Review Article

Functional evaluation before stone surgery: Is it mandatory?

Rishi Nayyar, Nikhil Khattar, Rajeev Sood

Department of Urology, RML Hospital and PGIMER, New Delhi, India

ABSTRACT

Functional evaluation of the renal unit has often been quoted as a standard practice for management of stone disease of the upper urinary tract. However, there is very little available evidence from the existing literature to directly support or refute this practice. Here we try to critically review the existing literature on related questions, put into perspective its clinical utility and attempt to rationalize the concept of functional evaluation in patients of renal stone disease in the contemporary era of minimally invasive surgery.

Key words: Intravenous urogram, nephrectomy, percutaneous nephrolithotomy, retrograde intrarenal surgery, renal function, ureteroscopy

INTRODUCTION

Use of functional evaluation studies before deciding on the treatment modality has been considered as a customary clinical practice and a standard teaching guideline for all patients of renal stone disease, though there is as yet no direct evidence from existing literature to support or refute its use. Also, no authority or institution recommends or denounces functional evaluation as part of its good practice guidelines for management of such cases. This probably started and continued thereon as standard teaching in the era of open renal surgery when stone removal was a very major undertaking and establishing renal function was customary to avoid being foolhardy at a later stage. Also, prior to emergence of cross-sectional imaging techniques there were not many investigations available at the disposal of clinicians to obtain detailed anatomical information without the use of contrast excretion from the kidneys and seeing the excretion on X-ray films. In the contemporary era it is well known that the functional information available from seeing contrast excretion on X-ray films is relative, crude and imprecise. Though, in most cases it is considered sufficient enough to decide regarding the choice of treatment modality in any index case.

At many non-academic centers practicing urology, most of the ureteric calculi are being managed without functional imaging and this has made the issue of dealing with ureteric calculi without an intravenous urogram (IVP)/ contrast enhanced computed tomography (CECT) debatable in clinical meets and conferences. The issue has not been addressed in the literature till date but it continues to be in common practice. For renal stones, the general agreement is to proceed only after functional imaging and the issue is not even debated. Here we critically deliberate upon the need of using contrast studies to ascertain the function of the renal unit before deciding upon the management of renal or ureteric stones in modern-day practice.

The various available tests that are used in the decision-making process for renal stone disease are listed in Table 1. It is easier to identify the best imaging modality for diagnosis of urinary stones as non-contrast computerized tomography (NCCT) based upon the sensitivity, specificity and predictive values.[1,2] But the optimal imaging modality before stone surgery is not as easily obvious. The anatomic details of the pelvicalyceal system, the stone and their interrelated anatomy as well as stone size, fragility, and function of the renal unit may all have a bearing on the clinical decision-making process. None of the presently available tests can provide all this information in one single investigation.

For correspondence: Dr. Rishi Nayyar, Department of Urology, RML Hospital and PGIMER, New Delhi - 110 001, India.
E-mail: nayyarrishi@gmail.com

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Table 1: Imaging techniques used in evaluation of cases with urinary tract stones in the contemporary era

Imaging techniques	Comments
Purely anatomic imaging techniques with no direct indication of function of renal units	
X-ray KUB	Information only regarding stone, No indication of renal, pelvicalyceal or ureteral anatomy and its relation to stone anatomy
Ultrasonography / Doppler	User-dependent, poor delineation of ureteral anatomy
Non-contrast CT ± 3D reconstruction	Detailed anatomical information
MRI ± Urography± 3D reconstruction	Expensive, detailed anatomical information, Poor for stone anatomy
Intra-operative retrograde or antegrade pyelography	Anatomical information only about one side pelvicalyceal system, may be used as adjunct during cases undergoing surgery
Functional imaging techniques	
Radionuclide scan (DTPA, MAG, LLEC etc) ± GFR	Only test which quantifies function in exact terms, but gives information only and purely about function of renal unit, No anatomical information except size and location of kidney
Intravenous urography (IVU)	Commonly used, based on contrast excretion
CECT ± Urography ± 3D reconstruction	Commonly used in developed nations, based on contrast excretion
Contrast MRI ± Urography ± 3D reconstruction	Expensive, based on contrast excretion

IVU and CECT provide the best and most complete detailed anatomical information though at the expense of some contrast toxicity.[1] However, in the contemporary era of endoscopic and minimally invasive surgery, these investigations may not necessarily be needed in all cases.[3,4] It has been suggested that failure to perform an IVU is not inevitably associated with a higher complication rate.[5] Similarly, there is a debate for routine need of such study before ureteroscopic removal of stones.[6]

The contentious issue while pondering upon the need of any functional evaluation before renal stone surgery is whether one can or should proceed with surgery based only on purely anatomic imaging techniques (X-ray, Ultrasonography/Doppler, non-contrast CT, magnetic resonance imaging (MRI), or intra-operative retrograde or antegrade pyelography), which do not give any direct information regarding function of the renal units. While one would always be wiser knowing more details about the patient, the clinical use of functional imaging before stone surgery can only be justified on two accounts. First, if the knowhow of function has an impact on the clinical decision-making. Secondly, if the anatomic information achieved with functional imaging techniques is irrefutably better than other pure anatomic imaging techniques. There is also a question of hazards associated with function studies, whereby if the hazard is significant but avoidable then these tests should not be done. As regards the legal aspect, the physician may feel more secure getting a functional study done as baseline investigation but this is again only because there is as yet no medical literature to support or refute the need of a functional study before stone surgery which could be used as legal evidence in defense of the clinician in court. The plea of not getting a functional study as a baseline for legal purposes shall not need any separate proof of concept other than the evidence in medical literature for its need in clinical practice.

Impact of functional evaluation on clinical decision-making before stone surgery

While most clinicians are used to making clinical decisions for stone surgery only after getting a functional study done, its need in an academic sense can be put to question if detailed anatomic information about the status of the excretory system and the stone could be obtained otherwise also. Since there is no direct available evidence, the argument about the need of a functional study can further be sub-studied under the following headings: (1) Can pure anatomic imaging be used to gauge kidney function in a broad sense like functional imaging techniques (IVU/CECT)? (2) Does knowledge of exact function affect the choice of treatment modality? And (3) if so, In how many cases?

Can pure anatomic imaging be used to gauge kidney function in a broad sense like functional studies?

Several methods of renal morphometry and volume assessment have been reported.[7] There is ample meandering evidence available in the literature which suggests that anatomical parameters like renal parenchymal thickness, renal length, area or volume, etc., provide sufficient information about the function of the renal unit and these are frequently considered as clinical surrogate markers of renal function.[8,9] Feder *et al.*, reported upon the use of NCCT for predicting differential renal function using the ratio of the parenchymal area of the two sides.[10] One hundred and eleven cases undergoing CT scan and renal scan were studied. They measured the average renal parenchymal thickness at both the upper and lower pole and then calculated the parenchymal area on either side by finding the product of average renal parenchymal thickness and renal length on that side. The ratio of the parenchymal area was calculated and compared to the differential shown on (99m) technetium- mercapto-acetyl-triglycine (MAG3) renal scan. This study showed a very high correlation (Pearson's correlation coefficient 0.959) between predicted and observed renal function, with average difference of 4.73% between the two. They concluded that CT may obviate the need for nuclear renal scan in some circumstances, thereby suggesting that information about the parenchymal bulk may be an equivalent indicator of functional status of that renal unit. In subset analysis, presence of infection had a bearing on the average functional difference, 6.54% vs. 4.28% (Pearson's

correlation 0.955 vs. 0.965, *P*=0.0045), in favor of uninfected patients. No statistically significant difference in predictive ability was found between contrast and non-contrast CT (4.13% vs. 4.92%, 0.967 vs. 0.954, *P*=0.3259. There was a statistically significant average functional difference in favor of unobstructed renal units (3.28% vs. 5.10%, *P*=0.0036) versus obstructed units. In another study of 33 cases of chronic renal obstruction CT- based renal parenchymal volume estimation was measured and percent renal volume was then compared with percent renal function, as determined by nuclear renal scan.[11] They also observed strong correlations between percent renal function and percent renal volume in all cases (r = 0.90, *P* <0.001), including the enhanced (r = 0.87, *P* <0.001) and non-enhanced (r = 0.95, *P* <0.001) groups. Moderately strong correlations were noted even in cases with poorer renal function, with values of r = 0.76, *P* <0.001 in the <40% and r = 0.64, *P* = 0.015 in the < 30% renal function subgroups. They concluded that differential renal volume measured from CT strongly correlates with differential renal function on nuclear renal scan for normal and chronically obstructed kidneys. In their opinion, CT may serve as a single radiological diagnostic study for anatomical and functional assessment in patients in whom a poorly functioning kidney is suspected. An average of about 15 min per patient were needed to complete volume measurements from CT images using technique based upon outlining of parenchyma on each slice. Sonographically measured renal volume has also been shown to provide more accurate estimates of glomerular filtration rate (GFR) in potential kidney donors, with lower prediction error, compared with formulas based on SCr or SCys.[12] Similar to these, there are several other studies which suggest significant clinical correlation between renal volume and function.[13-16]

Thus, it is evident that renal parenchymal bulk is a good enough indicator of overall function of that renal unit and certainly should be considered equivalent to the functional information available from IVU/CECT. In other words, in spite of no direct functional assessment, a yes or no type of presence of function in the renal unit can surely be gauged by merely assessing the parenchymal bulk on pure-anatomical imaging. This is certainly true for most patients who have no to minimal hydronephrosis with no associated parenchymal thinning. In these stone patients there is thus no need to separately assess renal function for the sake of assessing it.

Does knowledge of the exact function of the renal unit affect the choice of treatment modality?

The options for renal and ureteric stones vary widely in the current era ranging from medical expulsive therapy (Conservative/Watchful waiting), to extracorporeal shockwave lithotripsy (ESWL), ureteroscopic removal, percutaneous nephrolithotripsy (PCNL) or even open, laparoscopic or robotic surgery. The various decision-making parameters for renal or ureteral stone surgery are noted in Table 2. Each of these may have different degree of implications for different modalities of stone treatment. For example, before prescribing medical expulsive therapy or ESWL, the exact location of the stone and its relative anatomy to the pelvicalyceal system along with the degree of impaction and hydronephrosis are very important parameters. However, out of all, the only parameter related to the function of the renal unit is the absolute or differential function itself and the amount of filtration. As we know, the function of the kidney need not be assessed precisely for the decision-making in most cases. A vague 'yes or no' type estimation done by IVP/ CECT is usually considered as enough. Such 'yes or no' type estimation can indirectly be obtained from purely anatomic assessment as well whereby parenchymal bulk provides reasonably correct differential renal function as already discussed above. All the remaining parameters are purely anatomic factors and if known to the clinician, decision-making may logically be done equally proficiently with or without knowing the exact renal function, particularly in cases who have no loss of renal parenchymal bulk. Intraoperative fluoroscopy and retrograde pyelographyRGP provide another opportunity to further confirm/redefine anatomy before invasive surgical procedures (Ureterorenoscopy/Rertrograde intrarenal surgery/PCNL/ open or lapararoscopic) for stones.

The knowledge of exact renal function may, however, be essential in cases where anatomical information suggests significant loss of renal parenchyma and therefore its function and the issue to be decided is renal extirpation versus preservation. In other words, the issue of nephrectomy or partial nephrectomy in the presence of stones should

Table 2: Various factors that are useful in the clinical decision-making process of management of urinary calculi

Stone-related factors	Anatomy of the pelvicalyceal system and ureter and its relation to position, shape and number of stones	Patient-related factors	Others
Size Shape Number Composition Location Impaction	Degree of hydrouretero-nephrosis, obstruction or stasis Variations of anatomy of kidney and ureter - Single or duplicated system, Calyceal diverticulum, Extra or intra-renal pelvis, Megaureter, Anomalies of position and fusion etc Lower pole	Extremes of ages Obesity and Body habitus Infection Coagulopathy Diseases causing renal failure – Hypertension, Diabetes etc Renal failure	Single kidney Bilateral stones Function and filtration of the renal unit

be decided only with exact functional evaluation. In cases with renal failure and bilateral involvement, another issue based on function may be the decision between sides to be operated first. Even in such cases it has been demonstrated that differential renal function may be assessed on purely anatomic studies (as discussed above) and total GFR may be calculated using 24-h creatinine clearance, thus totally eliminating the use of functional imaging. Nevertheless, this needs to be further proven in prospective randomized studies before clinical recommendations can be made in this regard. Purely anatomic imaging however may not be useful for follow-up of cases with hydronephrosis as it may persist even after clearance of obstruction and stones. Bird *et al.,* have shown that there is considerable discrepancy and variability between independent radiologists reading NCCT for degrees of obstruction.[17] As per their study NCCT is reliably useful to differentiate between 'no obstruction' and 'obstruction' but not between degrees of obstruction. Erbas *et al.,* have recently reported in a retrospective study that renal parenchymal attenuation measurements and attenuation differences of both kidneys of the same patient could be useful in differentiating acute unilateral obstruction from chronic cases.[18] Assessment of finer changes in function and clearance of the renal unit are important parameters for follow-up.[19] A baseline exact functional evaluation is therefore surely useful for comparison purposes during follow-up in such cases.

Overall, it may be said that for most cases that have no hydronephrosis or loss of renal parenchymal bulk, functional evaluation probably has no impact on the clinical decision-making process. The clinician needs to be convinced about the fact that the parenchymal bulk is a good enough indicator of the presence of function in the kidney. Unilateral cases especially provide other side kidney for good comparison and treatment modality for stone treatment can thus be decided purely on detailed anatomic imaging only.

Cases with medical renal disease are a unique group where parenchymal bulk may not be a good indicator of overall function. In the absence of good evidence from the literature in this subgroup, presently it may be said that if a patient has renal failure on biochemical assessment then exact renal function should be ascertained using conventional radionuclide scans.

As an example, we may discuss a classic case of ureteric colic presenting with mid-ureteric 1.2 cm stone with minimal hydroureteronephrosis and good renal parenchymal thickness on NCCT [Figure 1a]. The modality of choice in the contemporary era is unarguably ureteroscopic removal of stone. Irrespective of a functional study one may proceed with it, cognizant of the fact that good and almost equal parenchymal bulk compared to the other side indicates function of that renal unit. And in this era of nephron preservation one would proceed with ureteroscopic removal even if there is moderate hydronephrosis and some associated loss of renal function. The question of the exact function of the renal unit arises only when there is severe loss of parenchyma and the clinical decision to be made includes nephrectomy/nephroureterectomy as an option [Figure 1b and c]. As a baseline, however, exact functional estimation is useful in patients presenting with significant hydronephrosis. Sometimes exact function is also important to decide for and prognosticate success of reconstruction irrespective of stone removal. For example in Figure 1b and c ureteric implantation is an integral part of the procedure for stone surgery and knowing the exact function of the renal unit in the presence of severe hydronephrosis is essential beforehand. Similarly, cases with ureteropelvic junction obstruction and severe hydonephrosis and loss of renal bulk with stones need to be assessed with exact renal function to decide for proceeding with reconstruction or considering extirpative surgery as well as prognosticating success of reconstruction. Endopyelotomy is one operative option for ureteropelvic junction obstruction which when being done in conjunction with stone removal may necessitate prior functional evaluation of the involved renal unit. Like ureteric reimplantation long-term results of endopyelotomy or even pyeloplasty are dependent upon residual renal function.[20-23] Other examples of the need of functional evaluation may be an issue of partial (polar) nephrectomy

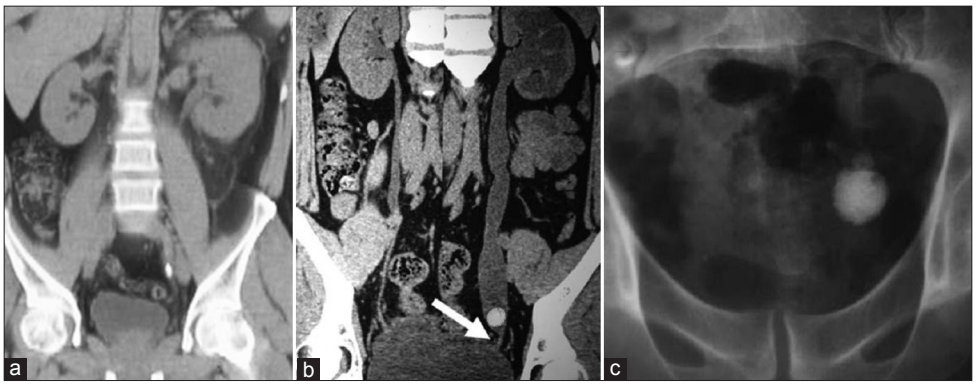

Figure 1: (a) NCCT showing mid-ureteric 1.2-cm stone with minimal hydroureteronephrosis and good renal parenchymal thickness. (b and c) Coronal reconstructed NCCT and X-ray KUB displaying left congenital megaureter with classical rat-tailed terminal end of ureter (arrow) and a single secondary rounded calculus

versus PCNL in presence of gross caliectasis with stones and loss of overlying parenchyma as given in Figure 2a and b. Visualization of clearance of contrast may be useful in a case where X-ray KUB/Ultrasonography(USG) suggest calyceal diverticulum, and RIRS versus PCNL is to be decided based on such visualization. Overall, while detailed anatomical information is a must for all stone cases, functional evaluation in the literal sense of the word is certainly not. Ureteric stones being taken up for ureteroscopic removal generally do not require any further detailed anatomical information, and any such need may be further satisfied by intra-operative fluoroscopy. Management of renal stones, on the other hand requires detailed calyceal anatomical information relative to the stone and further detailed anatomical imaging beyond USG and NCCT may become necessary in many cases where intra-operative fluoroscopy does not figure in the scheme of management. PCNL or RIRS like URS provide an opportunity to use intra-operative fluoroscopy to obtain further detailed anatomical information. In contrast, in patients being considered for ESWL, especially cases associated with hydronephrosis or caliectasis, a more detailed anatomical image may become necessary. In short, pre-surgical detailed anatomical information using spiral CECT and 3D reconstructed images or IVU may become necessary where USG or NCCT fail to furnish enough anatomical images to decide one out of several available modalities to tackle the stone. Also findings on USG/NCCT suggesting possibility of urinary tract anomalies, localized obstruction, secondary stones, etc., may prompt the clinician to attain more detailed anatomical imaging of the urinary tract.

Functional evaluation is beneficial in how many cases?

Even though the clinician is better informed, in up to 50-70% cases of urinary stones who present early with colics, have no to minimal hydronephrosis, and no renal failure, doing a functional study carries no advantage. This is because the decision to be made is never between renal preservation and nephrectomy. Secondly, choice of treatment modality is mostly based upon pure anatomical information. And above all anatomical imaging correlates very well with gross estimation of renal function. Other cases with renal failure, medical renal disease or significant loss of overlying parenchymal bulk may need functional evaluation to decide treatment modality, side to be operated first, provide baseline for follow up, etc. Care should also be taken regarding exact function estimation in cases with prior history suggestive of pyonephrosis, drained or otherwise, because infection may theoretically be associated with superadded loss of function.

Anatomic information from functional versus pure anatomic imaging techniques

Besides the impact of functional imaging on clinical decision-making, another important aspect to be considered is whether pure anatomical investigations can provide sufficient quantitative and qualitative anatomic information comparable to functional imaging techniques (IVU/CECT). All currently available pure anatomical studies have some limitations, though a combination of these may provide enough information needed for clinical decision-making. Ultrasonography is highly user-dependent and is poor for delineation of ureteral anatomy. Retrograde pyelography is an invasive test, not frequently used separate from surgery, and in fact may not always be possible, like in cases with non-localization of ureteric orifice or inability to cannulate. Also, it is considered a non-physiological imaging modality, and may not even delineate the entire system in the presence of impacted stone or severe obstruction. NCCT is a very useful test which combines information about all anatomy and is comparable to IVU for clinical decision-making in urinary stones. Stone detection rate is certainly better on NCCT.[24] However, three-dimensional (3D) reconstruction is not available everywhere and radiation exposure remains a

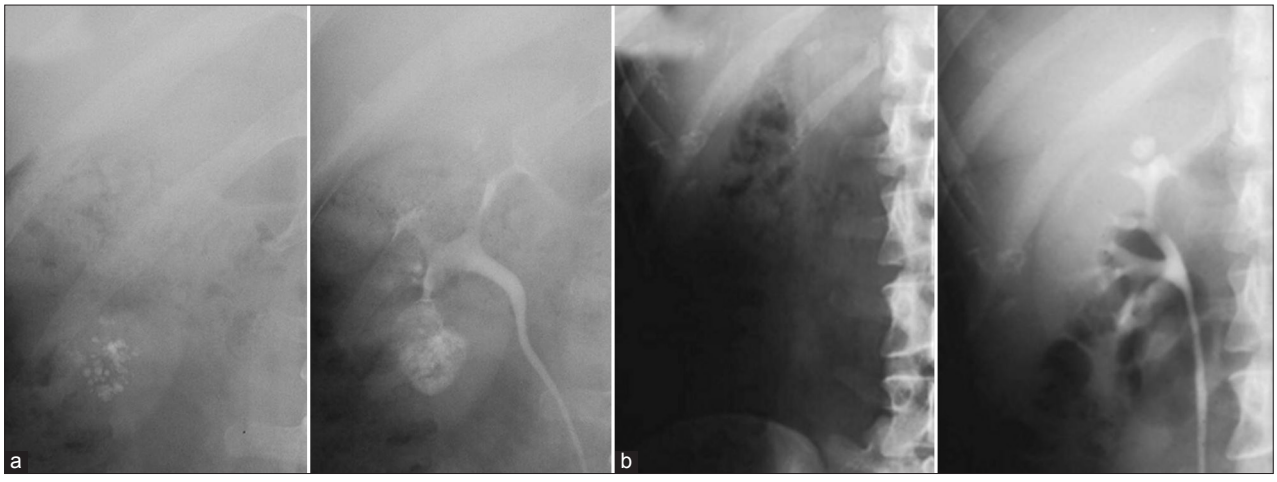

Figure 2: (a) Plain X-ray KUB and IVU films showing isolated lower pole calyceal ectasia with milk of magnesia (b) Plain X-ray KUB and IVU films showing upper pole stone in a calyceal diverticulum.

concern.[25-27] In one recent study, the median total effective radiation dose per patient was 29.7 mSv (inter- quartile range: 24.2, 45.1) totaling over the acute episode and short-term follow-up of stone cases. There were 22 (20%) patients who received greater than 50 mSv.[28] One sitting requires 3-5 mSv for IVU and 6-7 mSv for NCCT. The International Commission on Radiation Protection has set recommendations based on the data from atomic bomb survivors that occupational exposure to radiation should not exceed 20 mSv per year during a five-year period or 50 mSv in any single year.[29] MRI is relatively costly for routine use in all cases. Given all these limitations, functional imaging techniques (IVU/CECT) continue to be used frequently since they provide most and best anatomic information with one investigation.

Despite the fact that IVU/CECT provide good anatomical information in a single study, their use must be extremely judicious since they use intravenous iodinated contrast dyes and are not without harm. Contrast nephropathy may add to renal insult and function loss in 10-15%.[30] It not only affects the involved side but also puts the opposite unit at risk. Even severe renal failure and deaths (2%) have been associated with contrast nephropathy. Use of contrast adds to the cost of the study. Also there is a delay of definitive surgical management awaiting result of IVU. This is because IVU requires good bowel preparation beforehand. This results in continued loss of renal function from obstruction/ infection and increased duration of suffering for the patient. Doing CECT after NCCT entails additional radiation exposure. Radiation exposure should be minimized using newer techniques like low-dose protocols for CECT or IVU with digital tomosynthesis, etc.[31] In this era of nephron preservation, one may say that if avoidable contrast studies should be avoided.

CONCLUSIONS

There is good collateral evidence available in the literature to suggest that renal parenchymal volume correlates well with differential and absolute renal function. Functional imaging should not be indiscriminately used for all cases of urinary stone disease, because of its associated cost, time delay, and side-effects. In academic sense and as per logical reasoning, functional evaluation is not necessary in most cases that present early with colics, have no to minimal hydronephrosis, and have no renal failure with good renal parenchyma on USG/NCCT. Good overall anatomical information may be obtained by combining various purely anatomic imaging techniques in these cases. Functional evaluation should be considered when anatomical investigations suggest significant back pressure changes with parenchymal loss and there may be need to decide between nephrectomy or partial nephrectomy versus stone removal. Renal failure cases may also benefit from functional evaluation. Detailed prospective blinded randomized trials should be undertaken to directly address the need of functional evaluation before stone surgery.

Keypoints

1. No direct evidence is available from the literature to support routine use of functional evaluation for all cases of urinary stone disease.
2. Parenchymal bulk correlates strongly with differential and absolute function of the renal unit.
3. Exact functional status information is needed only for cases where anatomical information suggests possibility of nephrectomy or partial nephrectomy. Even in such cases it has been suggested that differential function can be ascertained based on parenchymal bulk.
4. Cases with medical renal disease need exact estimation of differential and absolute renal function using radionuclide scans as evidence is not clear about worth of parenchymal thickness in them.
5. In the absence of IVP/CECT all efforts must be made to have good anatomic information by combining USG/ X-ray KUB/ NCCT/ MRI/ MR Urogram/ RGP.
6. IVU/ CECT are still worthy and relatively safe modalities for obtaining good anatomic information from a single investigation and direct information about renal function from them is appreciable. Direct prospective randomized trials are needed before their use can be condemned for renal stone surgery.

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