Stone-free Outcomes of Flexible Ureteroscopy for Renal Calculi Utilizing Computed Tomography Imaging

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OBJECTIVE To assess stone-free rates following ureteroscopy (URS) for renal calculi at our institution using low-dose renal only computed tomography (CT).

METHODS A retrospective review of patients undergoing flexible URS for renal stones only with subsequent CT scan within 3 months. Meticulous basketing of all stone fragments was performed whenever possible. A "true" zero-fragment stone-free rate was determined by reviewing the CT scan and radiologist's report. Patients with nephrocalcinosis (as determined by visual inspection of papilla at the time of URS) were assigned the "stone-free" category.

RESULTS Flexible URS was performed in 288 renal units of 214 patients with renal calculi from 2013 to 2016. Median preoperative stone size was 6.2 mm with the average kidney containing 6.4 stones. An access sheath was used in 92% of cases. A total of 73% (209/288) renal units were completely stone free by CT assessment. Patients with residual fragments were as follows: 1 mm in 2% (7/288), 2-4 mm in 16% (46/288), and >4 mm in 9% of kidneys (26/288).

CONCLUSION The true stone-free rate in patients undergoing flexible URS for renal calculi utilizing active basketing of fragments as determined by strict CT assessment was 73%. In patients with residual fragments, the majority are 2-4 mm in size making URS a treatment option for renal calculi with excellent stone-free results. UROLOGY 124: 52−56, 2019.

Stone-free rate (SFR) is one of the determinants of ureteroscopy (URS) success rates. As radiologic imaging options have expanded, various measures of SFR have been utilized in the urological literature. Inconsistent reporting using x-ray, ultrasound, or computed tomography (CT) scan, and varying definitions of SFR contribute to data heterogeneity and complicate comparison of surgical techniques and outcomes.[1,2] A CT scan provides the most accurate assessment of SFR due to its ability to discern even the smallest stone fragments of 1 mm or less.[3] However, concern over expense, as well as excessive radiation exposure to stone-forming patients, has made standard CT scanning an infrequent postoperative assessment tool.[4] A low-dose *renal only* CT (LDCT) scan, however, offers reduced radiation exposure while preserving the superior stone fragment visualization of a CT scan in most patients.[27] We sought to assess the true SFR of URS at our institution using LDCT to provide an accurate assessment of contemporary URS success rates.

METHODS

After obtaining Institutional Review Board approval (study number 1605034699), a retrospective review of all patients undergoing flexible URS for renal stones with a subsequent CT scan (low-dose or regular dose) within 3 months of operation date was performed. In our institution, LDCT is routinely performed unless precluded by insurance considerations. The medical records, operative note, preoperative imaging, and postoperative CT report by the radiologist and images of every patient were reviewed by the primary investigator to determine a "true" zero-fragment SFR. Patient demographics, stone size and location, the use of ureteral access sheath, basket, or laser were noted. Stone composition and the results of postoperative LDCT scan were reviewed and tabulated.

Whenever possible, LDCT was performed at follow up to reduce radiation dose. LDCT is a study unique to Indiana University (IU) Health. Reasons for performing

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standard dose CT include imaging performed in another institution for insurance purposes, during acute admission, performed for other indications or due to limited insurance coverage of LDCT. If there was a concern for ureteric injury a delayed contrast CT urogram (CTU) was performed instead.

Our operative technique involved the use of a ureteral access sheath with meticulous basket retrieval of all stone fragments rather than "dusting" whenever possible. A high quality, digital flexible ureteroscope (Karl Storz FLEX XC by Karl Storz, El Segundo, CA) was utilized. We then performed "mapping" of each calyx to identify any stone fragments and to document the presence of nephrocalcinosis. Areas of significant papillary pitting, plugging, and extensive tissue calcification were examined and compared to live fluoroscopy and preoperative CT images noting corresponding areas of nephrocalcinosis. Radiographic contrast with fluoroscopy was used to ensure that no calyces were missed during "mapping." Patients with areas of calcifications noted on postoperative CT that corresponded to intraoperative findings of significant pitting, plugging, and/or tissue calcification (as opposed to a discrete stone) were considered to have nephrocalcinosis and assigned to the "stone-free" category. Study exclusions involved ureteral calculi alone without coexisting renal calculi (as LDCT typically images kidneys alone), secondary URS at the time of percutaneous nephrolithotomy, advanced medullary nephrocalcinosis making fair determination of stone-free status impossible, diagnostic URS in the absence of a visualized stone on preoperative imaging, patients undergoing routine prophylactic URS due to extremely rapid stone formation (eg, patients with renal tubular acidosis) making it difficult to distinguish a residual stone fragment from new stone formation, stones in ureteroscopically inaccessible locations (eg, calyceal diverticulum) that required further treatment with alternative procedures (eg, percutaneous nephrolithotomy), and patients with medullary sponge kidney.

RESULTS

Flexible URS with follow-up CT scan was performed in 288 renal units in 214 patients with intrarenal calculi from August 2013 to December 2016. There were 74 patients who underwent simultaneous bilateral URS. Overall, 55% of patients were female with an average age of 57 years (range 16-87 years). The average body mass index (BMI) was 33kg/m^2 (range 15-68) and median Anesthesia Society of America (ASA) score was 2. The mean preoperative stone size of the largest stone present was 6.2 mm (range 1-20 mm). The mean number of stones removed per kidney was 6.4 with the range from 1 to approximately 100 (as painstakingly counted at the time of URS). Anatomic abnormalities (horseshoe or ectopic kidney) were present in 6 (2%) kidneys with an average stone size of 10.5 mm in that group. An access sheath was used in 92% (265/288) of URS in order to allow for more efficient stone removal. In the remaining cases, basketing of 1-2 small stones without a sheath was performed. The primary stone location was lower pole in 33% (96/288), interpolar in 8% (22/288), upper pole in 10% (30/288), multiple stones dispersed throughout the kidney in 31% (88/288), renal pelvis in 6% (18/288), ureteropelvic junction in 1% (4/288), and not available in 10% (30/288). While ultimately related to the stone size, laser lithotripsy was utilized in 51% of URS (147/288) with basketing alone being sufficient in 49% of cases (141/288). The mean operating time was 54 minutes per kidney, ranging from 12 minutes to 02:55 hours (poor visibility with large stone burden).

The postoperative CT scan was performed at a median of 1 month postoperatively (typically at the 6-week follow-up clinic visit) with the range of 0-3 months as limited by the study design. Two hundred nineteen renal units (76%) had a low-dose CT scan and the rest (69/288, 24%) had a standard CT scan follow-up. Patient characteristics and operative outcomes of the 2 CT groups are compared in Table 1. A total of 209 renal units were completely stone free by CT assessment representing a 73% "true" zero-fragment SFR. The remaining 79 (27%) kidneys had residual fragments with a median residual fragment size of 3 mm (average 4.0 mm, range 1-14 mm). The largest fragment size was 1 mm in 2% (7/288), 2-4 mm in 16% (46/288), and >4 mm in 9% of all kidneys (26/288). The stone-free rate ranged from 57% for the largest stones (16-20 mm preoperative size) to 74% for the smallest stones (1-5 mm preoperative size) (Table 2).

Table 1. LDCT vs regular dose CT group comparison

	LDCT ($n = 219$)	Regular CT ($n = 69$)
Stone-free rate	76% (166/219)	62% (43/69)
Bilateral procedure	26%	23%
Patient age (median, y)	57	55
BMI (average, kg/m$^{2)}$	33	31
Time from operation to CT (mo)	1.25	1
Average preoperative stone size of largest stone (mm)	6.4	5.7
Average number of stones (per kidney)	6.7	5.4
Access sheath use	94%	87%
Laser use	51%	52%

CT, computed tomography; LDCT, low-dose renal only computed tomography.

Table 2. Stone-free rate by preoperative size

	Number	%
1-5 mm	99/133	74
6-10 mm	59/81	73
11-15 mm	19/29	66
16-20 mm	4/7	57
Unknown preoperative size	28/38	74
Total	209/288	73

Table 3. Stone-free rates by primary stone location

	Renal Units	%	Stone Free %
Multiple locations	88	31	60
Lower pole	96	33	77
Mid pole	22	8	73
Upper pole	30	10	87
Ureteropelvic junction	4	1	50
Renal pelvis	18	6	78
Not available	30	10	80
Total	288		

Of the small number of patients with renal anomalies, 50% (3/6 renal units) were stone free postoperatively. The stone-free rates by primary stone location are presented in Table 3. The stone-free rate in the "basketing only" group was 111/141 patients (79%). The stone-free rate in the "lasering and basketing" group was 98/147 patients (67%), likely due to large stone size in this group requiring lasering in the first place

Stone analysis was available for 93% of renal units (267/288). Stones were characterized by the predominant component present. As expected, the primary stone component was calcium oxalate mono- or dihydrate in the majority of patients at 65% (186/288) followed by calcium phosphate in 20% (57/288), uric acid in 4% (11/288), cystine in 1% (4/288), dicalcium phosphate (brushite) and calcium carbonate phosphate in 1% (4/288) each, and ammonium hydrogen urate in 1 (1%). Stone analysis was not available in 21 (7%) renal units.

DISCUSSION

The use of flexible URS for treatment of small to medium sized renal calculi is increasing all over the world.[6-8] We utilized CT scan assessment of stone-free rates to accurately determine URS stone-free outcomes for renal calculi. In our series of 288 renal units in 214 patients undergoing URS for renal calculi, the overall CT-defined zero-fragment stone-free rate was 73%.

All studies published to date using CT for imaging post-URS include both patients with renal and ureteral calculi making stratification of outcomes by stone location challenging in some instances. Of those studies where CT based outcomes for renal calculi can be separated out, the number of patients reported is very small. Portis et al in 2007 published a small series of URS patients assessed with CT reporting that 18/33 (59.5%) of renal calculi were stone free.[9] Rebuck and Nadler et al noted a stone-free rate of only 34.8% in another small series of 47 patients with renal calculi evaluated with CT.[10] Rippel et al published a larger series of 265 patients with renal and ureteral stones who had CT following URS; however, their "strict" definition of stone free included residual stone fragments up to 2 mm in size making that study not comparable to the data reported herein. Nonetheless, the "SFR" in the Rippel study was just 48%.[11] The current series is unique in that it focusses on renal calculi exclusively and comprises a far larger number of cases (288 kidneys) than prior reports with considerably higher stone-free rates.

The timing of follow-up imaging can influence SFR. Some smaller fragments may pass in the days and weeks following surgery while new stones could form weeks or months after URS. As with other reports, we limited our study period to 3 months post-URS to reduce potential contamination from new stone formation.

As seems axiomatic with procedures to treat nephrolithiasis, our stone-free rates varied inversely with stone burden, that is size and number (Table 2). Stone location appeared to have little influence on stone-free rates which is likely a reflection of our approach of active fragment retrieval.

URS success rates quoted in the urological literature vary greatly from 59% to 95%.[12] However, these outcomes can be misleading due to variable imaging techniques and stone free definitions. For example, an x-ray of the kidneys, ureter, and bladder (KUB) is unlikely to identify small residual stone fragments while an ultrasound may also miss stones (especially in an obese patient) or inaccurately estimate stone size.[13] A CT scan is the most sensitive imaging modality for the identification of renal stone fragments.[3] A low-dose noncontrast CT scan of the kidneys is an especially attractive option combining the superior imaging capability of a CT scan combined for stone and hydronephrosis detection with low radiation dose comparable to a KUB (1-2 mSV).[5,14,15] For example, the mean standard protocol CT radiation dose in one study of 4562 patients ranged from 6.5-8.5 mSV. Dose-reduced CT in a meta-analysis reported much lower radiation exposure with maximum effective doses of 0.7-2.8 mSV while maintaining pooled sensitivity and specificity of 0.97 and 0.95, respectively, compared with conventional CT.[16] Despite superior imaging offered by a CT scan, in a recent review by Hyams et al, over 75% of urological studies assessing stone outcomes used KUB as the primary postoperative evaluation.[2]

Indeed, there is some controversy about whether imaging of any sort is necessary following URS. Although American Urological Association (AUA) Guidelines recommend routine imaging following stone treatment procedures, a recent publication by Harper et al, documented that a majority (55%) of patients undergoing URS did not have any imaging performed within 3 months of their procedure.[17,18] Only 12% of URS patients had CT within the 3 month timeframe.

Another contentious issue is the definition of the SFR. Multiple studies count residual stone fragments as large as

<5 mm as “stone free.”[2] Utilizing this definition complicates appropriate comparison of various studies and surgical techniques. Approximately 1 in 5 patients with residual stone fragments ≤4 mm following URS will experience a stone event over the following 1.6 years making small residual fragments not so “insignificant.”[10] In another study, Chew et al noted fragments >4 mm were associated with significantly higher rates of stone growth, complications, and the need for reintervention.[19] These concerns have led to the emergence of the terms “zero-fragment” or “true” SFS.[13] Our standard practice is to report only the true SFR which is an absence of any residual stone fragments as defined by a CT scan.

Recently, the debate on the optimal technique for stone fragment management during URS has revolved around concepts of “basketing” vs “dusting.” In “basketing,” the goal is to render the kidney maximally stone free by active basket retrieval of all visible fragments. Typically a ureteral access sheath is used to expedite the process while maintaining low intrarenal pressures. Retrieved stone fragments are available for stone analysis. We routinely used a ureteral access sheath (92% of renal units) to allow for faster stone fragment extraction with superior visualization. Only in a handful of select cases with 1-2 small stones were basketing without a sheath performed. In “dusting,” high frequency, low energy holmium laser settings are used to pulverize the stone into small particles with the expectation that these fragments will pass spontaneously. “Dusting” allows for faster operative times without the need for additional staff to operate the basket and may eliminate the need for a ureteral access sheath and basket but carries the increased risk of incomplete fragment clearance.

There is limited data on the comparative stone clearance rates of “dusting” vs “basketing.”[20] The only published randomized study comparing dusting with basketing of ureteral stones utilized a semirigid ureteroscope in 60 patients and, despite concluding basketing is superior, omitted stone composition or the definition of the stone-free rate.[21] A prospective comparative study of 152 patients in 2016 from the EDGE research consortium suggested a higher SFR in the basketing group compared to dusting (86.3% vs 59.2%) with no difference in readmissions and reintervention rates at short follow up of 3 months.[22] Notably the EDGE study used KUB and ultrasound to assess SFR. The paucity of data is further exacerbated when published studies are viewed in the context of SFR definition as discussed above.

Appropriate identification of nephrocalcinosis at the time of URS is important in defining SFS. Nephrocalcinosis is a frequent finding in stone formers, even in the absence of systemic metabolic disorders, and is distinct from residual stone fragments. In a recent report, the frequency of nephrocalcinosis varies from 17% in calcium oxalate stone formers to 71% in calcium phosphate stone formers.[23] Further, the incidence of calcium phosphate stones is increasing.[24,25] In our study, a high-quality digital-flexible ureteroscope (Karl Storz FLEX XC by Karl Storz, El Segundo, CA) was used to identify areas of significant papillary pitting, plugging and extensive tissue calcification. These areas were compared to live fluoroscopy and preoperative CT images noting corresponding areas of nephrocalcinosis. Our unit is familiar with detailed inspection of papillary appearance, having recently introduced a papillary grading scale to describe these observations.[26] Patients with intraoperative findings of significant pitting, plugging, and tissue calcification (as opposed to a discrete stone) who had corresponding areas of calcification on postoperative CT were assigned to the “stone-free” category.

The majority (76%) of patients in our study had LDCT. Given the average BMI of 33 in our cohort, small stone fragments may not have been fully visualized with LDCT. This may be one explanation for the higher SFR reported in our study. LDCT has been shown to have a sensitivity of 96% for renal stones 3-4.9 mm and 100% for stones >5 mm but only 63% and 33% for 0-2.9 mm stones with BMI <30 and BMI >30, respectively.[27] Notably, this particular study had a small sample of only 13 patients with BMI >30. To reduce this concern, our radiology department utilizes current image post processing techniques and incorporates increased radiation dose for BMI greater than 30 to provide improved image quality.

One limitation of our study is its retrospective nature making it subject to bias. Another limitation is that surgery was performed by 2 experienced surgeons (JEL and AEK) limiting the study's reproducibility, although several fellows and residents worked with the surgeons during the study period. Another concern is that residual stones could have been overlooked and misclassified as nephrocalcinosis. We think that while it is possible that stones were missed, our reliance on the Storz digital instrument in all cases makes this less likely. The Storz device has a very wide field of vision and is significantly more maneuverable than other digital instruments duplicating the functionality of the best fiberoptic scopes.[28,29] Despite these limitations, the present study provides a true zero-fragment SFR in the hands of experienced operators.

CONCLUSION

In this retrospective study, the zero-fragment SFR in patients undergoing flexible URS for renal calculi utilizing active removal of fragments, as determined by strict CT assessment, was 73%. The SFR was inversely related to the stone burden treated. In patients with residual fragments, the majority were less than 4 mm in size. URS with modern ureteroscopes and techniques is a treatment option for renal calculi with excellent stone-free results.

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