Renal imaging used in Percutaneous Nephrolithotomy (PCNL)

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Abstract

Background: The worldwide prevalence of nephrolithiasis is around 5%- 15%, with a higher incidence in adults around the third and fourth decade of life**.** Percutaneous nephrolithotomy (PCNL) is the gold standard treatment for renal stones ≥2 cm, and it could be an option in some patients with renal stones less than 2 centimeters (AUA/EAU recommendation). There are multiple puncture techniques for PCNL, most of them are commonly guided by fluoroscopy, ultrasound (US), and computerized tomography (CT). Fluoroscopy is the most common method for conducting the percutaneous puncture by urologists worldwide using multiple monoplanar or biplanar fluoroscopic techniques[1]**.** Biplanar techniques provide better information about the depth and direction of the collecting system than monoplanar methods[2]**.**

Keywords: PCNL**,** Fluoroscopy, Ultrasound

Introduction:

The worldwide prevalence of nephrolithiasis is around 5%- 15%, with a higher incidence in adults around the third and fourth decade of life[3]. Percutaneous nephrolithotomy (PCNL) is the gold standard treatment for renal stones ≥2 cm, and it could be an option in some patients with renal stones less than 2 centimeters (AUA/EAU recommendation) [4]. There are multiple puncture techniques for PCNL, most of them are commonly guided by fluoroscopy, ultrasound (US), and computerized tomography (CT) [2].

[1] Preoperative imaging:

Importance of pre-op imaging:

1. Defining Stone burden and renal anatomy.
2. Relationship of the Kidney to Adjacent Organs.
3. Estimation of Stone Fragility.

(1) Defining stone burden and renal anatomy:

- **Plain Abdominal Radiography (KUB)**

KUB (kidney-ureter-bladder plain radiography) is readily available and inexpensive.With regard to detection of upper urinary tract stones, it has however a rather low sensitivity and specificity both with regard to renal (58 and 62 %, respectively) and ureteral (67 and 69 %, respectively) calculi [5] **.**

- **Intravenous Urography (IVU)**

Traditionally, IVU was the preferred imaging modality for both diagnosis of the stone disease and planning of treatment including access in PNL. With use of both anterior-posterior (AP) and oblique views, IVU presents the anatomy of the collecting system as well as its relationship to the ribs, there by predicting the need for asupracostal access [5].

- **Computerized Tomography (CT)**

Standard CT urography, has been proposed as the 'catch-all' diagnostic procedure for all renal tract anomalies[6]. Non-contrast CT (NCCT or CT KUB) unequivocally performs significantly better than IVU in the evaluation of acute flank pain and the diagnosis of urolithiasis[5]. Both sensitivity and specificity of NCCT in the evaluation of renal and ureteral calculi approach 100 % [7].

A 3-D CT not only presents exact volume, orientation and location of stone(s) in relation to the collecting system, there by facilitating selection of the optimal calyx for percutaneous access and , it also provides excellent perirenal organ mapping in combination with the CT images used for the 3-D reconstruction, thereby presenting the optimal plane of access in order to avoid injury of adjacent organs such asthe liver, spleen, colon and pleura, which is of special value in patients with unusual body habitus and renal anomalies. A 3-D CT demonstrates accurately the presence of parallel calculus-bearing calyces, and it displays calyceal orientation, thickness of narrowed calyces or the neck of a calyceal diverticulum[8].

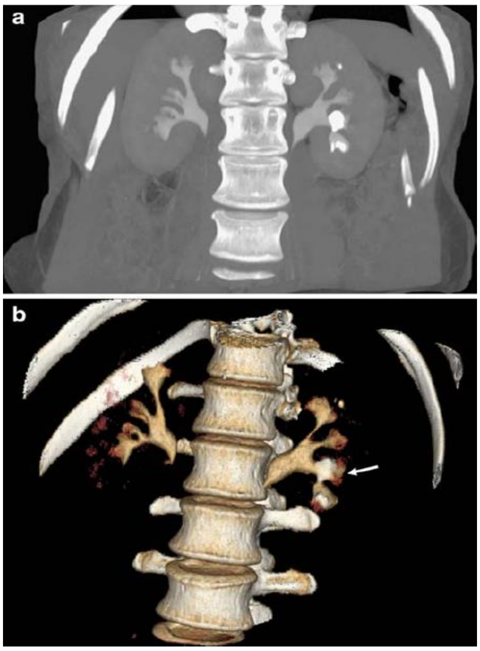


Figure (1): CT demonstrates stone shape and size thickness of narrowedcalyces[8]

Guy's scoring system (GSS):

GSS categorizes PCNL cases into four grades of complexity (Grade 1, 2, 3, and 4) depending on patients past medical history and non-contrast computed tomography (NCCT)[9,10].

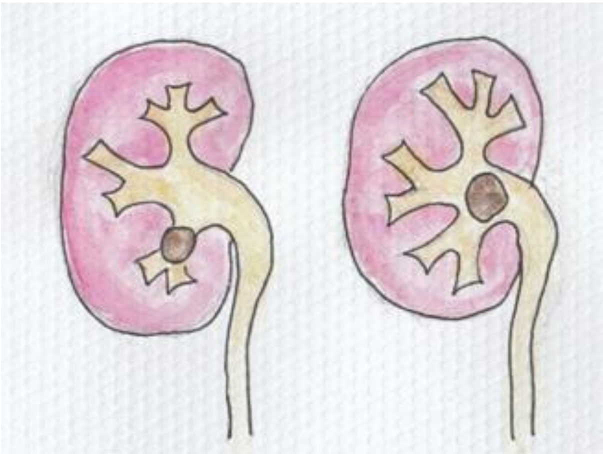
The purpose of these classifications is to simplify GSS, hence making this scale a more accurate tool, improving its acceptance and reproducibility. Our rearrangement of the GSS is based on a more homogeneous initial evaluation, as all our patients were categorized using a CT scan, opposite to the initial description by **Thomas, et al[9].**

de Souza Melo et al[11] who aimed to evaluate Guy's stone score (GSS) as a predictor of success and complications in PCNL. They prospectively evaluated 866 patients who underwent PCNL between June 2011 and October 2016. They found that GSS had an excellent negative predictive value for residual stones in addition to having very good prediction ability for other complications.

Sinha et al[12] prospectively evaluated the ability of Guy's Stone Score (GSS) in predicting stone clearance rate and complication rate (by modified Clavien grade) for renal stones treated by percutaneous nephrolithotomy. Their result showed that the final stone clearance rates were 93.9, 90.47, 85.71, and 77.77% in GSS I, II, III, and IV, respectively while the Clavien complication rates were 23, 61, 52, and 77.7% in GSS I, II, III, and IV, respectively. The conclusion was that GSS is a simple and easily reproducible system to preoperatively predict stone-free rate and perioperative complication rate. It helps in better patient counseling preoperatively.

GSS is easy to use and reproducible. In their original study. assessed 100 patients and showed that GSS was the only factor that significantly and independently predicted the stone-free rate. None of the other factors tested, including stone burden, operating surgeon, patient weight, age and comorbidity, were correlated with the stone-free rate[11] .

Grade 1



A solitary stone in the mid/lower pole with simple anatomy Or A solitary stone in the pelvis with simple anatomy

Grade 2

A solitary stone in the upper pole with simple anatomy Or Multiple stones in a patient with simple anatomy Or any solitary stone in a patient with abnormal anatomy

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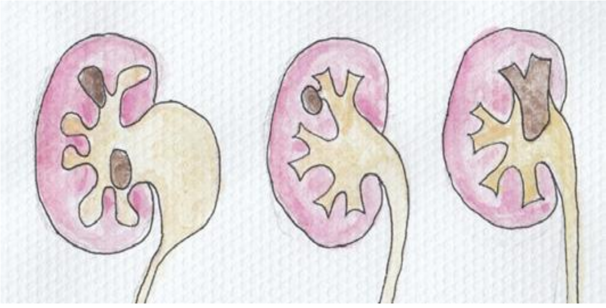
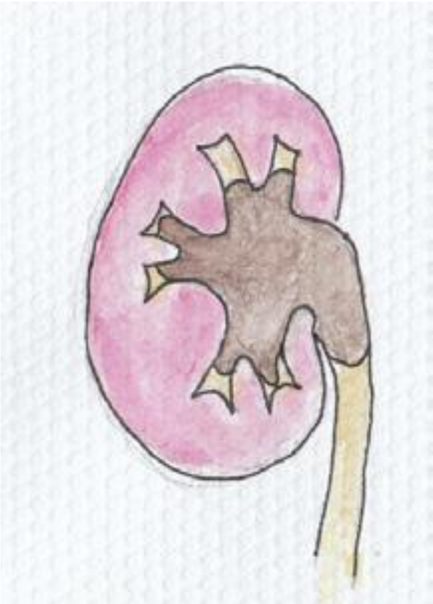
Grade 3



Multiple stones in a patient with abnormal anatomy Or Stones in a calyceal diverticulum Or Partial staghorn calculus

Grade 4



Staghorn calculus

Any stone in a patient with Spina Bifida or Spinal Injury. The GSS provides a simple, intuitive and reproducible tool for predicting SFS following PCNL

Figure (2): Grading of Guy's scoring system[9,10]

[2] Intraoperative imaging:

Fluoroscopy:

Traditionally, biplanar fluoroscopy with a rotating C-arm has been the most common imaging modality for obtaining percutaneous access in PNL, and regardless the imaging modality used for access guidance, intraoperative fluoroscopy complementary to endoscopy is considered indispensable for successful and safe stone removal.Tilting the C-arm towards the surgeon (20°–30°) and in the caudal or cranial direction depending on whether the lower or upper pole is being accessed presents the desired calyx – usually the posterior one – for end-on puncture[7] .

Radiation Safety Issues in Fluoroscopy During Percutaneous Nephrolithotomy:

Fluoroscopic guidance is the preferred technique for most of the stone therapies with PCNL. As endourology has become an important practice of urology, the use of fluoroscopic guidance has increased the exposure of urologists to the possibly deleterious effects of radiation[13].

Fluoroscopic imaging is widely used for urological interventions. There are wide variations in practices followed in different institutions and countries. In some places, radiologists are also involved, while at our center, only urologists carry out the procedures. Therefore, nontraditional radiation workers like urologists, residents of urology, technologists, anesthesiologists, and operating room staff should be aware of radiation doses they are involved[13] .

The practice of PCNL procedures seems to be quite safe with radiation point of view. The quick, easy, and economical method of estimation of radiation dose using survey meter may need further calibration with the standard thermoluminescence dosimetry method. Setting optimum x-ray parameters, incorporation of filters, and quality assurance tests are a few areas where medical physicists may help in further reduction of radiation doses[13].

To our knowledge this report represents the first study of a reduced fluoroscopy protocol for PCNL. Results suggest that extensive reductions in fluoroscopy time are readily achievable without compromising patient outcomes. Using less fluoroscopy during PCNL requires a paradigm shift in the training of future and practicing urologists. While a learning curve is inherent to a change of practice, these techniques can be safely and easily incorporated. Because patient safety remains paramount[14].

Patients with higher body mass index, greater stone burden, nonbranched stones and multiple nephrostomy access tracts are at risk for increased radiation exposure during percutaneous nephrolithotomy. Urologists must seek alternative strategies to minimize radiation exposure, such as tighter collimation to the region of interest, judicious use of magnification and the acquisition of as few images as possible during stone removal[15].

The International Commission on Radiological Protection recommends a limit of occupational dose exposure to 20 mSv/year over 5 years, with no more than 50 mSV in 1 year. Public exposure is limited to 1 mSv in a year[16].

These results demonstrate a substantial reduction in screening time compared with other published data, which is achievable with experience over time. The points of technique to minimize radiation exposure include:

1. Lock the C-arm so the only movement is in and out over the operating field.
2. Mark the stone position and "line-of attack" before puncture.
3. Avoid continuous screening.
4. Avoid protracted manipulation of the guidewire into the ureter.

substantial reduction have been suggested as a surrogate for technical expertise, and the ability to perform PCNL with a low radiation dose may be directly attributable to experience gained from a large caseload, further strengthening the argument for the centralization of stone surgery[16] .

Ultrasonography (US):

The limitations of using US alone for percutaneous puncture include difficulties inappropriate targeting of a non-distended calyx, poor image quality in obese patients,limited ability to identify anatomic details such a narrow infundibulum and difficulties in differentiating nephrocalcinosis from nephrolithiasis[7] .

On the other hand, in combination with fluoroscopy US offers clear advantages. US permits direct real-time inspection of the intended percutaneous tract avoiding injury to any major intrarenal vessels or perirenal organs, while at the same time securing exact end-onpuncture of the calyx[17] .

[3] Postoperative imaging:

Evaluation of residual Stones:

Traditionally, KUB and/or nephrotomograms were used to determine whether the patient was stone free after a PNL**.**Using flexible nephroscopy as gold standard reference, NCCT had a sensitivity of 100 % and a specificity of 62 % compared with 46 and 82 %, respectively, for KUB [18]**.**

Fowler et al. investigated the specificity and sensitivity of US in detecting renal calculi. They found an overall sensitivity of 24 % and a specificity of 93 %. The sensitivity was size dependent with the highest sensitivity (71 %) in stone sizes above 7 mm[19].

Evaluation of complications:

Intraoperative chest fluoroscopy seems to be sufficient to detect clinically significant pleural complications during PNL[5] **(Osther and Osther 2014).** Due to the fact that colonic perforation is most often retroperitoneal, colonic injury following PNLis often asymptomatic, and in these situations an antegrad enephrostogram before nephrostomy removal may reveal the presence of contrast in the colon[20] .

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