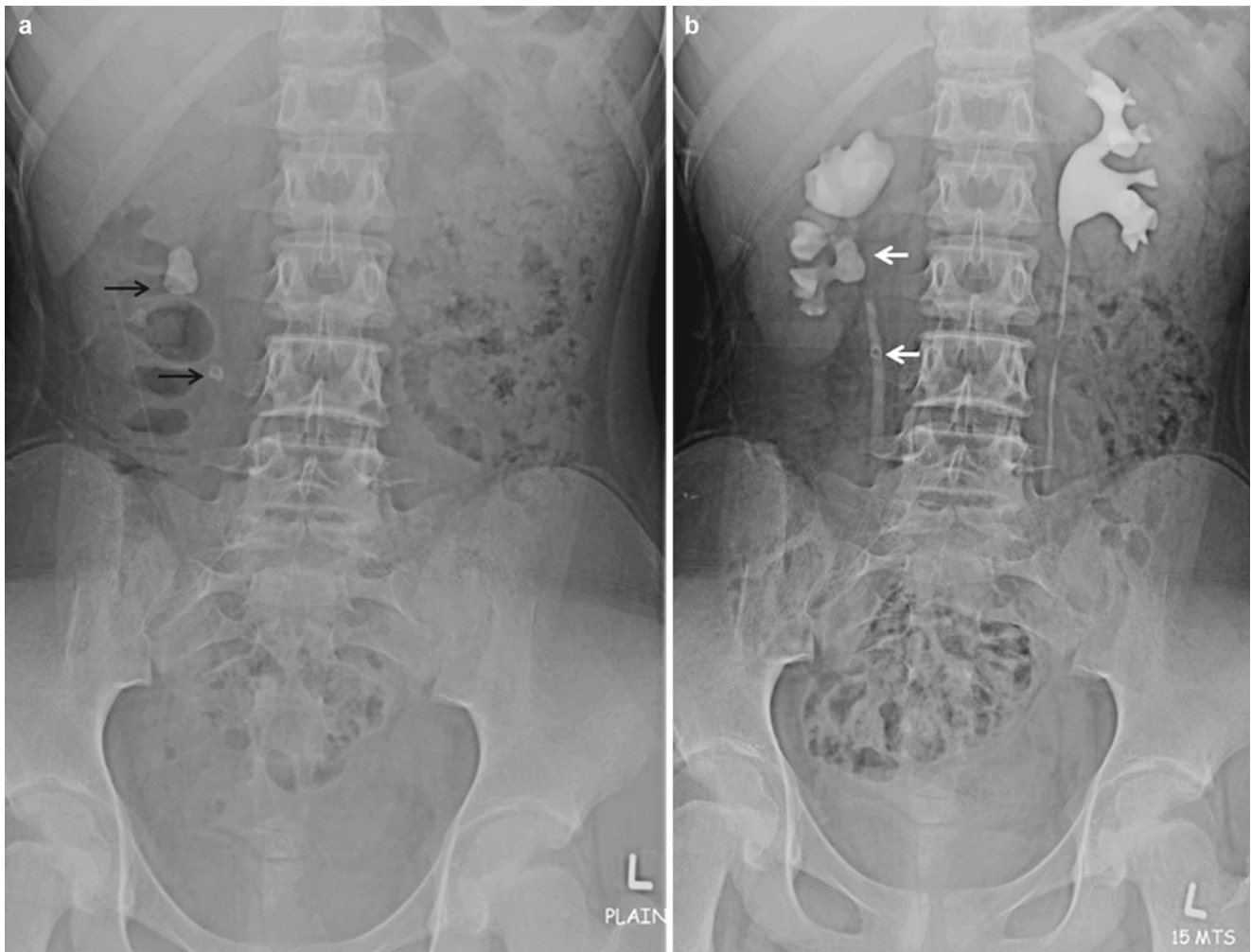
The contrast agent starts to be excreted by the kidney immediately after intravenous injection. Usually a standard dose of 50 ml of a low-osmolar contrast agent with an iodine content of 300–370 mg/ml is used in adults. In patients with normal renal function and no obstruction, the peak opacification of the upper tracts is obtained between 7 and 12 min after injection. The standard IVU series comprises of a control film, a cross kidney film immediately after the injection of the contrast agent (nephrographic phase), followed by cross kidney films at 5 and 10 min (pyelographic phase). A full-length film is taken when the ureters are being opacified, usually between 10 and 15 min. Further films and views may be needed as required to sort out particular questions in individual patients. The additional views include, but are not limited to, prone images, oblique images, and delayed films if one or both kidneys demonstrate delayed contrast excretion. The information derived from the IVP will be dependent on the availability of a radiologist to review each film as it is developed.

Ureteric stones are particularly well demonstrated on IVU examinations. These are shown as asymmetric or delayed excretion of contrast or filling defects. Occasionally, a continuous column of contrast within the ureters (which when unobstructed show peristalsis and are therefore never visible in their entirety) draws attention to the obstruction by a ureteric stone. When the direct visualization and the secondary signs are combined, the sensitivity of the IVU is reported to be 90 % (Fig. 33.3) [12].

Until fairly recently, the IVU was the mainstay for the assessment of urinary calculi, especially those lying in the ureter. The development of non-contrast CT pyelography has dethroned IVU, which is now seldom used in this context. Significant drawbacks in the routine application of the IVU include the contrast-related issues and the relatively long examination times, particularly in the presence of renal tract obstruction when delayed films may be required for several hours [13]. The IVU is a radiologist-intensive investigation.

## Computed Tomography

In computed tomography (CT), a mechanical gantry containing an X-ray tube and a bank of detectors rotates around the patient. Data are collected as the gantry rotates. Using mathematical calculations and computer modeling, the data is



**Fig. 33.3** Two films from an IVU series. (a) Control film obtained prior to the injection of contrast. This demonstrates two calcified opacities. The large opacity lies over the right renal area (*upper black arrow*). The smaller opacity (*lower black arrow*) lies in line of the right ureter. The left renal area is overlapped by bowel gas shadows. (b) Film taken 15 min after intravenous injection of an iodinated contrast medium.

The large opacity simulates contrast in the pelvis and without the presence of the control film may be misinterpreted (*upper white arrow*). The right ureteric calculus is clearly seen (*lower white arrow*). The left-sided collecting system is normal. The case highlights some of the shortcomings of the IVU. Renal pelvic and calyceal calculi may be completely undetectable on post-contrast images

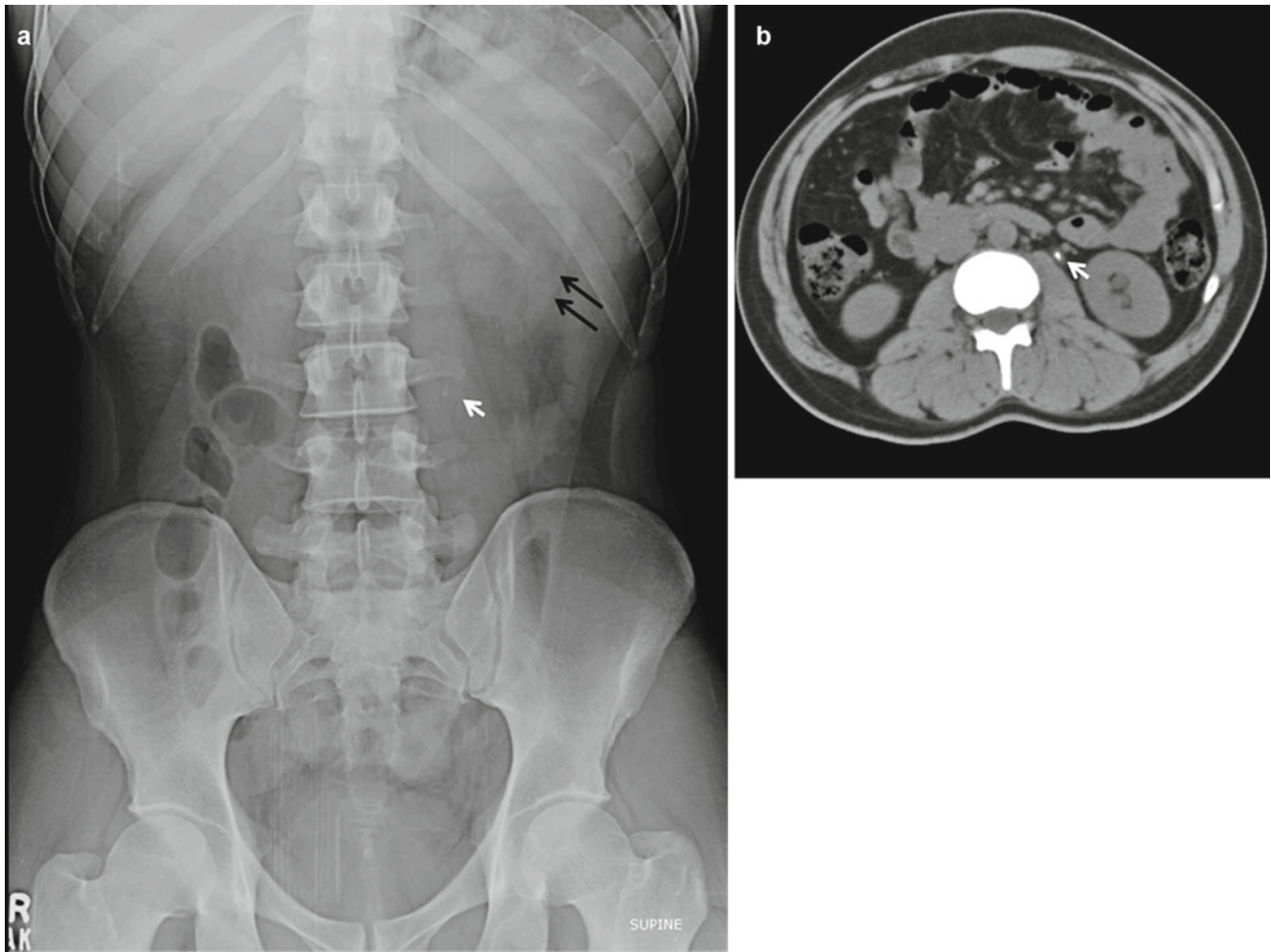
reconstructed to give an image. The CT scan is exquisitely sensitive to changes in density in the body. The stones that are lucent on plain films are clearly visualized on CT scans. In the early models of the scanners, the gantry rotated while the patient remained stationary. Only one axial image could be obtained at a time. After each acquisition, the patient was moved to the next image position, and the processes were repeated. This method of obtaining the CT is called incremental CT. As the images are acquired in suspended respiration to eliminate movement artifact, this meant that to cover the entire urinary tract it took many images, and therefore, many separate breath holds. This led to two artifacts: slice misregistration and partial volume averaging. Both led to

small stones being missed. The early CT scanners were therefore not suitable for stone detection [14].

The introduction of the helical CT into clinical practice in 1989 revolutionized CT scanning. During a helical scan, continuous image acquisition takes place as the patient is moved through the scanner. This allows a large area to be covered in a short time. As it was now possible to acquire volume data from the diaphragm to the pelvis in a single breath hold, both slice misregistration and partial volume effects were eliminated.

Smith et al. [15] published their paper comparing unenhanced CT with IVU in the context of acute flank pain in 1995. This has set the tone for the imaging of renal tract





**Fig. 33.4** (a) Plain abdominal film. Despite the absence of the overlying bowel the small left ureteric calculus (*white arrow*) is difficult to see. Had it overlapped the transverse process of a lumbar vertebra it would have been virtually invisible. The renal outlines (*black arrows*) are

clearly defined. (b) On the accompanying axial CT scan image, carried out 45 min after the plain film, the ureteric calculus (*white arrow*) is clearly identified. Note the absence of any secondary signs around the kidney

stones. With a sensitivity of 95–100 % and specificity of 94–96 %, this has become a vital part of stone imaging [1]. In addition to the high sensitivity and specificity, there are several practical advantages to using unenhanced CT. The need for contrast and its associated problems is eliminated, the scan time is short, there is no need for delayed imaging; and CT demonstrates lesions other than renal tract stones that may be the cause of the symptoms and radiolucent stones. Although not widely applied in clinical settings, CT has the ability to distinguish between the different types of stones based on their density, internal structure, and energy absorption [6, 14].

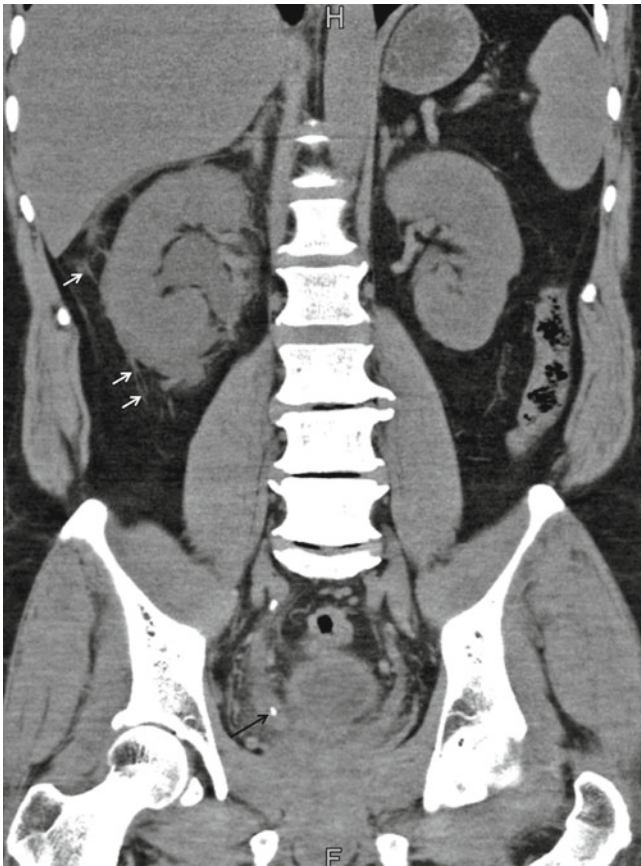
The procedure is simple. No preparation is required. A full bladder is helpful but not mandatory. Images are acquired in a single breath hold from the top of the diaphragm to the lower

margin of the ischial tuberosity. Images are reviewed ideally on an electronic terminal where the display densities can be manipulated. Both direct visualization of stones and indirect signs of ureteral obstruction are sought (Figs. 33.4 and 33.5).

The radiation received during a CT can be reduced by various means, including the low-dose CT, a topic that is discussed in some detail by Pierre in Chap. 35.

#### Conclusion

CT KUB has revolutionized the imaging of renal stones. Modern CT scanners offer a high degree of sensitivity and specificity with an excellent safety profile. As the patients with renal stones require repeated studies, cumulative radiation burden should be kept in mind when deciding upon the appropriate imaging method.



**Fig. 33.5** Coronal CT image from a patient with right-sided renal colic. Not only is the calculus in the right distal ureter clearly visualized (*black arrow*), the secondary signs of perinephric fat stranding (*white arrows*) are also present. In the absence of direct visualization of the calculus (the calculus either having been passed or too small to resolve), these secondary sign are extremely useful and may be used to confirm the diagnosis of renal colic as the cause of a patient's symptoms

## References

1. Portis AJ, Sunddaram CP. Diagnosis and initial management of kidney stones. *Am Fam Physician*. 2001;63(7):1329–38.
2. Levine JA, Neitch J, Verga M, Darymple N, Smith RC. Ureteral calculi in patients with flank pain: correlation of plain radiography with unenhanced helical CT. *Radiology*. 1997;204:27–31.
3. Mutgi A, Williams JW, Nettle M. Renal colic: utility of the plain abdominal roentgenogram. *Arch Intern Med*. 1991;151:1589–92.
4. Haddad MC, Sharif HS, Shahed MS, et al. Renal colic: diagnosis and outcome. *Radiology*. 1992;184:83–8.
5. Bailey SR, Tyrrell PNM, Hale M. A trial to assess the effectiveness of bowel preparation prior to intravenous urography. *Clin Radiol*. 1991;44(5):335–7.
6. Sandhu C, Anson KM, Patel U. Urinary tract stones – part I: role of radiological imaging in diagnosis and treatment planning. *Clin Radiol*. 2003;58:415–21.
7. Talati J, Khan S, Biyaban R, Khan RA, Naz I, Abbas F, et al. Reduction of radiation exposure to patients in the follow-up of shockwave lithotripsy. *BJU Int*. 2000;85:404–7.
8. Katzberg RW. Urography into the 21st century: New contrast media, renal handling imaging characteristics and nephrotoxicity. *Radiology*. 1997;204:297–312.
9. Morcos SK. Prevention of contrast media nephrotoxicity – the story so far. *Clin Radiol*. 2004;59(5):381–9.
10. Caro JJ, Trindade E, McGregor M. The risks of death and of severe nonfatal reactions with high- vs low-osmolality contrast media: a metaanalysis. *AJR Am J Roentgenol*. 1991;156:825–32.
11. Namasivayam S, Kalra MK, Torres WE, Small WC. Adverse reactions to intravenous iodinated contrast media: a primer for radiologists. *Emerg Radiol*. 2006;12:210–5. doi:10.1007/s10140-006-0488-6.
12. Dalla Palma L, Pozzi-Mucelli R, Stacul F. Present day imaging of patients with renal colic. *Eur Radiol*. 2001;11:4–17.
13. Ahmed F, Abdul Zafar M, Khan N, Haider Z, Ather MH. A paradigm shift in imaging for renal colic – is it time to say good bye to an old trusted friend? *Int J Surg*. 2010;8(3):252–6.
14. Heidenreich A, Desgrandschamps F, Terrier F. Modern approach of diagnosis and management of acute flank pain: review of all imaging modalities. *Eur Urol*. 2002;41(4):351–62.
15. Smith R, Rosenfield AT, Choe KA, Essenmacher KR, Verga M, Glickman MG, et al. Acute flank pain: comparison of non-contrast-enhanced CT and intravenous urography. *Radiology*. 1995;194:789–94.