Factors Affecting Outcomes of Percutaneous Nephrolithotomy in Horseshoe Kidneys

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OBJECTIVE To analyze the patient- and procedure-related factors affecting the outcomes of percutaneous nephrolithotomy (PNL) in horseshoe kidneys (HSKs).

METHODS A retrospective analysis was done of patients with stones in HSKs treated with PNL in 3 referral centers between 1998 and 2013. Demographics, along with perioperative characteristics, were evaluated in detail as to whether or not they had an effect on the success and complication rates.

RESULTS A total of 54 HSKs with calculi in 53 patients were treated with PNL. Mean stone size was 28.4 ± 19.6 mm (range, 10-120 mm). Fifty-three patients were treated through a single tract, and 1 patient required additional access. Access was directed to the upper calyx (n = 27), middle calyx (n = 17), and lower calyx (n = 10) through the intercostal (n = 23) and subcostal (n = 31) areas. Flexible nephroscopy was used in 18.5% of the procedures. Postoperative complications were observed in 9 (16.7%) of the procedures. Success rate was 66.7% after a single session of PNL and increased to 90.7% with additional treatments. Although patient demographics, preoperative imaging, and other operative measures did not have significant effect on the complication rate, stone complexity and multiplicity, in combination with flexible nephroscopy, were found to significantly affect the success rate ($P = .026$, $P = .043$, and $P = .021$, respectively). However, in multivariate analysis stone multiplicity was the only factor that affected success rate ($P = .004$).

CONCLUSION Stone parameters play an important role in achieving stone-free status in HSKs. Use of flexible nephroscopy positively affects the success rate by allowing reaching the peripherally located calices. UROLOGY 84: 1290−1294, 2014. © 2014 Elsevier Inc.

The common renal fusion abnormality, horseshoe kidney (HSK), originates from the abnormal fusion of metanephric blastema during the embryologic period.[1] Normal anatomic positioning of the kidneys is arrested by the inferior mesenteric artery due to fusion in the lower poles, resulting in malrotation, anterior displacement, and ectopy of the kidneys. The incidence of this issue has been reported to range from 1 in 400 to 1 in 666.[1,2] Kidney stones are found in approximately 21%-60% of HSK cases, making them one of the most common complications.[1]

Features that complicate the treatment of urolithiasis in HSKs include an anteriorly displaced renal pelvis, poor renal drainage, variability in vascular structure, malrotation, and ectopic location. Although shockwave lithotripsy (SWL) and ureteroscopic laser lithotripsy (URS) are generally recommended for small calculi, percutaneous nephrolithotomy (PNL) is the most commonly used treatment option for large and/or complex renal calculi or in cases where other treatment modalities have failed in HSK. Despite the increased success of PNL, attributable to advances in technology and refinements in operation technique, it still has a significant complication rate.

Although factors affecting the success and complication rates of PNL in anatomically normal kidneys are well researched, studies exploring variables associated with outcomes of PNL in HSKs are limited. A recent study evaluating parameters related to success of PNL found that stone parameters were significant.[3] To achieve better PNL results in this specific group of patients, therefore, further studies are warranted. In this study, we aimed to systematically analyze the patient- and procedure-related factors affecting the outcomes of PNL in HSKs.

METHODS

After obtaining institutional review board approval, a retrospective analysis was done of patients with stones in HSKs treated with PNL in 3 referral centers between 1998 and 2013. Same surgical teams in each center performed the procedures. The following patient demographics were collected: age, gender,

Financial Disclosure: *The authors declare that they have no relevant financial interests.*

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Submitted: June 24, 2014, accepted (with revisions): August 7, 2014

http://dx.doi.org/10.1016/j.urology.2014.08.008
0090-4295/14

stone-related parameters, prior therapies, preoperative imaging methods, operative details, and success and complication rates. These demographics, along with perioperative characteristics, were evaluated in detail as to whether or not they had an effect on the success and complication rates.

All patients were evaluated with basic laboratory and radiologic methods. Blood count, urinalysis, creatinine, blood urea nitrogen, and coagulation profile were studied. Patients with positive urine culture were treated, as appropriate. All patients underwent a detailed radiologic assessment including intravenous urography (IVU) and/or computed tomography (CT). Stone size was measured based on the imaging method used. Stone complexity (simple, partial staghorn, complete staghorn, or complex stones) and stone multiplicity (single or multiple) were evaluated.

Operative Technique

All procedures were done in prone-positioned patients under general anesthesia, with the guidance of fluoroscopy. After gaining access under fluoroscopy, the tract was dilated up to 30 Fr and an Amplatz sheath (Cook Surgical, Bloomington, IN) was inserted into the collecting system. Stone disintegration was performed using ultrasonic, pneumatic lithotripter or laser, through a 24 Fr rigid and/or 15 Fr flexible nephroscope. Additional access was created in any requirement. After endoscopic and fluoroscopic assessment of stone-free status, nephrostomy tubes were left in place. The following intraoperative variables were recorded for analysis: access site (intercostal or subcostal), access location (upper, middle, or lower pole calyx), and nephroscope used (rigid or rigid and flexible).

Patients were reevaluated with laboratory tests and plain radiography of kidneys, ureters, and bladder postoperatively. Complications were graded using the Clavien Classification System.[4] Nephrostomy tubes were removed on postoperative day 1 or 2. Unless there was an unresolved issue, patients were discharged after removal of the nephrostomy tubes. Stone-free status or the presence of asymptomatic fragments <4 mm on first-month CT were both recorded as successful outcomes. Final success was assessed after axillary treatment modalities.

Statistical Analysis

Statistical analysis was performed using SPSS 16.0 Windows software (SPSS Inc., Chicago, IL). In the univariate analyses, continuous variables were compared using the Mann-Whitney *U* test. Categorical variables were analyzed for statistical significance using the chi-square or the Fisher exact test. If any parameter was found to be significant with univariate analysis, further investigation took place using multivariate binary logistical regression analysis. In all analyses, 2-sided hypothesis testing was carried out, and *P* values <.05 were deemed significant.

RESULTS

A total of 54 HSKs with calculi in 53 patients (36 males and 17 females) were treated with PNL in 3 referral centers. The mean age was 46.03 ± 18.6 years (range, 9-78 years). Average stone size was 28.4 ± 19.6 mm (range, 10-120 mm). Of the 53 patients, 13 (24.5%) had previous kidney interventions, including SWL (n = 6), URS (n =5), PNL (n = 3), and open surgery (n = 1). Demographic measures are listed in Table 1.

Table 1. The demographics of the patients are listed

Preoperative Parameters	Value
N	54
Mean age (y)	46.03 ± 18.6 (9-78)
Sex (male/female)	36/17
Mean stone size (mm)	28.4 ± 19.6 (10-120)
Stone complexity, n (%)	
Simple stone	18 (33.3)
Partial staghorn	15 (27.8)
Complete staghorn	12 (22.2)
Complex (multicaliceal)	9 (16.7)
Stone number, n (%)	
Single	23 (42.6)
Multiple	31 (57.4)
Stone laterality (right/left)	22/32

Fifty-three patients were treated through a single tract, and 1 patient required additional access. Access was directed to the upper calyx (n = 27), middle calyx (n = 17), and lower calyx (n = 10) through the intercostal (n = 23) and subcostal (n = 31) areas. Flexible nephroscopy was used in 18.5% of the procedures.

Postoperative complications were observed in 9 (16.7%) of the procedures. A mild fever was the most common complication (Clavien grade 1), and was treated medically in 3 cases. Viral enteritis (Clavien grade 2) presenting with diarrhea was observed in 1 patient and managed with intravenous fluid replacement. Urine leakage (Clavien grade 1) was observed in another patient and resolved spontaneously in fourth day of surgery, without need for an intervention. Blood transfusion (Clavien grade 2) was required in 2 (3.7%) patients postoperatively. Other treated complications included urinary tract infection (UTI; n = 1; Clavien grade 2) and sepsis (n = 1; Clavien grade 4; Table 2). In the statistical analysis, we found that patient demographics (age, stone complexity, stone multiplicity, and intervention history), preoperative imaging method, and other operative measures (access site, location, number, and nephroscopy type) did not have a significant effect on the complication rate of PNL in HSKs (Table 3).

The success rate was 66.7% after a single session of PNL. Although 30 (59.3%) of them were totally stone free, small fragments <4 mm were detected in 4 cases (7.4%). With additional treatments, including URS (n = 7) and PNL (n = 7), the success rate increased to 90.7% (including 5.6% small fragment rate). In univariate analysis, stone complexity and multiplicity, in combination with flexible nephroscopy, were found to significantly affect the success rate (*P* = .026, *P* = .043, and *P* = .021, respectively). However, in multivariate analysis, stone multiplicity was the only factor that affected the success rate (*P* = .004; odds ratio, 7.87; confidence interval, 1.96-31.57; Table 3).

COMMENTS

Nephrolithiasis is one of the most common clinical presentations of HSK and is seen in 21%-60% of cases.[1] Risk

Table 2. Outcomes of procedures are summarized

Parameters	Value
Mean access number	1.01 ± 0.13 (1-2)
Access location, n (%)	
Upper calyx	27 (50)
Middle calyx	17 (31.5)
Lower calyx	10 (18.5)
Access site, n (%)	
Intercostal	23 (42.6)
Subcostal	31 (57.4)
Flexible nephroscopy usage, n (%)	10/54 (18.5)
Complication rate, n (%)	9/54 (16.7)
Clavien grade 1	
Fever	3
Urine leakage	1
Clavien grade 2	
Viral enteritis	1
Urinary tract infection	1
Bleeding requiring blood transfusion	2
Clavien grade 4	
Sepsis	1
Initial success rate, n (%)	36 (66.7)
Stone free	32 (59.3)
Fragments <4 mm	4 (7.4)
Additional treatment, n (%)	14 (25.9)
URS	7
PNL	7
Final success rate, n (%)	49/54 (90.7)
Stone free	46 (85.2)
Fragments <4 mm	3 (5.5)

PNL, percutaneous nephrolithotomy; URS, ureteroscopic laser lithotripsy.

Table 3. The effect of parameters on complication (P^1) and success rate (P^2)

Parameter	P^1 Value	P^2 Value
Clinic (Dep A/B/C)	.37	.57
Age	.84	.71
Stone size	.31	.28
Stone complexity	.12	.026
Stone multiplicity (yes/no)	.71	.043
Preoperative imaging method	.14	.92
Previous intervention history (yes/no)	1.0	.31
Access number	.16	.33
Access location (upper-middle-lower calyx)	.34	.68
Access site (subcostal-intercostal)	.47	1.0
Usage of flexible nephroscopy	.66	.021

factors for stone formation in patients with HSK include impaired collecting system drainage related to high ureteral insertion, the unusual course of the upper portion of ureter over the isthmus, abnormal vascular structure; increased risk of UTI (30%); and metabolic conditions. With improvements in endourologic methods, treatment of stones in HSK has shifted from open surgery to minimally invasive methods.[1] Although PNL is the most commonly used technique, SWL, URS, and laparoscopy are other minimally invasive treatment methods used for calculi in HSKs.

SWL is accepted as the primary treatment modality for small renal calculi, even within anatomically abnormal kidneys.[5-8] The stone-free rate (SFR) of SWL for HSK reported in the literature ranges from 27.8% to 75.9%.[6-8] The main drawbacks for SWL in HSK are increased skin-to-stone distance due to anterior displacement of HSK, difficulty in localizing stones in an oblique position (due to the spine acting as an obstacle), and impaired renal drainage. Ray et al[8] reported on a series of patients with HSK treated with SWL, and investigated factors related to success rate. At the third month of follow-up, they had achieved a 63.6% success rate, with a mean 1.71 SWL sessions per stone but the SFR was only 39.1% due to impaired stone clearance. In the multivariate analysis, stone burden, stone localization, and body mass index were all found to be predictive factors for the success of SWL. In the present study, 6 patients had a history of failed SWL therapy.

Since the introduction of a new generation of flexible ureterorenoscopes in recent years, retrograde intrarenal surgery has gained wide acceptance and popularity. There are only limited number of studies presenting the outcomes of URS for the treatment of stones within HSKs.[9-11] The mean stone sizes reported in these 3 studies are 14, 16, and 17.8 mm. Although the SFR after a single session of URS was reported to be between 70%[11] and 75%,[9] Molimard et al[10] achieved an 88.2% SFR with staged therapy (41.2%). Despite the advantages of shorter hospitalization time, decreased complication and morbidity rates, and comparable SFRs, increased stone size and lower pole localization were significant in negatively affecting the success of URS in HSKs. In the present study, the mean stone size was 28.4 mm (range, 10-120 mm), and 5 patients had a history of failed URS therapy.

With advancements in lithotripter and optical technologies, refinements in PNL techniques, and increased experience, PNL has become the primary treatment option for large renal calculi, even for abnormal kidneys. Factors complicating surgery for HSK patients include increased access tract length due to anterior displacement and malrotation. The upper pole access tract is recommended, as it offers the ability to reach all calices, the pelvis, and proximal ureter and provides better alignment with the long renal axis, preventing excessive torque that may lead to bleeding. In addition to its intrarenal advantages, the risk of pleural injury is comparatively low due to inferior displacement. In the literature, the usage of upper pole caliceal access for PNL in HSK ranges from 48% to 100%.[12-16] Among these studies, Raj et al[12] reported only 1 case requiring chest tube placement in the series with 62.5% upper pole access rate. In the present study, the upper pole calyx was the most common access route (50%). The reason it was used, 50% of the procedures is related to the multisurgeon aspect of the study. Access via the subcostal area was done in 57.4% of cases. None of our patients were observed to have thoracic complications. In the statistical analysis, the access site and location did not have a significant impact on patient outcomes.

To achieve high rate of success in complex renal calculi and/or complex and abnormal renal anatomy, the use of flexible nephroscopy is very important. In addition, it lowers complication and morbidity rates secondary to multiple tracts by decreasing the requirement for additional access. Although it is not routinely used by some authors,[13,17] in the study reported by Miller et al,[14] the routine use of flexible nephroscopy was reported as one of the reasons for their high success rate. They achieved an 84.1% initial SFR and a 93.2% success rate after "second look" nephroscopy in 11.4% of the kidneys. By contrast, the use of flexible nephroscopy did not have a significant impact on stone-free status in a recently published study.[3] In the present study, flexible nephroscopy was used in addition to rigid nephroscopy in only 18.5% of the procedures. Although we prefer to use flexible nephroscopy especially in anatomically abnormal kidneys, flexible nephroscopy was not steadily available during procedures in all centers. Additional access was required in only 1 patient. In univariate analysis, the use of flexible nephroscopy was found to be significant in achieving stone-free status ($P = .021$). In multivariate analysis, however, it was not found to be statistically significant with regard to the success rate.

Preoperative radiologic assessment plays a key role in deciding on proper treatment methods and in planning of the access tract, especially in abnormal kidneys. Although IVU provides information about collecting system anatomy and obstructions, CT gives more detailed information about both the urinary tract and neighboring organs. Arrested ascending and abnormal positioning of HSK and defects in lateroconal fascia are associated with retrorenal and posterolateral colon. The fusion of anterior and posterior renal fascia, lateroconal fascia, makes the postero-lateral margin of anterior pararenal space where ascending and descending colon lie. Some authors state that CT is the recommended imaging modality before PNL as an aid in planning the proper access route to avoid complications in HSK.[18,19] Fortunately, medially localized access tract to the dorsomedially or dorsolaterally oriented calices decreases the risk of colon injury in HSKs. In the present study, CT, IVU, or both CT and IVU were used in 34, 4, and 15 patients, respectively. We did not observe any patients with postoperative colonic injury. Statistical analysis showed that prior imaging modality had no effect on the outcomes of PNL in HSK.

Previous studies presented that PNL is a safe and efficient method for HSKs and has a similar complication and success rate compared with the same surgery in normal kidneys.[20,21] Notably, patients with HSKs did not specifically carry an increased risk of bleeding during PNL because of the anteriomedial localization of their vascular structures. Upper pole access and use of flexible instruments are other factors thought to reduce the risk of bleeding. In the literature, blood transfusions were necessary for 0%-13.3% of the patients.[14,22] In the present study, a blood transfusion was required for only 2 patients (3.7%). On the other hand, infectious complications are not rare; recurrent UTIs are one of the most common complications of HSK.[23] To decrease infection-related complications, Miller et al[14] recommend prescribing antibiotics for 2 weeks before PNL, even if the urine culture is negative. In their series, the overall complication rate was reported to be 14.3%, with a 2.85% rate of urosepsis. In our series, UTI (n = 1) and urosepsis (n = 1) were the only infectious complications that needed to be treated medically. Our overall complication rate of 16.7% was similar to that reported by other investigators. In our statistical analysis, no specific parameter was found to be significant in predicting complications of PNL in HSKs.

Stone size, complexity, and multiplicity are all important parameters in making decisions about the treatment regimen and in predicting surgical outcomes. Although success rates are inversely proportional to increasing stone burden and complexity, complication rates rise proportionally with an increase in stone burden.[24] Skolarikos et al[3] found that stone complexity, multiplicity, and burden all affected the success rate. But in multivariate analysis, staghorn stones predicted poor outcomes. In the present study, stone parameters were not found to be related to the complication rate. On the other hand, stone complexity and multiplicity were significant factors affecting the success rate. On multivariate analysis, stone multiplicity was the only factor affecting success rate. Although our initial success rates were lower than others reported in the literature, after additional sessions of PNL (n = 7) and URS (n = 7), we achieved a success rate of 90.7%.

The main limitations of our study were its retrospective design and small sample size. In addition, data were collected from 3 different centers using diverse techniques and with differing amounts of experience. Despite these limitations, we believe our results may be of assistance in predicting the complication and success rates of PNL in HSKs.

CONCLUSION

Stone disease in HSKs represents a surgical anatomic challenge. Although complications are less affected by demographic and operative parameters, stone complexity and multiplicity play an important role in achieving stone-free status in this multicenter analysis. The use of flexible nephroscopy positively affects the success rate by allowing surgeons to reach the peripherally located calices.

References

1. Yohannes P, Smith AD. The endourological management of complications associated with horseshoe kidney. *J Urol*. 2002;168:5-8.
2. Weizer AZ, Silverstein AD, Auge BK, et al. Determining the incidence of horseshoe kidney from radiographic data at a single institution. *J Urol*. 2003;170:1722-1726.
3. Skolarikos A, Binbay M, Bisas A, et al. Percutaneous nephrolithotomy in horseshoe kidneys: factors affecting stone-free rate. *J Urol*. 2011;186:1894-1898.
4. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg*. 2004;240:205-213.
5. Sheir KZ, Madbouly K, Elsobky E, Abdelkhalek M. Extracorporeal shock wave lithotripsy in anomalous kidneys: 11-year

experience with two second-generation lithotripters. *Urology*. 2003;62:10-16.
6. Kirkali Z, Esen AA, Mungan MU. Effectiveness of extracorporeal shockwave lithotripsy in the management of stone-bearing horseshoe kidneys. *J Endourol*. 1996;10:13-15.
7. Lampel A, Hohenfellner M, Schultz-Lampel D, et al. Urolithiasis in horseshoe kidneys: therapeutic management. *Urology*. 1996;47:182-186.
8. Ray AA, Ghiculete D, D'A Honey RJ, Pace KT. Shockwave lithotripsy in patients with horseshoe kidney: determinants of success. *J Endourol*. 2011;25:487-493.
9. Weizer AZ, Springhart WP, Ekeruo WO, et al. Ureteroscopic management of renal calculi in anomalous kidneys. *Urology*. 2005; 65:265-269.
10. Molimard B, Al-Qahtani S, Lakmichi A, et al. Flexible ureterorenoscopy with holmium laser in horseshoe kidneys. *Urology*. 2010; 76:1334-1337.
11. Atis G, Resorlu B, Gurbuz C, et al. Retrograde intrarenal surgery in patients with horseshoe kidneys. *Urolithiasis*. 2013;41:79-83.
12. Raj GV, Auge BK, Weizer AZ, et al. Percutaneous management of calculi within horseshoe kidneys. *J Urol*. 2003;170:48-51.
13. Symons SJ, Ramachandran A, Kurien A, et al. Urolithiasis in the horseshoe kidney: a single-centre experience. *BJU Int*. 2008;102: 1676-1680.
14. Miller NL, Matlaga BR, Handa SE, et al. The presence of horseshoe kidney does not affect the outcome of percutaneous nephrolithotomy. *J Endourol*. 2008;22:1219-1225.
15. Gupta NP, Mishra S, Seth A, Anand A. Percutaneous nephrolithotomy in abnormal kidneys: single-center experience. *Urology*. 2009;73:710-715.
16. Mosavi-Bahar SH, Amirzargar MA, Rahnavardi M, et al. Percutaneous nephrolithotomy in patients with kidney malformations. *J Endourol*. 2007;21:520-524.
17. Shokeir AA, El-Nahas AR, Shoma AM, et al. Percutaneous nephrolithotomy in treatment of large stones within horseshoe kidneys. *Urology*. 2004;64:426-429.
18. Skoog SJ, Reed MD, Gaudier FA Jr, Dunn NP. The posterolateral and the retrorenal colon: implication in percutaneous stone extraction. *J Urol*. 1985;134:110-112.
19. Ghani KR, Rintoul M, Patel U, Anson K. Three-dimensional planning of percutaneous renal stone surgery in a horseshoe kidney using 16-slice CT and volume-rendered movies. *J Endourol*. 2005; 19:461-463.
20. Ozden E, Bilen CY, Mercimek MN, et al. Horseshoe kidney: does it really have any negative impact on surgical outcomes of percutaneous nephrolithotomy? *Urology*. 2010;75:1049-1052.
21. Osther PJ, Razvi H, Liatsikos E, et al; Croes PCNL Study Group. Percutaneous nephrolithotomy among patients with renal anomalies: patient characteristics and outcomes; a subgroup analysis of the clinical research office of the endourological society global percutaneous nephrolithotomy study. *J Endourol*. 2011;25: 1627-1632.
22. Jones DJ, Wickham JE, Kellett MJ. Percutaneous nephrolithotomy for calculi in horseshoe kidneys. *J Urol*. 1991;145:481-483.
23. Gross AJ, Fisher M. Management of stones in patients with anomalously sited kidneys. *Curr Opin Urol*. 2006;16:100-105.
24. Seitz C, Desai M, Häcker A, et al. Incidence, prevention, and management of complications following percutaneous nephrolitholapaxy. *Eur Urol*. 2012;61:146-158.