The Effect of Stone Localization on the Success and Complication Rates of Percutaneous Nephrolithotomy

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Purpose: To evaluate the effect of stone localization on the success and complication rates of the percutaneous nephrolithotomy (PNL) procedure.

Materials and Methods: Five hundred seventy-eight PNL procedures that were performed in our clinic were retrospectively evaluated. The patients were divided into seven groups according to the localization of the renal stones as: group 1, patients having stones only in the upper calyx; group 2, patients having stones only in the pelvis; group 3, patients having stones only in the lower calyx; group 4, patients having partial staghorn stones; group 5, patients having multiple calyx stones; group 6, patients having stones in both the pelvis and lower calyx and group 7, patients having complete staghorn stones. The first three groups were defined as simple stones, and the other four groups were defined as complex stones.

Results: The mean stone clearance rate was 77% in simple stones and 53% in complex stones (P = .005). The complication rate was significantly higher only in the group with complex staghorn stones at a rate of 19.5% (P = .006). The difference between preoperative and postoperative hematocrit concentrations was the least in the group that had stones in the pelvis and this value was statistically significantly lower than the patients with complex staghorn stones (P = .027). The mean duration of the operation and the number of ports was higher in patients with complex stones.

Conclusion: The localization of stone affects the success and complication rates of the operation.

Keywords: kidney calculi; surgery; nephrostomy; percutaneous; treatment outcome; adverse effects.

INTRODUCTION

The introduction of percutaneous nephrolithotomy (PNL) to the practice of urology and its becoming the gold standard in the treatment of large kidney stones occurred in a very short time period. In fact, with the use of this treatment, which first began to be interpreted as experimental in 1970s, the rate of open surgical procedures for renal stones decreased below 1% by 2002.[1,2] By means of the learning curve duration of 60 cases that could be assumed to be a short period, the interest of all urologists in this operation has increased and caused it to be a widely-used procedure.[3] PNL can be used safely in children under 3 years by avoiding disastrous complications and morbidities in open surgical treatment of kidney stones.[4] Besides, PNL can be applied in prone position as well as supine and flank suspended supine position easily.[5]

Although at first, it was a method that was mostly used in the treatment of small renal stones in single localizations, it was later successfully used in the treatment of larger complete staghorn stones.[6] When the simple stones and complex stones are compared, it is known that the success rate in simple stones is higher and more than one kidney access and prolonged surgical duration increases the complications and similarly the presence of multiple or staghorn stones increases the risk of bleeding.[7-9] Mousavi-Bahar and colleagues described a new technique for displacing the complex stones from an inaccessible calyx to an accessible calyx by the single pre-existing tract.[10] It is thought that the presence of stones in the pelvis and major calyx suggest higher success rates than the presence of stones in the minor calyx and this is the reason for the low success rates in staghorn stones.[11] However, PNL has now become the first choice in the treatment of renal stones larger than 2 cm.[12] The current study aimed to evaluate the effect of the localization of stones on the intraoperative and postoperative outcome of the PNL procedure in patients with renal stones.

MATERIALS AND METHODS

Five hundred seventy-eights PNL procedures were performed in our clinic between 2004 and 2013, and 548

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patients for which the data could be reached were retrospectively investigated.

PNL procedures were performed with indications appropriate with the current guidelines.[11] These indications were the presence of stones larger than 2 cm or the presence of stones that were unresponsive to shock wave lithotripsy (SWL) treatment. A 22 French (F) (Wolf®, Richard Wolf, GmbH, Germany) nephroscope and a 24 F (Storz®, Karl Storz Endoskope, Tuttlingen, Germany) rigid nephroscope were used for operations. In some pediatric patients, a 17 F MiniPerc (Storz®, Karl Storz Endoskope, Tuttlingen, Germany) was used and in some patients, a 14 F flexible nephroscope (Storz®, Karl Storz Endoskope, Tuttlingen, Germany) was used. The lithotripsy procedure was executed by using ultrasonographic, pneumatic, or combined (ultrasonic and pneumatic) methods. The operations were performed by urologists who were experienced in PNL or senior assistants who had assisted a sufficient number of operations under the guidance of an urologist.

The patients were divided into seven groups according to the position of the renal stone or stones according to the vertical axis as: group 1, patients having stones only in the upper calyx; group 2, patients having stones only in the pelvis; group 3, patients having stones only in the lower calyx; group 4, patients having partial staghorn stones group 5, patients having multiple calyx stones; group 6, patients having stones in both the pelvis and lower calyx and group 7, patients having complete staghorn stones. The first three groups were defined as simple stones and the other four groups were defined as complex stones. We have excluded the patients with just middle calyx stone, pelvis and middle or upper calyx stone; because patients' number was so small. We have excluded second and third PNL procedures too. All of patients were operated firstly PNL.

The duration of hospital stay was accepted as the duration of hospital stay after the day of the operation. The surface area of the stones were calculated with [(height × width × π) / 4] formula. The change in hematocrit (hct) was calculated by the difference between the preoperative and the postoperative 24th hour values. In patients who had transfusion of erythrocyte suspensions, hct value before transfusion was accepted as the postoperative hct value. In patients who had erythrocyte transfusion during the perioperative period, the value was calculated by subtracting three units from the postoperative hct value for every

Table 1. Clinical and demographic characteristics of study subjects.

Variables	Values
Patients number	538
Total kidney units	578
Mean age (years) (range)	41.6 ± 15.4 (3.5-81)
Sex (male/female)	240/298
Mean body mass index (kg/m²) (range)	26.4 ± 5.6 (14-60)
Stone side (right/left)	208/330

unit of erythrocyte suspension.

The starting of the surgery was accepted as the first introduction of the Chiba needle to the skin after insertion of the urethral catheter in the prone position. The time of end of the surgery was accepted as the time of the removal of the Amplatz tube following the insertion of the nephrostomy tube through the Amplatz tube. The time in between was accepted as the surgical duration. The duration of fluoroscopy was calculated as the total pedaling time of the fluoroscopy pedal during the operation. The clearance of the stone was accepted as the complete absence of the stone or the presence of a maximum of one stone in one calyx not causing infection, obstruction, or pain and additional treatment requirement with maximum 4 mm diameter. The complications were graded according to Clavien classifications. Grade 1 complications were not included in the evaluation. The number of kidney accesses was accepted as the number of nephrostomy tubes inserted to the kidney after the operation and more than 1 access (angular Y access) from a single access was accepted as single port. The patients in both groups were compared in terms of age, body mass index (BMI), duration of hospital stay, surface area of the stone, preoperative and postoperative hct differences, amount of blood transfusions, duration of operation and fluoroscopy, complication rates and stone clearance rates.

For statistical analysis, Fisher's exact test, Pearson's chi square, Kruskal-Wallis and one way ANOVA tests were used. For post-hoc analysis LSD (Least Significant Difference) test was used. A value of $P < .05$ was accepted as significantly difference.

RESULTS

When the total 548 were examined, the number of males

Table 2. Operative value by stone localizations.

Variables	Patients No.	Stone Surface (mm²)	Duration of Operation (min)	Access No. (%)	Complication Rate (%)	Stone-Free Rate (%)
Simple Stones						
Upper calyx	53	715 ± 772	70 ± 56	1.09 ± 0.35	9.4	79.2
Pelvis	132	560 ± 394	74 ± 52	1.05 ± 0.28	4.5	75.7
Lower calyx	180	632 ± 445	84 ± 52	1.08 ± 0.37	6.1	79.4
Complex Stones						
Partial staghorn	88	1021 ± 827	85 ± 52	1.46 ± 0.6	5.7	70.4
Multiple calyx	32	966 ± 526	105 ± 50	1.96 ± 0.64	9.3	56.2
Pelvis and lower calyx	47	1029 ± 1050	102 ± 52	1.44 ± 0.54	10.6	46.8
Complete staghorn	46	1436 ± 641	116 ± 52	2.08 ± 0.91	19.5	39.1

was 308 and the number of females was 240. Bilateral PNL was performed in 30 patients. A total of 578 PNL procedures were performed; 248 on the right kidney and 330 on the left kidney. The mean age of the patients was 41.6 years (range, 3.5-81 years), and mean BMI was 26.4 kg/m^2 (range, 14-60 kg/m²) (**Table 1**). While the mean duration of hospital stay was 5.3 days, the shortest duration of hospital stay was 2 days and the longest duration of hospital stay was 34 days. There was no difference between groups in terms of duration of hospital stay (*P* = .924).

The surface area of the stone that was obtained by using the two dimensional size of the stone was accepted as the size of the stone. There was no difference between the upper calyx (715 mm²), pelvis (560 mm²) and lower calyx (632 mm²) groups (*P* > .05). The size of the stones in patients having partial staghorn (1021 mm²), multiple calyx (966 mm²) and combined pelvis and lower calyx stones (1029 mm²) was significantly larger than the first three groups (*P* = .005); it was significantly lower than the group with complete staghorn (1436 mm²) stones (*P* = .005) (**Table 2**).

The mean duration of operation in all patients was 86 ± 54 min. There was no difference in terms of duration of operation in groups with upper calyx (70 ± 56 min), pelvis (74 ± 52 min) and lower calyx (84 ± 52 min) (*P* > .05). The mean duration of operation was significantly longer in patients with multiple calyx (105 ± 50 min), combined pelvis and lower calyx stones (102 ± 5 min) and complete staghorn (115 ± 52 min) stones when compared with the first three groups (*P* = .01) (**Table 2**).

The mean duration of fluoroscopy in all patients was 6 min (range, 0-46 min) and there was no significant difference between groups (*P* = .077). The mean number of kidney accesses in all patients was 1.3 ± 0.6. There was no difference between the patients with upper calyx (1.09 ± 0.35 min), pelvis (1.05 ± 0.28) and lower calyx (1.08 ± 0.38) stones in terms of the mean number of accesses. The number of accesses in patients with partial staghorn (1.46 ± 0.6) and combined pelvis and lower calyx (1.44 ± 0.54) stones was significantly higher than the first three groups (*P* = .001); it was significantly lower than the patients with multiple calyx (1.96 ± 0.64) and complete staghorn (2 ± 0.91) stones (*P* = .001) (**Table 2**).

The preoperative and postoperative mean hct difference was 6.1 ± 4.4% (0.1-28.5%). The mean number of erythrocyte suspension units that was transfused was 0.3 ± 0.7 (range, 0-6). In the comparison of the groups, the decrease in hct in the group with pelvic stones (5.3 ± 3.6%) was significantly lower than that of the group with combined pelvic and lower calyx stones (7.3 ± 5.8%) (*P* = .006), partial (6.6 ± 4.8%) (*P* = .027) and complete staghorn stones (7.3 ± 3.9%) (*P* = .007).

The stone clearance rates in patients with upper calyx, pelvis and lower calyx stones was 79.2%, 75.7%, and 79.4%, respectively (*P* = .403). The success rate in simple stones was 77%. The stone clearance rate in patients with partial staghorn, multiple calyx, combined pelvis and lower calyx, and complete staghorn stones was 70.4%, 56.25%, 46.8% and 39.1%, respectively. The mean success rate in complex stones was 53% and it was significantly lower than for simple stones (*P* = .01) (**Table 3**).

When all patients were considered, the complication rate was 7.6%. The lowest complication rate was in the group with pelvic stones (4.5%) and the highest complication rate was in the group with complete staghorn stones (19.5%). The complication rate in upper calyx stones was 9.4% and it was found to be high when compared with the simple stones, although not statistically significant (*P* > .05). In the comparison of the groups, the complication rate was significantly high only in the group with complete staghorn stones (*P* = .006). Additionally, the mean complication rate in complex stones was 10.1% and it was significantly higher than for simple stones (*P* = .006) (**Table 3**). The most frequent complication that was seen in the current series was hemorrhage. Out of 41 patients with hemorrhage, nephrectomy was conducted in only one patient due to unpreventable hemorrhage and selective arterial embolization under angiography was conducted on 4 patients; in other patients hemorrhage was controlled with blood transfusions. Pneumonia in 2 patients and cellulitis in the area of operation in 1 patient was treated with antibiotic therapy. A double J ureteral stent was inserted into the urethra in 2 patients with pelvis perforation and in 3 patients with persistent (longer than 24 hours) urine leakage and was treated by keeping the stent in place for 4 weeks. The hemothorax in 2 patients, which developed due to the intercostal approach, was treated by the insertion of a chest tube. The small intestinal perforation that developed in 1 patient was recognized during the operation and treated with primary repair under open surgery. The urosepsis that developed in 4 patients after PNL was treated with intense antibiotic and fluid therapy (**Table 4**).

DISCUSSION

By using a nomogram called “S.T.O.N.E. Nephrolithometry”, Okhunov and colleagues attempted to predict the postoperative success and complications with the preoperative data before the PNL procedure.[13] Those in which 1-2 calyx were affected were scored with “1” point, those in which 3 calyx were affected were scored with “2” points, and those with staghorn stones were scored with “3” points. With the increase in the total score, the stone clearance rate decreased and the complication rate increased. Again in the same study, it was found that while the mean number of calyx that were affected was 1.8 in

Table 3. Comparison of simple and complex stones operative databases.

Variables	Simple Stones (n = 365)	Complex Stones (n = 213)	*P*
Stone surface (mm^2)	618 ± 537	1090 ± 774	.001
Duration of operation (min)	75 ± 53	98 ± 51	.02
Access number	1.07 ± 0.34	1.68 ± 0.65	.003
Complication rate (%)	6.6	10.1	.006
Stone-free rate (%)	77	53	.005

Table 4. Complications according to Clavien classification.

Grade	Type of Complication	Patients Number	Treatment
Grade 2	Serious bleeding	36	Blood transfusion
	Pneumonia	2	Antibiotics
	Cellulite on lumbar region	1	Antibiotics
Grade 3a	Pelvis perforation	2	Double J ureteral stent insertion for 4 weeks
	Persistent urine leakage	3	Double J ureteral stent insertion for 4 weeks
	Hemothorax	2	Insertion chest tube
Grade 3b	UPJ stenosis	1	Pyeloplasty
	Perirenal hematoma	4	Selective angioembolization
Grade 4a	Retractable bleeding	1	Nephrectomy
	Bowel perforation	1	Primary repairing
Grade 4b	Urosepsis	4	Antibiotics

Abbreviation: UPJ, ureteropelvic junction.

patients who were cleared from the stones, it was 3.3 in patients with residual stones, and the difference was statistically significant.[13] It seems that the highest success rate in patients with stones in single calyx localization and the lowest success rate in complete staghorn stones the current study is parallel to the aforementioned study.
Muslumanoglu and colleagues demonstrated in their study that the success rate in simple stones was 85% and was 52% in complex stones ($P < .01$).[7] Similarly in our series, it was demonstrated that in 75% of the patients with complex renal stones, there is a need for more than 1 port and the complication rate in these patients is higher.
In a study that graded the complications that develop during PNL according to the Clavien classification, the "Guy's Stone Score" scoring system was used in the prediction of complications.[9] According to this study, the success rate of the operation in patients with staghorn stones, abnormal renal anatomy, and spinal deformities decreased and the complication rate increased. Similarly, in patients with upper calyx stones, the success rate was lower and the complication rate was higher when compared with the patients with lower calyx and pelvis stones. The higher complication rate in upper calyx stones than pelvis or lower calyx stones and similarly the higher complication rate in staghorn stones in the current series also support the aforementioned study.
Lee and colleagues reported the rate of major complications during PNL procedure as 6%.[14] However, in their study they did not accept hemorrhage as a major complication. On the other hand, when Segura and colleagues included the hemorrhage within the major complications, they reported the rate of major complication as 6.2%, and 3% of this was reported to be hemorrhage.[15] However, the low complication rate in this study could be contributed to the fact that it was performed in 1985 and at that time, fewer aggressive PNL procedures were performed. In the current study, the total complication rate was 7.6%, which is parallel to the literature.
The literature review revealed that the rate of hemorrhage requiring angioembolization was 0.8-1.4% and the need for nephrectomy was 0.1-0.3%.[16,17] In the current series, hemorrhage requiring angiographic embolization occurred in 4 patients (0.7%) and in 1 patient, nephrectomy was required due to unpreventable hemorrhage (0.17%). One study concluded that the factors increasing the hemorrhage during PNL are staghorn stones, high BMI, increased load of stones, prolonged surgical duration and the absence of hydronephrosis.[18] The current study revealed that the least hemorrhage was found in patients with stones that were localized in the pelvis and the reason for this was the low load of stones, low number of calyx, and short duration of surgery.
In the literature, it was reported that the incidence of intestinal damage was 0.7%, the incidence of double J ureteral stent requirement due to urine leakage was 1.1%, and the incidence of collecting system perforation was 0.4%.[15] In the current series, intestinal perforation that developed in only 1 patient (0.17%) was recognized in the early period and repaired perioperatively, urine leakage requiring double J ureteral stent insertion developed in 3 (0.5%) patients, and collecting system perforation developed in 2 (0.34%) patients.
Upon evaluation of the duration of hospital stay after PNL, Olbert and colleagues reported the mean duration of hospital stay as 7 (3-26) days.[19] Although they have demonstrated that with the decrease in BMI and with the increase in size of the stone, the duration of hospital stay increased, the current series reported the mean duration of hospital stay as 5.3 days and no correlation was found with the localization of the stone. The longest duration of hospital stay in the current series was 34 days. At first this patient underwent bilateral open nephrolithotomy and bilateral PNL was performed in the same session. However, as bleeding occurred after bilateral PNL, an erythrocyte transfusion was given. Furthermore, a blood transfusion reaction developed in the patient, followed by pleural effusion and pneumonia, and the duration of hospital stay was prolonged.
Predictive factor of residual stones after PNL are complete staghorn stones and the presence of additional calyceal stones. Complications are high if PNL is not performed by an experienced endourologist or if preoperative urine culture is positive.[20] The decrease in the success rate in complex stones in the current series can be attributed to the increase in stone load together with the localization of the stone. In fact, this situation is an inevitable result of the increase in volumes of complex stones.

CONCLUSION

It is possible to predict the success and complication rates before the PNL procedure according to the localization of the stone in the kidney. With the increase in the number of calyx that are affected by the stone, the success rate decreases and complication rate increases. Although the success rate in upper calyx stones is parallel to the other simple stones, the complication rate in some is higher. All of these factors should be considered and the possible risks and the patient should be informed of the possibility of the requirement of additional procedures prior to the operation.

CONFLICT OF INTEREST

None declared.

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