Size is Not Everything That Matters: Preoperative CT Predictors of Stone Free After RIRS

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OBJECTIVE To define computed tomography (CT) predictors of residual fragments after retrograde intrarenal surgery (RIRS) for kidney stones up to 20 mm in patients never submitted to surgical procedures for stone removal.

METHODS From August 2016 to August 2017, symptomatic adult patients with kidney stones less than 20 mm treated by RIRS had their pre- and postoperative CT prospectively evaluated in search for predictors of residual stone fragments. Stone size, stone volume, number of stones, stone density, and location were evaluated in preoperative CT and analyzed as predictors for residual stone fragments on 90 POD CT. Stone location was represented by the infundibulopelvic angle (IPA) measured for each stone on preoperative noncontrast CT using multiplanar reconstruction.

RESULTS Ninety-two patients were successfully submitted to RIRS. Bilateral procedures were performed in 23 patients (25%) resulting in 115 renal units operated. Operative time was 54.5 ± 26.7 minutes (mean ± SD) and 96.7% (89/92) of the patients were discharged up to 12 hours after the procedure. Postoperative CT demonstrated stone-free in 86 of 115 (74.8%), 0-2 mm in 10 of 115 (8.7%), and > 2 mm residual fragments in 19 of 115 (16.5%) procedures. Logistic regression analysis revealed steep IPA was a predictor for any residual stone fragment after RIRS for kidney stones < 20 mm (*P*= .012). ROC curve showed that IPA < 41° was associated with a higher chance of residual fragments after RIRS.

CONCLUSION IPA < 41° is associated with a higher chance of residual fragments after RIRS for kidney stones up to 20 mm. UROLOGY 132: 63−68, 2019.

Stone-free rate (SFR) is one of the most important goals of the treatment for urinary stone disease. Inability to achieve stone-free status is a predictor for hospital re-admission and re-hospitalization increasing patient's stone burden.[1,2] To date, stone size is the major parameter for choosing the method of treatment. Retrograde intrarenal surgery (RIRS) is currently recommended for the treatment of kidney stones up to 20 mm by the European Association of Urology (EAU) and American Urological Association (AUA) guidelines.[3,4]

SFRs vary between studies and several different predictive models emerged to help patients and urologists to make a better treatment decision.[5-8] Although reproducible, these predictive models are not adopted in daily use due to their dependence on several clinical and CT parameters.[9,10]

Computed tomography (CT) is widely used preoperatively for kidney stones evaluation. Guidelines suggest avoiding shock wave lithotripsy in lower pole kidney stones with unfavorable CT parameters such as steep infundibular pelvic angle, long and narrow infundibula.[3] The negative impact of abnormal collecting system anatomy on SFR of RIRS is already known.[7] However, little is known about the impact of stone features analyzed by CT on SFR of RIRS in normal collecting systems.

The aim of this study was to define CT predictors of residual fragments after RIRS for kidney stones up to 20 mm in patients never submitted to surgical procedures for stone removal.

Conflict of Interest: Alexandre Danilovic - speaker Coloplast, BD; Bruno Aragão Rocha - no conflict; Fabio Cesar Miranda Torricelli - no conflict; Giovanni Scala Marchini - no conflict; Carlos Batagello - no conflict; Fabio Carvalho Vicentini - speaker Boston Scientific; Olivier Traxer - consultant for Coloplast, EMS, Boston Sci Olympus, IPG Medical, Rocamed; Publio Cesar Cavalcante Viana - no conflict; Miguel Srougi - no conflict; William Carlos Nahas - no conflict; Eduardo Mazzucchi - speaker Boston Scientific, Promedon, Apsen.

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MATERIAL AND METHODS

From August 2016 to August 2017, we conducted a prospective trial of consecutive patients with kidney stones treated by RIRS. Pre- and postoperative CT were evaluated by a senior radiologist to analyze predictors of residual stone fragments. Our hospital's ethics committee approved the study protocol and written informed consent was obtained from all patients according to the Declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects.

Symptomatic adult patients, with kidney stones between 5 mm and 20 mm that accepted to be treated by RIRS, were included in this study. We limited lower calyx stones to up to 15 mm. Multiple and bilateral kidney stones were included in the study.

Patients with kidney malformations, ureteral stenosis, previous ipsilateral endoscopic or open kidney surgery, hydronephrosis, indwelling double J stent, and contraindications for RIRS were excluded.

All procedures were performed under general anesthesia in a standardized method briefly described as follows by a single experienced surgeon (AD).

A Nitinol 0.035" guide wire (Coloplast – DK) and a PTFE 0.035" guide wire (Coloplast – DK) were inserted up to the renal pelvis under fluoroscopic guidance. Semi-rigid ureteroscopy was performed as an initial step in all procedures. A ureteral sheath 10/12F × 35 cm (Coloplast – DK) was then placed up to the upper ureter and the flexible ureteroscope (URF-P5, Olympus – JN) was inserted for direct inspection of all renal calices before lithotripsy. Stones located in the lower calyx were displaced to a more favorable calyx for laser lithotripsy whenever possible. Laser lithotripsy was performed with a 270 micron Holmium laser fiber (Dornier). Laser setting was adjusted during lithotripsy from 12 Hz and 0.6 J-15 Hz and 0.4J, using Dornier H30 laser machine (Dornier). Stone fragments >2 mm were removed with a 1.5 F tipless basket (Coloplast – DK). Stone fragment size was compared to the guide wire and if equal or less in diameter were left behind. Stone fragments were flushed with saline from lower and middle calyces to renal pelvis in order to facilitate spontaneous passage. Pyelography through the ureteral sheath was performed at the end of procedures and a 6 F silicone double J stent (Coloplast – DK) with an external string was located. The ureteral sheath was removed under direct ureteroscopic vision. Patients were maintained under analgesics and antibiotics on a prophylactic dose until double J removal on the 10th postoperative day (POD). Alpha-blockers were not used in this study. Operative time was defined from the beginning of cystoscopy till the end of insertion of double J stent.

Pre and postoperative noncontrast CT were performed using a 64-slice GE Lightspeed CT Scanner (General Eletric) with a slice thickness of 1 mm. Radiation low-dose protocol (low tube charge current – 60 mAs) was applied in patients with BMI < 30 Kg/m^2 and standard protocol (160 mAs) in patients with ≥ 30 Kg/m^2. CT was evaluated in the magnified (400%) bone window (width, 1600 HU/level, 500 HU) in 3 axes. Radiologist was blind to the preoperative CT and RIRS data.

Stone size, stone volume, number of stones, stone density, and location were evaluated in preoperative CT and analyzed as predictors for residual stone fragments on 90 POD CT. Stone size was considered the stone longest diameter regardless CT axes. Stone volume was calculated using ellipsoid formula as length x width x depth x π x 0.167.[3,6,11] Stone density was measured by free hand ROI determination coincident with the stone borders. In case of multiple stones, stone size and volume were considered the sum of the stones longest diameter and the sum of all

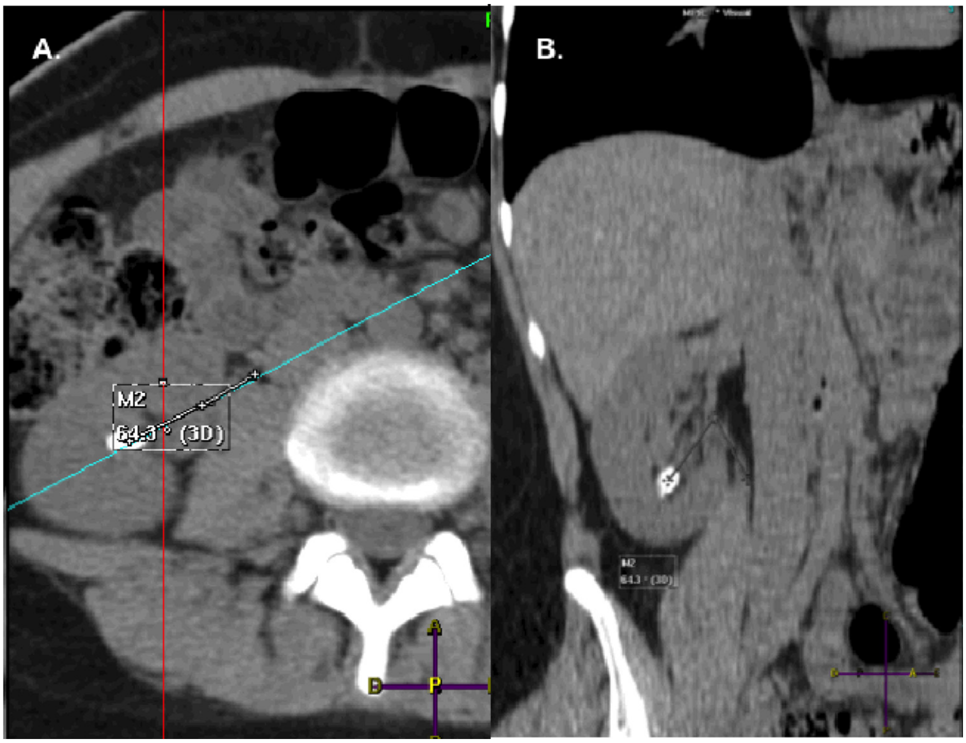

Figure 1. Measurement of the infundibulopelvic angle on MPR CT. The center of the stone was aligned with the proximal ureter in the axial plane (**A**). The angle tool was used in the coronal plane to obtain the IPA (**B**). (Color version available online.)

stones volume. Density was considered of the largest stone only due to inaccuracy in measuring density of small stones. Stone location was represented by the infundibulopelvic angle (IPA) that was measured for each calculi on preoperative CT. IPA was measured using mutiplanar reconstruction (MPR) CT by ISite (Philips, ND). IPA was considered the inner angle formed by the crossing of ureteropelvic axis and central axis of the infundibulum similar to Elbahnasy's method.[12] The center of the stone was aligned with the proximal ureter in the axial plane (Fig. 1A) and the angle tool was used in this new oblique plane derived from stone-proximal ureter alignment to obtain the IPA (Fig. 1B). Here, we describe a simple step-by-step IPA measurement protocol at noncontrast CT with MPR in details. Step 1: launch MPR tool at your DICOM viewer system; Step 2: find the stone at axial view and put the center of orthogonal axes at the center of the stone; Step 3: rotate the horizontal line so that it crosses the proximal ureter and the stone (stone is the pivot of rotation); Step 4: automatically when performed step 3, the coronal view will be changed to an oblique view that contains the stone, the infundibulum, and the ureteropelvic axis. In this plane, use an angle measurement tool to measure IPA.

Surgical complications were recorded based on Clavien-Dindo classification during the 90 days of follow-up.[13]

Statistics

Sample size was calculated based on the percentage of renal units with residual fragments bigger than 2 mm by noncontrast CT of 38%.[14] Therefore, sample size for the study was 115 renal units that detect significant odds ratio higher than 1.8 with test power of 80%. Categorical data were described as frequency and percentage and continuous data as mean and standard deviation.

Preoperative noncontrast CT stone size sum, stone volume sum, stone density, number of stones, and IPA were investigated as potential predictive factors for stone free after RIRS. These variables were compared using univariate analysis between those who were and were not stone free. Next, a stepwise backward multiple regression analysis including all variables and then only those significant was performed. ROC curve was used to determine the cutoff value for stone free prediction. SAS 9.0 program (SAS Institute Inc.) was used with a significance level of 5%.

RESULTS

From August 2016 to August 2017, 101 patients (127 renal units) were submitted to RIRS. Failure to place the ureteral sheath occurred in 12 of 127 renal units (9.4%). These patients were managed with double J stenting for a second procedure and were excluded from this study. Therefore, 92 patients were successfully submitted to RIRS. Bilateral procedures were performed in 23 patients (25%) resulting in 115 renal units operated. Clinical data and stone features evaluated by noncontrast CT on bone window were summarized in Table 1. Operative time was 54.5 ± 26.7 minutes (mean ± SD) and 89 of 92 (96.7%) of the patients were discharged up to 12 hours after the procedure.

Postoperative bone window noncontrast CT demonstrated stone-free in 86 of 115 (74.8%), 0-2 mm fragments in 10 of 115 (8.7%), and > 2 mm residual fragments in 19 of 115 (16.5%) procedures. Univariate analysis showed that only a steep IPA (P= .012) was significantly associated with any residual stone fragment after RIRS. The multivariate logistic regression analysis including all variables revealed that besides IPA, size (P= .02) and number of stones (P= .04) might had significant influence on SFR and were included in the final model in which only steep IPA remained significant (Table 2). On ROC curve, an IPA < 41° was associated with a higher chance of residual fragments after RIRS (Fig. 2).

Clavien-Dindo postoperative complications grade I, II, and IIIb occurred in 14 (15.2%), 5 (5.4%), and 1 (0.1%) of 92 patients, respectively. The 90 POD CT revealed 1 asymptomatic small subcapsular hematoma in a stone-free renal unit and 2 asymptomatic hydronephrosis, 1 in a stone-free renal unit and other in a renal unit with > 2 mm residual fragment. Both cases were further investigated with diethylenetriaminepentaacetic acid (DTPA) renogram that resulted in no urinary obstruction.

Table 1. Clinical data of 92 patients submitted to RIRS and stone features of the 115 renal units submitted to RIRS

Gender, F (%)		60 (65.2)
Age (mean ± SD, range), y		46.8 ± 14.1, 18-79
BMI (mean ± SD, range), Kg/m^2		28.1 ± 4.8, 19.0-45.5
ASA N (%)	I	38 (41.3)
	II	44 (47.8)
	III	10 (10.9)
Charlson N (%)	0	36 (39.1)
	1	18 (19.6)
	2	17 (18.5)
	3	7 (7.6)
	4	7 (7.6)
	5	2 (2.2)
	6	1 (1.1)
	7	2 (2.2)
	8	1 (1.1)
	9	0 (0.0)
	10	1 (1.1)
Bilateral procedures, N (%)		23 (25)
Multiple stones (%)		69 (60.0)
Stone size (mean ± SD, mm)		7.92 ± 3.81
Stone size sum (mean ± SD, mm)		14.92 ± 7.26
Stone volume sum (mean ± SD, mm^3)		435.5 ± 472.7
Stone density (mean ± SD, HU)		989.4 ± 330.2
Stone location		
Inferior calyx, N(%)		100 (37.3)
Medium calyx, N(%)		76 (28.3)
Superior calyx, N(%)		68 (25.4)
Renal pelvis, N(%)		24 (9.0)
Stone composition		
Calcium oxalate monohydrate, N (%)		55 (47.8)
Calcium oxalate dihydrate, N (%)		49 (42.6)
Calcium phosphate, N (%)		10 (8.7)
Uric acid, N (%)		1 (0.9)

RIRS, retrograde intrarenal surgery.

Table 2. Predictors for residual stone fragments after RIRS

CT Parameter	Degrees of Freedom	Q-Square	*P* Value
Stone size	1	3.400	.065
Stone volume	1	0.984	.321
Stone density	1	0.381	.537
Number of stones	1	0.045	.836
Infundibulopelvic angle	1	6.329	.012

RIRS, retrograde intrarenal surgery.

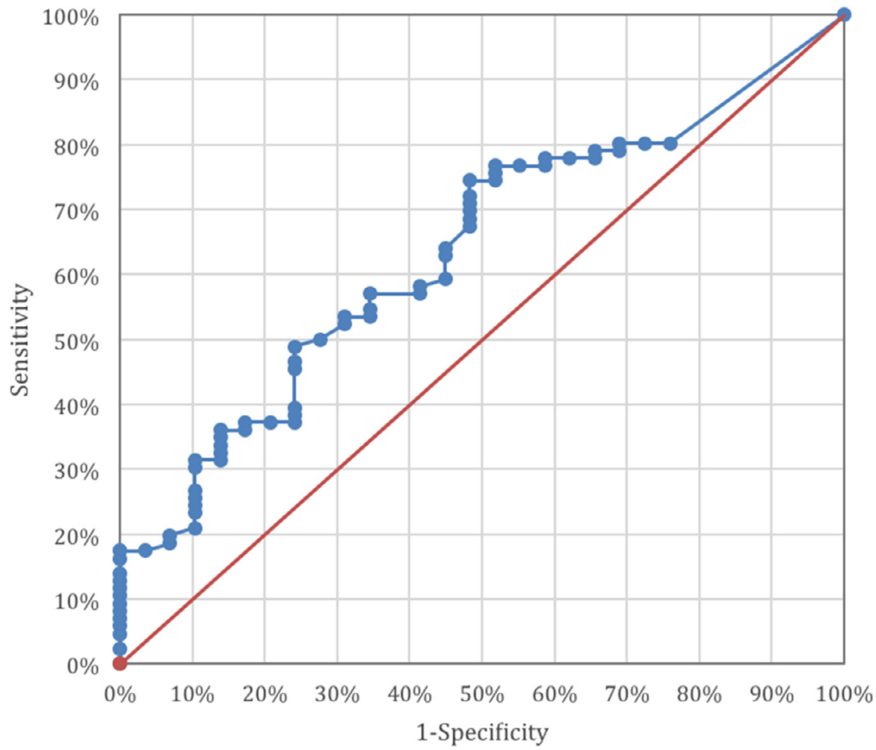

Figure 2. Infundibulo pelvic angle ROC curve. (Color version available online.)

Comment

It is already established that RIRS have higher SFRs for kidney stones up to 20 mm than for larger stones.[3,4] However, within this scenario of patients with kidney stones up to 20 mm, other parameters may play an important role in predicting SFR. Therefore, preoperative CT parameters other than only stone size should be evaluated to better advise patients regarding SFR after RIRS. We demonstrated in a prospective trial that IPA < 41° is associated with a higher chance of residual fragments after RIRS for kidney stones up to 20 mm in normal collecting systems.

IPA is classically described using intravenous urograms. However, intravenous urograms is being phased out of clinical practice as the imaging technique of choice, since CT is more frequently used in the diagnosis of urolithiasis.[3] CT is the most complete image study for the evaluation of urinary calculi. CT resources such as windowing, magnification, and three-dimensional (3-D) imaging should be used to better plan an interventional treatment and to prevent complications.[15] CT stone features such as size, density, location, and stone-to-skin distance have been used to indicate shock wave lithotripsy.[3,16] However, stone size remains to be the only feature used to indicate flexible ureteroscopy.[3] We thought to study preoperative CT parameters as stone size, volume, density, number, and location to better predict SFR after RIRS for kidney stones up to 20 mm.

We used noncontrast CT for the pre- and postoperative evaluation of all the patients of this study. Other authors analyzed predictors of SFR after RIRS but using a combination of different imaging as radiography of the kidneys, ureters and bladder and renal ultrasound, or noncontrast CT.[17,18] Few retrospective studies analyzed predictors for SFR after RIRS using only noncontrast CT.[7,8,14] Therefore, the methodology of our study is more reliable as used prospective data from noncontrast CT for all patients. Moreover, timing of postoperative imaging for RIRS is not established yet. The majority of studies performed postoperative imaging at 4-6 weeks[7,17-19] and few at 30-90 days.[8,14] We believe early control images are useful for evaluation of complications such as dilation of collecting system or subcapsular hematoma but may show some residual fragments that could pass spontaneously within 3 months after RIRS.[20] As a result, early control images tend to show a lower SFR than 90 POD images and may lead to unnecessary additional procedures. Therefore, we chose to perform the noncontrast CT on 90 POD for all patients.

Magnified bone window noncontrast CT should be preferred for urinary stone evaluation due to better image quality for dense objects as it minimizes noise artifacts close to the stone limits.[21] Free-hand ROI stone density should be measured in the magnified bone window CT in order to better perceive the true margins of the stone. 3-D imaging helps to plan percutaneous nephrolithotomy puncture sites for treating staghorn stones.[22] 3-D CT should be used to measure the 3 longest diameters of the stone thereby giving a more accurate evaluation of the stone burden.

The infundibulum angle, as previously described by Elbahnasy et al,[12] provides a better metric than merely stone location in inferior calyx because not all inferior calyx are challenging. Knowing the infundibulum angle, the surgeon may anticipate the difficulties he is about to face and even choose a different procedure or a different ureteroscope. NCCT multiplanar reconstruction with our simple IPA measurement method allows a precise evaluation of the IPA. Moreover, it is a simple CT tool for urologist and radiologist use and it is available at any DICOM viewer used worldwide (for example: OsiriX, Horus, RadiAnt, Isite, Carestream, among others).

As a result, we were able to analyze if there is a critical angle for flexible ureteroscopy. We did not use infundibulum width and length because its measurements were not precise in a non-contrast CT in an empty collecting system. Moreover, dilation of the collecting system with saline during flexible ureteroscopy probably changes the measurements of the length and width of the infundibulum. On the other hand, dilation of the collecting system does not significantly alter the angle between calculi and renal pelvis. Besides, the angle is of utmost importance because it may prevent the scope to reach the stone and forcing the scope into a steep angle may damage the scope flexible mechanism and the collecting system itself while trying to reach the stone.[23] Even if one could reach a lower calyx with a steep angle, stone relocation is not always possible and forced deflections while using Holmium laser may cause ureteroscope damage by laser fiber fracture due refraction into the cladding and fiber jacket.[24,25] Therefore, the previous knowledge of IPA of a lower pole stone is important to predict SFR and also to avoid flexible ureteroscope damage. If a steep IPA is anticipated, the urologist may prefer a single use ureteroscope to manage the case without jeopardizing a reusable scope or change the procedure to mini percutaneous nephrolithotomy.

Our study demonstrated a steep IPA of < 41° is associated with a higher chance of residual fragments after RIRS for kidney stones up to 20 mm. Inferior results were also observed in other studies with the treatment of lower pole stones by shock wave lithotripsy[26] and by flexible ureteroscopy.[27] However, some authors did not find difference in SFR of RIRS due to stone location in the lower pole, including a large retrospective study with CT control 30-90 days after RIRS.[14,28] The retrospective nature of these studies or more possibly because not all lower pole calyces have an angle so steep to prevent residual fragments to drain to renal pelvis or to prevent proper inspection during flexible ureteroscopy might have caused these conflicting results. Percutaneous treatment seems to be less affected by stone location. Studies comparing RIRS to percutaneous nephrolithotomy demonstrated better SFR for the last and less complication for the former.[29,30] We also had few complications with only 1 Clavien IIIb for the placement of a stent.

This study has several strengths. It is a prospective observational study looking for predictive factors for SFR after RIRS using CT for 100% of the evaluations. Moreover, CT scans were analyzed by a senior radiologist blinded for surgical and CT results. All CT scans were analyzed by the best way possible with magnification, bone window, and 3-D images. A senior urologist performed all surgeries in order to guarantee a standard procedure. Same type of flexible scope and same disposable devices were used in all procedures to reduce bias. We analyzed only patients never submitted to surgical procedures to remove urinary stones and without previous stenting. Therefore we increased our internal validity due to a more homogeneous sample. However, this study has limitations. We did not evaluate the infundibulum length or width and we do not know if these CT parameters may influence the SFR. Moreover, we acknowledge that this study was developed in a high-volume reference center and the best possible CT image was used. Therefore, our results should be confirmed by other centers with different surgeons using other types of scopes and disposables.

CONCLUSION

The IPA is a predictor of success of RIRS. An Infundibular pelvic angle < 41° measured on NCCT is associated with a higher chance of residual fragments after RIRS for kidney stones up to 20 mm.

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