

EFFICIENCY OF IMAGING METHODS PRIOR TO PERCUTANEOUS NEPHROLITHOTOMY

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ABSTRACT

The most important step of percutaneous nephrolithotomy (PCNL) is planning the puncture site. A well selected puncture will facilitate nephroscopic navigation and stone clearance. The traditional methods for planning the puncture are intravenous urogram or retrograde pyelogram. Either of these imaging tools is adequate, but new tools such as 3D reconstructed tomography should be more accurate. Many recently developed imaging tools are promising, but no one is still ideal. The imaging techniques that we currently use have specific advantages and disadvantages. The purpose of this review is to summarise different imaging tools and their effectiveness prior to PCNL.

Keywords: Imaging, percutaneous nephrolithotomy, renal stone.

INTRODUCTION

The purpose of the present study is to evaluate the effectiveness of imaging methods prior to percutaneous nephrolithotomy (PCNL). Radiological imaging techniques constitute the most important step in both diagnosis and treatment planning of urinary stone disease. Before interventions, contrast enhanced re-imaging such as intravenous urography or computerised tomography is recommended to evaluate anatomy of the renal collecting system. Despite this recommendation, most urologists do not perform any contrast enhanced imaging before PCNL. The most important reason for this is radiation exposure, and the risk of allergic reactions and contrast nephropathy due to the contrast agents. Our aim is to find the optimal imaging tool prior to PCNL.

PLAIN ABDOMINAL RADIOGRAPHY (KIDNEY, URETER, AND BLADDER [KUB])

Although most of the stones, especially calcium containing stones, are opaque and can be visible

on plain abdominal radiography, uric acid, or urate containing stones are not visible. In clinical practice KUB is the most often used radiographic imaging modality for urologists. Its limiting factors are bowels, gas, and non-opaque or poor opaque renal stones, and some other extra-renal calcifications, such as mesenteric calcifications.¹ In studies that compare the computed tomography (CT) and KUB, the KUB has a lower sensitivity in the diagnosis of stones, ranging between 45-56%, and with specificity between 67-69%.²⁻⁶ Yet a combination of KUB and ultrasonography increases its sensitivity.⁷ Its main advantages are availability, stone size measurement, and postoperative follow-up for residual stones. The disadvantages are radiation exposure, no information about kidney anatomy and surrounding organs, radiolucent stones, and limitations of the bowel gas.⁸

Intravenous Urography (IVU)

IVU remains the first line radiologic method to diagnose urinary system stones for many urologists. Performing the IVU is relatively safe and easy for many departments.¹ The risk for anaphylactic reactions with low osmolality contrasts is

approximately 9/1,000,000.⁹ The site and size of the stones, detailed pelvicalyceal anatomy, renal function, calyceal diverticula, duplex systems, and renal obstruction can be easily defined with IVU.^{10,11} It also shows the relationship of the pelvicalyceal structure and the ribs. The risk and planning of supracostal access could be evaluated with the help of IVU. One of the most important steps to locate the posterior calyx with IVU might be difficult. Some authors^{12,13} suggest that the posterior calyces locate medially. Eisner et al.¹⁴ suggests the opposite, that the second lateral to the medial one is the posterior calyx. The main disadvantage of the IVU is 2D imaging modality, non-opaque stones, and no information of the surrounding organs of the kidney. The major advantage is a detailed pelvicalyceal anatomy and an idea of the function of the kidneys.

Ultrasonography (USG)

Ultrasound is one of the easiest and safest diagnostic tools for urolithiasis but it has some limitations. Over 5 mm diameter renal stones can be easily identified with USG but smaller stones have less acoustic shadow, and thus are very difficult to diagnose.¹⁵ The size and site of the stone can be measured by USG but many urologists want to confirm location with IVU prior to USG. The identification of the collecting system, especially non hydronephrotic systems, is difficult for USG. Other diagnostic problems include poor image quality in obese patients and an inability to differentiate nephrolithiasis and nephrocalcinosis. Planning access prior to PCNL grey scale USG is not reliable enough and, compared with CT pelvicalyceal anatomy and surrounding solid organs identification, is still poor. Fowler et al.¹⁶ found that USG could identify 39% of multiple renal stones so this is a great disadvantage for PCNL access planning. Ekici et al.¹⁷ evaluated the accuracy of KUB and USG combination versus non contrast helical computed tomography (NCCT) and found the combination of KUB and USG highly sensitive (97.9%).

USG has been used by many urologists during the puncturing of the collecting system.¹⁸ USG guidance puncture without fluoroscopy has also been reported.¹⁹ This radiation free puncture technique is a good choice for paediatric populations and the intraoperative identification of kidney-related organs may avoid organ injuries. The 4D USG provides real time 3D images which provide a 360° viewing of the area.²⁰ The accuracy of the

4D USG has been evaluated during renal puncture on experimental studies; it provides good quality punctures, such as 2D USG, but improvements in the technology should be expected.²¹⁻²³ The main advantages of USG are that it is portable, radiation free, cheap, and that radiolucent stones are also visible. The disadvantages are that there is a limited accuracy for renal stones and poor anatomic detail. The European Association of Urology (EAU) guideline suggests USG as the first line imaging modality for paediatric patients with urolithiasis.¹⁰

CT

NCCT is the gold standard imaging tool for identification of urinary system stones because of its high sensitivity and specificity of up to 100% and 97%, respectively.¹¹ Except for indinavir and matrix stones, over 99% of the stones can be seen on NCCT.²⁴ NCCT provides information about size, location of the stones, and surrounding organs such as the pleura, colon, and liver.^{25,26} The incidence of retrorenal colon was reported at 1.7% and many studies have reported colon perforation during PCNL.^{27,28} Planning a safe puncture, especially for multicalyceal stones and renal anomaly, is possible with NCCT.²⁹ However, despite its advantages, the NCCT does not give enough information like that concerning the draining of infundibulum and the function of the kidneys. Similarly, planning the route for the puncture is not as easy as with IVU. Multiplanar reconstructions using 3D volume rendering may overcome these limitations and decrease the need for IVU for planning punctures.^{30,31}

The new generation Dual Energy CT (DECT) devices improve imaging of urinary calculi with half dose radiation. DECT provides the same anatomical information and gives far more detail about stone information without extracting the stone.³² DECT reports the stone information as uric acid or non-uric acid with 100% sensitivity and specificity.^{33,34} Jepperson et al.³² showed the ability of DECT to differentiate between small fragments adjacent to ureteral stents or nephrostomy tubes. Toebker et al.³⁵ evaluated the split bolus CT protocol. They injected Iomeron® at 15 ml 10 minutes before, and 80 ml 65 seconds before the scan. The protocol allows the combining of three phases (true and virtual non-contrast phases, and a contrast enhanced phase) and reconstructs transverse and coronal images. This technique provides the determination of stones 5 mm or larger with CT urogram images.

Patel U et al.³⁶ recorded the CT pyelographic movie and watched it in the operating room to plan the renal access and endourologic navigation before the PCNL procedure. There is an instrument that combines flat-panel fluoroscopy with CT capability and makes 3D reconstructions called DynaCT (Siemens, Germany). DynaCT provides real-time intraoperative and postoperative data, enabling preoperative planning and results with high accuracy imaging.³⁷ CT is recommended prior to PCNL in patients with anatomical or renal anomalies, radiolucent stones, renal insufficiency, and contrast allergy.³⁸ In addition, stone density can be calculated and the composition of stones can be obtained.

The major problem with repeated NCCT is high cumulative radiation exposure. The international Commission on Radiation Protocol recommends not exceeding 20 mSv per year during a 5-year period, or 50 mSv in only 1 year.⁷ Using risk models, it has been estimated that 1/1,400 patients at 60 years old and 1/1,000 patients at 40 years old, undergoing NCCT, would develop solid organ cancer and leukaemia due to radiation.³⁹ Paediatric patients are more sensitive to radiation because of actively dividing cells. Tepeler et al.³⁸ evaluated the CT examination and IVU prior to PCNL in paediatric patients and found no difference in successes and complications between the two modalities.

The mean radiation dose of the abdomen CT, enhanced CT, and IVU are about 5 mSv, 25-35 mSv, and 1.3-3.5 mSv, respectively.⁴⁰ Low dose CT has decreased the radiation dose to 0.5-3.5 mSv. EAU guidelines recommend low dose NCCT to patients with body mass index <30 if CT is indicated.¹⁰ The major advantages of the CT are high diagnostic accuracy, where almost all stones are visible, and that information of the kidney-related organs

and calyceal anatomy may be reconstructed. The disadvantages are radiation exposure, limited availability, and no information about kidney function with NCCT.

Magnetic Resonance Imaging (MRI)

MRI provides better imaging of the soft tissue in comparison with CT but it is not reliable for urinary system stones.¹¹ MRI is a radiation free technique and may be considered as an alternative to USG for pregnant and paediatric patients. Magnetic resonance Urography (MRU) may be an alternative to IVU. The site of the obstruction may be seen clearly but the identification of the stone by signal void may be difficult.⁴¹ The accuracy of MRU in urinary stones when combined with tesla 2-weighted 3D series is 92.8% with sensitivity between 96.2-100% and specificity of 100%.⁴² 3D MRI and 3D CT images with volume and surface rendering software provide an endoscopic view of the organs; the technique is known as virtual endoscopy. Virtual cystoscopy and ureteroscopy have been performed with high sensitivity.⁴³ The main advantage of MRI is that there is no ionising radiation. The disadvantages are limited availability and limited experience.

CONCLUSION

EAU guidelines recommend a contrast study (enhanced CT or IVU) if stone removal is planned, because the anatomy of the renal collecting system needs to be assessed prior to stone surgery or shock wave lithotripsy. But use of repeated CT or IVU would increase the risk of cancer development. We hope that advances in technology will provide us with radiation-free or low-dose radiation imaging with detailed functional urological anatomy.

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