



Analysis of stone-free rates and residual fragment sizes following standard percutaneous nephrolithotomy: mistakes in the treatment of non-opaque kidney stones

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Abstract

Our presented study aimed to evaluate the possible effects of stone opacity, on both the success of percutaneous nephrolithotomy and the sizes of residual fragments following the procedure. Medical records of patients undergoing PCNL treatment for kidney stones at our clinic between July 2014 and May 2022 were evaluated in a retrospective manner. A total sample size of 304 patients with the required criteria was included. Patients were divided into two groups based on the radiopacity status of the stones assessed in the kidney-ureter-bladder graphy (KUB) [Group O ($n = 211$): opaque, Group N ($n = 93$): non-opaque)]. Demographic data, laboratory results, and surgical follow-up information were comparatively evaluated between groups. The mean age and percentage of female patients were higher in Group N (45.2 vs. 25.1%; $p < 0.001$). Also, patients in this group were associated with more comorbidities. No significant difference was present regarding stones' laterality, size, surface area, and localization. Cases in the Group N group demonstrated higher median hemoglobin reduction [1.7 (IQR = 1.2–2.5) vs. 2 (IQR = 1.6–2.6); $p = 0.047$]. The stone-free rates in Group O patients were higher (67.8% vs. 53.8%; $p = 0.014$). The size of the residual fragments was meaningfully larger in Group N cases [8 (IQR = 7–13) vs. 10 (IQR = 8–16); $p = 0.032$]. Finally, no significant difference was observed between the groups regarding both minor (as grade 3a and below) and major (grade 3b and above) assessed by the Modified Clavien-Dindo Classification. Our data show that treatment of patients with so-called non-opaque kidney stones by PCNL results in low SFR and larger residual fragments, which is due to a variety of errors that should be avoided by appropriate measures.

Keywords Standard · Percutaneous · Nephrolithotomy · Non-opaque · Mistakes

Introduction

Advances in surgical equipment and endoscopic techniques have significantly changed urinary stone surgery over the past three decades. These developments have made surgical removal of urinary stones easier [1]. Due to the high success rate and low risk associated with minimally invasive procedures including extracorporeal shock wave lithotripsy (ESWL), flexible ureteroscopy (fURS), and percutaneous nephrolithotomy (PCNL), these techniques have largely replaced open surgery [2]. As a minimally invasive alternative, PCNL was found to be associated with significantly higher stone-free rates (SFR) than the other conventional methods for the treatment of large stones (> 20 mm) in the upper urinary system. The European Association of Urology (EAU) treatment guidelines for urolithiasis still recommend PCNL as the therapy of choice for stones larger than 20 mm [3].

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Published outcomes of several series report the overall success rate of PCNL ranging from 56 to 96%. [4–7]. In addition to the stone-related factors (location, number, opacity status, and size), the degree of hydronephrosis and the surgeon's experience, have been found to play a certain role in the final outcome of the procedure. Multiple scoring systems, including Guy's stone score and the S.T.O.N.E nephrolithometry, can be used to predict the success of the PCNL procedure [8]. Many experienced urologists have performed the technique under fluoroscopic guidance to achieve a better understanding of the renal anatomy, accurate placement of surgical instruments, and quantification of the residual stone burden [9].

Fluoroscopic guidance during all steps of the PCNL surgery may offer reliable information on the presence and location of residual stones. However, it is clear that the opacity status of the stone(s) may affect the monitorization of the course of the procedure and the status of residual fragments.

In this present study, based on our clinical observations, we aimed to evaluate the possible effects of stone opacity on the presence, as well as the size of the residual stones after PCNL applications. Additionally, we sought to discuss the mistakes we make in PCNL operations in light of contemporary endourology literature and to offer recommendations to improve stone-free rates for upcoming operation plans.

Materials and methods

The Helsinki Statement on research ethics was strictly followed during this investigation. The research project was approved by the institute's ethics review board. We retrospectively reviewed the medical records of patients who had had PCNL treatment for kidney stones at our clinic between July 2014 and May 2022. Patients with horseshoe kidneys, ptosis, malrotated kidneys, or multiple calyceal accesses were excluded from the study. In this manner, the records of 304 patients may be retrieved.

Prior to surgery, each patient got a radiological examination that included kidney, ureter, and bladder graphy (KUB) and non-contrast computed tomography (NCCT). The renal parenchymal thickness was calculated using the maximum axial segment thickness. The patient was given general anesthesia throughout every procedure. After inserting the proper ureteral catheter in the lithotomy position, all patients were turned to the prone position. After contrast was delivered into the renal collecting system through a ureteral catheter, the posterior calyx was reached using C-arm fluoroscopy and an 18-gauge needle. In all procedures, we conducted a dilatation up to 30 Fr, with the use of Amplatz dilators. A 26 Fr nephroscope (Karl Storz SE & Co. KG, Tuttlingen, Germany) was inserted into the collecting system after the Amplatz sheath was properly positioned.

Pneumatics were used to break up the stones (Vibrolith®, ELMED). The stone fragments were removed using forceps. After lithotripsy, if the stones were opaque, intraoperative stone-free control was carried out using C-arm fluoroscopy, and all calyces were attempted to be seen using a rigid nephroscope. These residual fragments were also removed, if possible. Fluoroscopy was unable to provide useful information about stone-freeness in non-opaque stones, hence intraoperative stone-free control was conducted by focusing primarily on accessible calyces under nephroscopic vision. A 16 Fr nephrostomy was placed into the renal pelvis at the end of the procedure, and it remained there for three days in the absence of any negative side effects. The Modified Clavien-Dindo Classification was used to group surgical-related complications.

KUB was carried out the day following surgery. In most cases, nephrostomy tubes are clamped on day three following surgery. While patients experiencing discomfort had antegrade nephroureterography, those with no pain had their nephrostomy tubes removed. In patients with ureteral blockages, the nephrostomy was reversed after the insertion of a double-J catheter. NCCT was used to establish a conclusive diagnostic of stone-free status 3 months after surgery. If any residual fragments smaller than 4 mm in diameter were regarded as stone-free.

Patients were divided into two groups according to the radiopacity status in KUB. Patients with radiopaque stones were grouped under Group O ($n = 211$), and those with radiolucent stones were grouped under Group N ($n = 93$). Several characteristics of both groups were compared, including their ages, the kind of stones they had, the patients they treated, and the outcomes of their surgeries.

SPSS 22.0 was utilized for the statistical analysis (SPSS Inc., Chicago, IL, USA). Means and standard deviations were displayed for the continuous variables. In cases where normal distribution was not observed, these data were expressed as median-(IQR). Both the T test and the Mann–Whitney U test were used to make comparisons between these variables. The numerical or percentage representations of the categorical variables were used. These variables were compared using the χ^2 and Fisher's exact test. The finding was determined to be statistically significant at the $p < 0.05$ level.

Results

The distribution of gender and mean age were significantly different amongst the groups. The mean age and percentage of female patients in Group N were higher (45.2 vs. 25.1%; $p < 0.001$). Also, Group N was associated with more comorbidities when compared to the other group using Charlson Comorbidity Index. Body mass indexes did not

differ significantly between the groups, however, a higher proportion of patients in Group O were taking anticoagulants (14.2% vs. 5.4%; $p=0.017$). In terms of data like stone side, stone size, stone surface area, and stone position, there were no statistically significant differences between the groups. In terms of stone density ratios, Group O was higher (1125.31 ± 382.00 vs. 508.3 ± 157.1 ; $p < 0.001$), although both groups' rates of hydronephrosis were comparable. The triangulation access approach was found to be employed more frequently in group N than in the other group (52.1% vs. 67.7%; $p=0.008$). Preoperative hemoglobin and creatine values from the laboratory were comparable between groups. Table 1 includes a detailed record of demographic characteristics and preoperative findings.

In terms of postoperative data, Group N's mean hemoglobin levels were lower than those of the other group (13.00 ± 1.64 vs. 12.40 ± 1.87 ; $p=0.008$). Additionally, this group had a greater median hemoglobin reduction [1.7

(IQR = 1.2–2.5) vs. 2 (IQR = 1.6–2.6); $p=0.047$]. Nevertheless, despite these findings, there were no appreciable differences between the groups in terms of transfusion needs. While there were no significant differences in the length of hospitalization or the frequency of postoperative fever across the groups, Group O had a higher SFR (67.8% vs. 53.8%; $p=0.014$). Last but not least, when groups were compared for the size of residual stones, Group N had higher values [8 (IQR = 7–13) vs. 10 (IQR = 8–16); $p=0.032$]. Rates of ureteroscopic intervention and double-j stent placement owing to emergency ureteral blockage during the first postoperative week were comparable between groups, as were flexible URS intervention required for residual stones within 6 months postoperatively. Postoperative follow-up data are given in Table 2.

When complications were classified as grade 3a and below as minor, and grade 3b and above as major complications using the Modified Clavien-Dindo Classification, no significant difference was observed between the groups. Table 3 provides a classification of perioperative and postoperative complications.

Table 1 Demographic characteristics and preoperative findings

	Group O ($n=211$)		Group N ($n=93$)		<i>p</i>
Gender					<0.001
Male	158	74.9%	51	54.8%	
Female	53	25.1%	42	45.2%	
Age	46.05	± 14.54	49.58	± 13.48	0.044
Charlson comorbidity index [median-(IQR)]	0	(0–2)	1	(0–2)	0.013
Body mass index (kg/m ²)	28.13	± 4.51	27.87	± 4.63	0.697
Anticoagulant use	30	14.2%	5	5.4%	0.017
Stone laterality					0.144
Right	78	37.9%	42	45.2%	
Left	128	62.1%	51	54.8%	
Stone size (mm)	25.79	± 9.71	26.04	9.85	0.955
Stone surface area (mm ²)	337.36	± 243.79	342.48	$\pm 264 > 71$	0.895
Stone location					0.160
Pelvis	135	64.0%	53	57.0%	
Upper	1	0.5%	1	1.1%	
Midle	7	3.3%	0	0.0%	
Lower	27	12.8%	19	20.4%	
Multi	41	19.4%	20	21.5%	
Phranchymal thickness (mm)	18.99	± 4.72	19.13	± 4.51	0.881
Stone density (HU)	1125.3	± 382.00	508,3	± 157.1	<0.001
Presence of hydronephrosis	158	74.9%	73	78.5%	0.299
Method of access					
Bull's eye	110	52.1%	63	67.7%	0.008
Triangulation	101	47.9%		32.3%	
Preop hemoglobin (g/dL)	14.90	± 1.75	14.64	± 1.76	0.175
Preop creatin (mg/dL)	0.94	± 0.29	0.92	± 0.29	0.499

Table 2 Postoperative follow-up data

Postop hemoglobin (g/dL)	Group O (n = 211)		Group N (n = 93)		p
	13.00	± 1.64	12.40	± 1.87	
Hemoglobin drop (g/dL) [median-(IQR)]	1.7	(1.2–2.5)	2	(1.6–2.6)	0.047
Blood transfusion	13	6.2%	10	10.8%	0.124
Operative time (min)	172.5	± 44.6	168.4	± 40.5	0.554
Hospitalization (day) [median-(IQR)]	4	(3–5)	4	(3–5)	0.702
Postop fever	11	5.2%	3	3.2%	0.332
Stone free rate	143	67.8%	50	53.8%	0.014
Residual fragment sizes (mm) [median-(IQR)]	8	(7–13)	10	(8–16)	0.032
Ureteroscopic inter in the 1st postop week	5	2.4%	2	2.2%	0.634
Flex. URS during postop 6 months	11	2.5%	6	2.3%	0.424

Postop postoperative. Inter intervention. Flex Flexible. URS ureterorenoscopy

Table 3 Classification of perioperative and postoperative complications

		Group O (n = 211)		Group N (n = 93)		p
Modified clavien-dindo classification						
	0	142	67.3%	67	72.0%	0.565
	1	52	24.6%	12	12.9%	
	2	7	3.3%	8	8.6%	
	3a	0	0.0%	2	2.2%	
	3b	2	0.9%	0	0.0%	
	4a	4	1.9%	0	0.0%	
	4b	3	1.4%	1	1.1%	
	5	1	0.5%	3	3.2%	

Discussion

Our study's major conclusion is that patients with radiolucent stones may have a higher likelihood of residual fragments following PCNL which tend to be meaningfully larger in size when compared with the opaque ones. To our knowledge, our study is the first that compares the presence and size of residual fragments after PCNL based on the opacity status of the stone(s) treated. Due to its higher SFRs than the other minimally invasive techniques and lower risk of complications than open surgery, conventional PCNL is the recommended therapy alternative for large renal stones [1]. Published data so far have clearly demonstrated that residing fragments after endourological procedures may grow further and/or produce symptoms. Moreover, a higher frequency occurring within a relatively shorter time interval of stone-related occurrences was found to be associated with larger residual fragments [2]. In modern endourology, achieving the maximum SFRs in a single session is one of the main goals and it is crucial to predict the outcome of the procedure reliably.

In their retrospective analysis of 101 patients' results, Maghsoudi et al. discovered that while the volume of bleeding was larger than that of opaque stones, PCNL was less successful in treating stones that were invisible

on plain radiography [8]. Additionally, they were unable to detect a statistically significant difference in overall operation times between the two groups in this investigation. Although the size of the residual fragments was not estimated and compared in this study, the other findings broadly support the results of our research. In our study, Group N saw a greater hemoglobin reduction than the other group, and the stone-free examination conducted three months after the procedure lagged the other group. In terms of operation times, we did not discover a substantial difference between the two groups.

On the other hand, Gucuk et al. chose a different viewpoint and attempted to ascertain the impact of Hounsfield Units (HU) detected in preoperative NCCT on the ultimate success of PCNL [10]. When CT HU was more than 1000, they reported increased SFRs. In stones with HU < 1000, which includes both opaque and non-opaque stones in KUB, SFR was lower. A different research found that 630 was the ideal cut-off value for HU assessed in NCCT to be seen as opaque in KUB [11]. This value was 800 in a study for ureteral stones [12]. To put it another way, it is clear that there is no set threshold value for the HU value identified in NCCT to make stones seem opaque in KUB. Due to this, we choose to categorize the stones' opacity using the KUB, which has the same technological basis as fluoroscopy. We believed that KUB would provide

us with more pertinent information about our ability to spot the stone during fluoroscopy. Based on the HU value measured by the NCCT, Gucuk et al., in contrast to us, classed stones above 350 as opaque. Furthermore, this study found that with non-opaque stones, the mean SFR was also lower. Again in this study, the dimensions of the residual fragments were not taken into account [10].

One of the main findings of our study was that SFR was found to be lower for nonopaque stones after PCNL and the median size of residual fragments was meaningfully larger in these cases. This situation could easily be explained by the fact that stones that are not identified well under fluoroscopy during the operation can be overlooked in the majority of such cases. In addition, our results are obtained in cases operated with standard PCNL, where endoscopic combined intrarenal surgery (with a flexible cystoscope or nephroscope combined with a rigid nephroscope) was not used in any of these cases, a method that achieves higher SFR in complex stones in a single session [13]. For this reason, for residing stones that are not visible in the fluoroscope, screening the renal calyces with a flexible endoscope may be beneficial for our future operation plans.

Another finding from our research showed that we mostly used the triangulation method to access the collecting system in opaque stones. This preference could be due to the surgeon's intention to use the monopolar method and Bull's Eye technique on opaque stones to reach the stone directly. Previous research has demonstrated that the rate of hemoglobin reduction and stone-free rates for the Triangulation and Bull's Eye techniques are comparable [14].

When we look at the age distribution between the groups, the mean age of the patients in the non-opaque stone group was slightly higher than the other group. The most common type of radiolucent stone is uric acid stone [15]. Age is one of the factors that increase the frequency of these stones [16]. It is conceivable to explain the difference in mean age between the groups in this manner, but this is only an approximation because we lack patient data on stone analysis. Furthermore, the patient group with non-opaque stones had a higher prevalence of anticoagulant drug use, however, we discontinued these drugs 5–7 days prior to the standard PCNL procedure as per the unwritten protocols of practice at our clinic. However, it should be noted that the decrease in hemoglobin was significantly higher in Group N.

Our overall stone-free rate of 63.4% (193/304) is notable, but it is lower than the values reported in the previous studies [4–7]. It is possible that the remaining fragments missed by ultrasonography and conventional radiography were identified by using computed tomography as a routine approach in our clinic, after 3 months following PCNL. Additionally, we need to express some of our mistakes during the PCNL operation with honesty. Modern endourology advises against using the provided approach for residual fragment control

following routine PCNL, which is one of our series' most major flaws. In the case of opaque stones, we were using fluoroscopy and a rigid nephroscope to do these checks after stone removal. The choice of residual stone management using only a rigid nephroscope remained for patients with non-opaque stones. This is a major reason for our low level of success. The current evidence suggests that patients with large and/or complex urolithiasis might benefit from the adjunct of flexible nephroscopy and/or ureteroscopy to rigid PNL. The evidence thus far shows that flexible nephroscopy and/or ureteroscopy, when added to rigid PCNL, can help patients with large and/or complicated urolithiasis [17]. Our results emphasize the importance of early radiological evaluation with reliable means (NCCT) to outline the presence and size of the residual fragments in cases undergoing PCNL for non-opaque renal stones. With this approach future stone-related attacks which may affect the quality of life of the patient and possible alterations in the morphology/function of the affected kidney could be prevented.

Limitations

Firstly, the absence of stone analysis data is viewed as a drawback. Not conducting a stone analysis is one of the most frequent mistakes made when treating kidney stones referred to as non-opaque. Since we do not have this possibility at our institute, it is unfortunate to say that we did this obvious mistake unintentionally. Uric acid stones are the most typical kind of non-opaque stones. Uric acid makes up around 10% of kidney stones, and in patients with this category of urinary stones, medical dissolving therapy can be a successful noninvasive treatment option. By boosting the urine pH (target > 6) with potassium citrate or sodium bicarbonate supplementation, medical dissolution treatment is accomplished [18, 19]. Our treatment seems to be incomplete in radiolucent stones after PCNL. The secondary limitation of this study is that it was conducted retrospectively. In addition, the findings could be influenced by the fact that the data originated from a single center, and the operations were performed by surgeons with varying degrees of experience. However, we believe that our study with a sufficient number of cases will still contribute to the literature because of the lack of information on the effect of opacity status on residual stone sizes after standard PCNL. Also, although this study is reported from an endemic area for urinary stone disease, many institutions still use traditional ways to perform PCNL. Many urology clinics lack basic equipment, such as a flexible nephroscope. Unfortunately, stone analysis labs are not widely obtainable, making it difficult for patients to access this evaluation. We honestly shared our results and clearly expressed our mistakes. It is hoped that after reading this research, endourologists that perform PCNL with

comparable techniques to ours would honestly assess and evaluate their findings and rectify their shortcomings.

Conclusion

Our current findings clearly indicate that patients with non-opaque kidney stones may have a higher rate of residual fragments after standard PCNL treatment, and these fragments tend to be larger. Based on this fact, evaluation with reliable means (NCCT) to outline the presence and size of the residual fragments in cases undergoing PCNL for non-opaque renal stones is paramount important to limit future possible stone-related events. In contrast to our provided series, it is evident that endoscopic techniques other than fluoroscopy must be utilized for residual stone control during PCNL. Moreover, the significance of stone analysis following PCNL should be highlighted.

Author contributions ÜY, contributed in the conception of the work, conducting the study, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. KS, contributed in the conception of the work, conducting the study, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work. MU, contributed in the conception of the work, conducting the study, revising the draft and agreed for all aspects of the work. ME contributed in the conception of the work, conducting the study, revising the draft and agreed for all aspects of the work. CK, conducting the study, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work.

Declarations

Conflict of interest The authors declare no competing interest.

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