Urologia Internationalis

Original Paper

Urol Int 2020;104:758–764
DOI: 10.1159/000509330

Received: May 15, 2020
Accepted: June 8, 2020
Published online: July 23, 2020

Comparison of Middle and Lower Calyceal Access for Renal Pelvis Stone in Percutaneous Nephrolithotomy: A Prospective Randomized Study

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Keywords
Percutaneous nephrolithotomy · Urolithiasis · Ultrasound · Complication

Abstract
Objective: The aim of the study was to evaluate the possible effects of calyceal choice for renal puncture under sonographic guidance on the outcomes of percutaneous nephrolithotomy (PNL). ***Materials and Methods:*** A total of 70 patients for whom ultrasound-guided PNL was planned for 20–30-mm single renal pelvic stones were prospectively allocated to group 1 (*n*:35) with middle calyx entry or group 2 (*n*:35) with lower calyx entry. Procedure-related parameters such as duration of operation, stone-free rates, complication rates, and radiation exposure time were analyzed in detail. ***Results:*** The mean age of the patients was 45.67 ± 1.50 years and the mean stone size was 316.4 ± 17.95 mm^2. There was no significant difference regarding the age, BMI, stone burden, and the grade of hydronephrosis between the groups. Skin to collecting system distance was significantly shorter in the middle calyx entrance ($p = 0.021$). Total duration of the procedure was again significantly shorter in group 1 cases (74.69 ± 2.94 min) than in group 2 (84.29 ± 4.25 min) ($p = 0.003$). Regarding the success rates, the postoperative stone-free rate was higher in group 1 (91.4% in group 1, 80.0% in group 2, $p = 0.305$). Last, there was no statistically significant difference in hemoglobin reduction rates, blood transfusion requirements, and complication rates between the 2 groups. ***Conclusion:*** Getting access to the renal pelvis through the middle calyx during ultrasonic guided PNL procedure is more advantageous to lower the calyceal approach by reducing both the duration of the PNL procedure with significantly higher stone-free and comparable complication rates.

Introduction

As a result of substantial evolvement over the last 3 decades, percutaneous nephrolithotomy (PNL) technique became the preferred treatment option in larger stones both in adults and children [1–3]. In addition to the experience gained, improvements in instrument and lithotripsy technology resulted in the safe and successful performance of this technique with significantly high stone-free rates of >90% [4–6]. However, despite these

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evident advantages of this approach, some well-known complications may be encountered during all stages (initial puncture, stone disintegration, and extraction etc.) as well as after the procedure [7–9]. Related with the type as well as severity of complications, a proper, well-planned puncture through the most dependent calyx of the kidney seems to be highly important to limit the chance of such severe complications, namely, bleeding and injury to the surrounding organs.

To our knowledge, there is no consensus reached so far on the optimal access to the collecting system during PNL. Apart from limited published data comparing ultrasonography and fluoroscopic guidance access in PNL, there is also no recommendation provided by either the European Association of Urology or the American Association of Urology guidelines regarding percutaneous access to the kidney. In this present prospective study, we aimed to evaluate the efficacy and safety of 2 different puncture techniques (lower and middle pole approaches) on the operative parameters in renal pelvis stones and also complications observed during PNL procedures performed under ultrasound-guided (UG) access.

Patients and Methods

Study Population

Seventy patients presenting with 20–30-mm single renal pelvic stones and undergoing UG-PNL operation were included. Patients younger than 18 years, with renal anomalies, previously identified ureteral pathologies, and non-dilated renal collecting systems were excluded from the study program. Prior to the treatment, a detailed information regarding the procedure and possible re-treatment sessions, additional procedures, or complications had been explained to all patients, and a written informed consent was obtained.

In addition to a detailed history and thorough urogenital examination, biochemical evaluation, urinalysis, and urine culture-sensitivity tests were performed. Radiological evaluation included ultrasonography, kidney-ureter-bladder film, and low-dose computed tomography to assess the renal anatomy, degree of hydronephrosis, position of the relevant kidney with neighboring organs and location, and burden of the stone(s) to be treated. Stone area has been calculated by using the 2 dimensions of the stone(s) from computed tomography images. All patients with positive urine culture were treated by proper antibiotics before the procedure.

Study Design

This study is a prospective single-center, randomized clinical trial with simple randomization [1:1], which was performed in a referral hospital in Dr. Lutfi Kirdar Kartal Training and Research Hospital. For randomization procedure, a simple randomization method by generating a random digit (0–70 in each group) has been used. Even numbers have been used for cases in whom an access was made through middle calyx and odd numbers have been used for cases with an access through lower calyx.

All PNL procedures were performed in prone position by a senior urologist, and all accesses to the renal collecting system were performed under sonographic guidance. Depending on the choice of the calyx to be punctured for renal access, the patients were divided into 2 different groups, namely, group 1: patients in whom a renal puncture was made through middle calyx; group 2: patients in whom a renal puncture was made through lower calyx. While the primary outcome of our study was to evaluate the ultimate stone-free rates after both approaches, secondary end points were the evaluation of operational duration, complication rates and the mean fluoroscopy time in both groups in a comparative manner.

Surgical Technique

PNL Procedure

Following general anesthesia, first a lithotomy position was given and a 5 F open end ureteral catheter was placed into the relevant ureter till ureteropelvic junction area in all cases during cystoscopy. Following this procedure, the patient was brought into prone position for PNL. Calyceal puncture under full sonographic guidance was done with an 18-gauge percutaneous entrance needle (Boston Scientific, Natick, MA, USA) through 2 different approaches in both groups as stated above. Following the puncture, a 0.038-inch guide wire was inserted into the collecting system (into the ureter when possible) and Amplatz mechanical dilatators were used for tract dilatation (Amplatz sheath, Boston Scientific, Natick, MA, USA) until 28–30 F. Following the placement of an appropriate access sheath a standard 26 F nephroscope (Karl Storz, Tuttlingen, Germany) was inserted and ultrasonic lithotripsy (Swiss Lithoclast®, EMS Electro Medical System, Nyon, Switzerland) was used for stone disintegration. Fragments were removed by suction, tipless basket, or grasping forceps. At the end of the procedures, a re-entry nephrostomy catheter (14 F) was placed, and an antegrade pyelography was performed to check for possible complications in all cases. While the open end ureteral catheter was removed at the end of the operation in

Table 1. Evaluation of patient and stone characteristics in both groups

	Overall (n = 70)	Group 1 middle calyx (n = 35)	Group 2 lower calyx (n = 35)	p value[a]
Age, years	45.67±1.50	47.17±2.19	44.17±2.03	0.3197
BMI, kg/m^2	27.99±0.47	28.09±0.69	27.89±0.66	0.8350
Stone burden, mm^2	316.4±17.95	328.80±30.84	304.10±18.65	0.4962
HU	987.8±30.21	1,014.0±44.14	961.1±41.40	0.3809
Degree of hydronephrosis, grade	2.17±0.06	2.11±0.08	2.22±0.10	0.4005
Skin-to-calyx distance, mm	90.81±2.59	84.91±3.68	96.71±3.39	0.0214

HU, Hounsfield unit. [a] Comparison between group 1 and group 2.

Table 2. Evaluation of the procedure-related parameters with an emphasis on the duration of the interventional steps in both groups

	Overall (n = 70)	Group 1 middle calyx (n = 35)	Group 2 lower calyx (n = 35)	p value[a]
Mean duration of the procedure, min	79.51±2.82	74.69±2.94	84.29±4.25	0.0003
Mean duration of open end catheter insertion, min	25.67±0.85	25.49±0.94	25.85±0.76	0.4582
Mean duration of access to the collecting system, min (including dilatation)	15.29±0.56	13.06±052	17.51±0.83	<0.0001
Mean duration of fragmentation and stone removal, min	30.91±1.84	28.06±2.35	33.77±2.79	0.1224
Mean fluoroscopy time, s	15.11±1.20	13.89±1.40	16.34±1.94	0.3090

[a] Comparison between group 1 and group 2.

all cases, nephrostomy tube was removed on the first or second postoperative day as soon as the urine became clear.

Outcome Assessment

All patients were re-evaluated by a plain abdominal film and/or sonography after 24 h and by a non-contrast abdominal tomography after 4 weeks. The procedure was considered successful if there were no fragments at all or if the size of the residual fragments were smaller than 4 mm. In addition to the duration of the procedure as a whole and also all relevant stages as well, the duration of radiation exposure, hospitalization period along with the mean duration of a nephrostomy tube, mean drop in hemoglobin levels, all intraoperative, and postoperative complications have been evaluated.

Statistical Analysis

The prism 5.0 (GraphPad Software, San Diego, CA, USA) was used for the statistical analysis. Data are presented as the mean ± SD of the mean. Student's t test or Mann-Whitney U test was used for both comparison of descriptive statistical methods and evaluation of quantitative data, and χ^2 or Fisher's exact test was used to compare the qualitative data between 2 groups; a 2-sided $p < 0.05$ was considered statistically significant.

Results

A total of 70 cases (male/female 43/27) presenting with large-sized (20–30 mm) solitary pelvic stones were treated with standard PNL under UG access. Demographic as well as radiologic characteristics of the cases are being given in Table 1. All stones were located in renal pelvis, and there was no significant difference regarding the size of the stones in both groups.

Evaluation of Our Findings in Both Groups Revealed Following Data

First of all, there was no significant difference between the groups with respect to the age, BMI of the cases, and the grade of hydronephrosis. However, as the most important parameter to be considered for a successful puncture, the skin-to-collecting system distance was meaningfully shorter in cases treated through middle calyx punc-

Table 3. Evaluation of the outcomes of the procedures in terms of success rates as well as early postoperative follow-up data

	Overall (n = 70)	Group 1 middle calyx (n = 35)	Group 2 lower calyx (n = 35)	p value[a]
Stone-free rate, n (%)	60 (85.7)	32 (91.4)	28 (80.0)	0.3059
Residual stone >4 mm, n (%)	10 (14.3)	3 (8.6)	7 (20.0)	0.1789
Mean drop in Hb levels, g/dL	1.59±0.11	1.69±0.18	1.50±0.12	0.3966
Mean duration of nephrostomy, day	1.98±0.14	2.01±0.15	1.94±0.19	0.8645
Mean hospital stay, days	3.11±0.13	3.20±0.19	3.03±0.19	0.5319
Secondary intervention, n (%)	7 (10.0)	2 (5.7)	5 (14.3)	0.4283

[a] Comparison between group 1 and group 2.

Table 4. Evaluation of the type and grade of complications according to modified Clavien classification in both groups

Grade	Complication	Overall (n = 70)	Group 1 middle calyx (n = 35)	Group 2 lower calyx (n = 35)	p value[a]
1	Fever >38°C, n (%)	7 (10.0)	3 (8.6)	4 (11.4)	1.0000
	Hemorrhage not requiring blood transfusion, n (%)	6 (8.6)	3 (8.6)	3 (8.6)	1.0000
2	Hemorrhage requiring blood transfusion, n (%)	6 (8.6)	4 (11.4)	2 (5.7)	0.6733
3a	Double J stent placement for urine leakage >24 h, n (%)	2 (2.9)	–	2 (5.7)	0.4928
3b	Endoscopic treatment for ureteral stone, n (%)	4 (5.7)	1 (2.9)	3 (8.6)	0.6139

[a] Comparison between group 1 and group 2.

ture (p = 0.021). While the total duration of the procedure was noted to be 74.69 ± 2.94 min in group 1 cases (middle calyx entry), this value was 84.29 ± 4.25 min in group 2 cases (lower calyx entry) with a statistically significant difference in favor of middle calyceal approach (p = 0.003). The main reason for such a meaningfully shorter procedural duration was that the middle calyx puncture under sonographic guidance was performed in a much shorter time period when than the lower calyx approach. On the other hand, radiation exposure time was another important factor to be evaluated, and although not statistically significant, this duration was noted to be shorter again in group 1 cases undergoing PNL procedure through middle calyceal puncture (13.89 ± 1.40 s in group 1, 16.34 ± 1.94 s in group 2 respectively, p = 0.309) (Table 2).

Regarding the success rates, the postoperative stone-free rate was higher in group 1, but the difference was again not statistically significant (91.4% in group 1, 80.0% in group 2, p = 0.305). Additionally, there was no statistically significant difference with respect to the hemoglobin reduction rates between both group of cases (1.69 ± 0.18 group 1, 1.50 ± 0.12 group 2 [p: 0.396]) (Table 3). Finally, evaluation of the complication rates in the light of Clavien grading system has revealed no statistically significant difference in blood transfusion requirement and significant complication rates between the 2 groups (Table 4).

Discussion

Percutaneous removal of larger stones sizing >20 mm became the preferred treatment alternative for the minimal invasive management such as calculi with reported stone-free rates of >90% [3, 5, 9]. Related with the puncturing and entering to the renal collecting system, although fluoroscopic guidance has been used in a commonly accepted manner in all parts of the world, increasing experience in sonographic applications has enabled the endourologists to puncture the collecting system under sonographic guidance (either with free hand or by using specific attachment systems) in a practical and effective way [10–12]. Puncturing the kidney with this technique seems to have some cer-

tain advantages among which the quick identification of the desired calyx with limited radiation exposure is the most important factor to be mentioned [13, 14].

On the other hand, regarding the choice of most appropriate calyx for a successful stone clearance, endourologists tended to use the lower calyces more commonly than the middle and upper calyces to puncture the kidney and get an access renal collecting system [15]. However, in the light of the accumulated experience so far and the possible effects of calyceal choice on the course as well as the final outcome of the PNL procedure, endourologists began to focus seriously on the choice of most suitable calyx for a practical and successful access. Related with the advantages of the dependent calyx to be chosen for a "perfect" puncture, the most important factors will be the axis of the puncture line and also the distance of this line from the skin to the desired calyx. It is very clear that a direct puncture to a calyx taking the stone just on the axis of this access line will require no high-angled instrument movements during the procedure by providing certain advantages to the surgeon for a successful and complication-free procedure. In other words, an acute angle between the targeted calyx and the long axis of the kidney may complicate the procedure to a certain extent.

Additionally, puncturing the dependent calyx on a parallel angle to the axis directed to the stone and performing the stone disintegration and/or removal procedures with this alignment will give the chance to visualize the stone(s) just in front of the scope for a practical and quick disintegration process. This approach will in turn again cause no torque of the scope with considerably limited chance of stone migration. Middle calyceal access will also give the chance to approach the stone from its superior surface to limit the fragment displacement in the kidney collecting system. Thus, keeping all these advantages which will certainly limit the complications and allow a completely stone-free status in mind, it is clear that a middle calyceal puncture particularly for stones located in renal pelvis will be the most rational approach. This approach will also lower the procedural (anesthesia) duration and limit the fatigue as well as radiation exposure risk both for the operating surgeon and the patient. Moreover, puncturing through middle calyx for such stones will provide an increased maneuverability in the collecting system. If the surgeon needs any additional maneuver to reach to the upper, lower calices and also proximal ureter with minimal torque and deformity, access from the middle calyx will certainly limit the chance of such problems on both the endoscope and renal tissue. Last but not least, the durability of percutaneous scopes and accessories will certainly be longer due to a smooth, uncomplicated (with no torque, bending, and forcing) maneuvers which will cause a cost-effective procedure profile.

Published limited data so far also indicated the abovementioned advantages of calyceal puncture through middle calyx with safe and successful outcomes. Caglayan et al. [16] reported that middle calyceal access was superior outcomes in terms of the operation time, mean hemoglobin drop, and requirement of additional access tract in lower calyceal stones. Related with this issue, while in their original study, Song et al. [17] found the procedural duration to be significantly shorter in the middle pole access group compared with upper pole and lower pole accesses. Last but not least, by comparing the operative durations between middle calyceal and lower calyceal approaches, Falahatkar et al. [18] were able to show that the operative time was significantly shorter in the middle calyx group than in the lower calyx group (60.7 vs. 80.1 min, respectively) and that there was no statistically significant difference in Hb reduction rates, blood transfusion requirement, and complication rates between the 2 puncture sites.

Regarding the possible reasons for such a higher success rate obtained from middle calyceal access, the authors stated well that the quick, practical access via the middle calyx, establishment of a proper angle between the middle calyx tract and long axis of the kidney, and optimal alignment of the access with the ureteropelvic junction could be among the possible factors considered. Last but not least "although not as significant as the success rates," the complication rates were also found to be limited during middle calyceal access where excessive torquing of the rigid nephroscope against the pelvicalyceal system to reach an inaccessible calyx has been reported to be the most important cause of bleeding during PNL [16–18].

In this present study, we aimed to evaluate the possible effects of calyceal choice (middle or lower calyx) for renal puncture under sonographic guidance on the stone-free rates and complications during and after PNL. Evaluation of our findings clearly showed that first of all as a main parameter, the skin-to-collecting system distance was shorter in the middle calyceal puncture. The total duration of the procedure was significantly shorter when compared with an access through lower calyx due to the quick puncture of the collecting system in a much shorter time period when compared to lower calyx approach. On the other hand, although not statistically significant, radiation exposure time was noted to be shorter in cases undergoing a middle calyceal puncture for PNL of renal pelvic stones. The postoperative stone-free rate was also higher in these cases, but the difference was not statisti-

cally significant (91.4 vs. 80% respectively). Last but not least, there was no statistically significant difference in Hb reduction rates, blood transfusion requirement, and complication rates between the 2 puncture sites.

Our current study is the first prospective and randomized one evaluating the advantages and disadvantages of lower versus middle calyceal puncture under sonographic guidance in a comparative manner. Evaluation of our data clearly emphasized the advantages of middle calyx puncture both for the treated cases as well as the surgeons themselves. First of all, the skin-to-stone distance has the shortest distance when compared with the other parts of the collecting system to be punctured. A direct puncture to the renal pelvis through the middle calyx will shorten both the puncture, dilation, and also the total procedural (anesthesia) time with limited radiation exposure. Additionally, this approach will enable the surgeon to visualize the renal pelvis and ureteropelvic junction area under full control which will further increase the chance of stone disintegration and complete removal. Additionally, the rate of complications, particularly the need for transfusion, was similar and comparable in both approaches making the middle pole puncture more advantageous. We believe that middle calyceal puncture under sonographic guidance could be the best approach in the percutaneous management of large renal pelvis stones with certain advantages allowing a shorter procedure with meaningfully higher stone-free rates.

Our study has 2 main limitations among which the first is the limited number of cases in each group that could be mentioned. Second, our current study evaluated the possible advantages of middle calyceal puncture only in the removal of renal pelvic stones. However, we believe that despite these limitations as the first prospective randomized study including the comparative data on the choice of renal puncture site during PNL under sonographic guidance, our findings will be contributive enough to the existing information published in the literature. Further randomized prospective studies including stones located in other parts of the kidney in large series of patient population are certainly needed.

Conclusions

Approach to the renal pelvic stones during the PNL procedure has commonly been through the lower calyceal puncture based on the false belief that this approach will be associated with lower complication rates. However, our findings clearly demonstrated the evident advantages of puncturing through the middle calyx under sonographic guidance for the management of large pelvic stones. Higher stone-free rates with limited complications and radiation exposure due to shorter procedural duration are the major advantages of this approach that should be considered particularly in high-risk patients.

Statement of Ethics

All procedures performed in the study involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Study protocol was approved by the Ethics Committee of the relevant hospital (Local ethical approval No. 2019/514/155/2).

Conflict of Interest Statement

The authors declare that they do not have any conflicts of interest to disclose.

Funding Sources

The authors did not receive any financial support.

Author Contributions

B.E.: project development, data analysis, and manuscript writing; K.S.: manuscript writing and editing and supervision; F.U.: data collection; A.H.S.: data collection; B.S.: data analysis; C.C.: data collection; A.S.: data collection and editing; and F.T.: data analysis and editing.

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