ORIGINAL RESEARCH

Analysis of the Clinical Efficacy and Safety of Percutaneous Nephrolithotomy in Patients with Anatomical Variations: A Single Center Retrospective Study

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Introduction and Objective: Percutaneous Nephrolithotomy (PCNL) is the standard of care for renal stones >2cm. Kidneys with anatomical disparities resulting from fusion (horseshoe), malrotation, ectopic location (allografts) and bifid collecting systems present as a challenge because variations in vasculature, calyceal rotation and intervening viscera may make percutaneous access treacherous. Reported here is the authors' experience with PCNL in these types of kidneys.

Methods: A chart review was done on all patients who underwent PCNL at the National Kidney and Transplant Institute (NKTI) from 2012-2016. Those with anatomical variations were identified and analyzed. Patient demographics (age, gender, co-morbidity) and stone characteristics (Guy's stone score, laterality) were summarized. Intraoperative parameters such as location of puncture site (upper, mid, inferior calyces), number of tracts (single vs. multiple), operative time, estimated blood loss (EBL), and length of hospital stay (LOS) were analyzed. The primary endpoints were stone-free and complication rates according to the Clavien-Dindo (CD) classification.

Results: A total of 1,657 PCNLs were performed during the study period, of which 42 had anatomical variants. The mean age was 45.2±8.8 (R= 28-65) with a male to female ratio of 3:1. There were 18 horseshoe (42.9%), 15 bifid (35.7%), 7 malrotated (16.7%) and 2 renal allografts (4.8%.); Laterality-wise, 28 (67%) were left-sided, 12 (29%) were right-sided and 2 (5%) had right-sided pelvic kidneys (allografts). The Guy stone scores were 3 and 4 in 13 (30%) and 29 (70%) patients, respectively. The mean stone diameter was 3.8±0.6 cms. (R=2.5-5.5). Majority, n=37 (88%) were treated with an upper pole access. Thirty-six (86%) needed a single tract and while six (14%) required multiple tracts (bifid pelvis). The mean operative time was 111.5±28.1 mins. (R=65-188), EBL was 461±278.4 cc (R=200-1300). LOS was 3.6±0.94 days (R=2-7). The stone-free rate was 95%. Twenty-five (59.5%) complications were documented. Fifteen (35.7%) had fever: Grade I CD, and 10 (23.8%) required transfusion: Grade II CD. There was no mortality.

Conclusion: PCNL still persists as the treatment of choice for nephrolithiasis in kidneys with variations in anatomy or position. A high stone clearance rate can be achieved while minimizing complications.

Key words: Percutaneous Nephrolithotomy (PCNL), anatomical variants, stone-free rate, complications

Introduction

Renal stone disease affects 10-20 % of the population worldwide. Previously, the surgical options for the treatment of renal calculi were limited to open stone surgery. However currently, different modalitites are now available such as extracorporeal shockwave lithotripsy,

retrograde intrarenal surgery and percutaneous nephrolithotripsy.

Percutaneous nephrolithotomy is a minimally invasive endoscopic procedure for removal of large renal stones via a nephroscope passing into the collecting system. It is now considered as the gold standard for renal calculi more than 2 centimeters in size.

Different renal anatomic variants can be diagnosed during adulthood, including ectopic or fused kidneys (e.g. horseshoe anomaly). In these kidneys, the incidence of stone formation is higher due to associated urinary stasis and infection. The application of PCNL to these kidneys (kidneys not located in their usual anatomical location or those with aberrant anatomical variants) can be very challenging due to their unusual location (ectopic) or aberrant position. Kidneys with anatomic variants have unusually positioned renal pelvis and calyces, and aberrant blood supply. Ureteropelvic junction obstruction (UPJO) may also be present resulting from dense fibrous tissue at the proximal ureter or a high-inserting ureter.

Unique challenges in PCNL may result from intervening visceral organs such as the small or large bowel, making them prone to injury during the initial access. Consequently, this may affect the choice of calyceal entry and the ability to clear the stones effectively. For this reason, many prefer to treat these anomalous kidneys with stones using conventional open surgery.

The suggested predisposing factors include the abnormal position of the renal pelvis and calyces, anomalous vasculature, distortion of the upper ureter or the ureteropelvic junction (UPJ) by a dense amount of fibrous tissue, and a high-inserting ureter with abnormally-positioned UPJ.

The objective of this study was to evaluate the clinical safety and efficacy of PCNL for patients with congenital renal anomalies performed in NKTI as well as to compare the demographic data and preoperative profile of patients with renal anatomical variants

Reported here is the authors' experience with percutaneous nephrolithotomy with kidneys having anatomic variations performed at a single center.

Methods

Study Design

This is a retrospective cohort study that evaluated the clinical safety and efficacy of PCNL in patients with renal anatomic variants.

Sample Size

Sample size was computed using prevalence of 0.05 and precision 0.10 with a result of 34. Sample size was computed using pROC package of R ver3.6.3

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> power.roc.test(auc=0.960, sig.level=0.05, power=0.99)

     One ROC curve power calculation

         ncases = 6.178686
       ncontrols = 6.178686
             auc = 0.96
       sig.level = 0.05
           power = 0.99
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Study Population

Records of patients who underwent percutaneous nephroilithotomy from 2012-2016 were reviewed. The sample size was computed based on the aforementioned formula.

Those with anatomical variations were identified and analyzed. Patient demographics (age, gender, co-morbidity) and stone characteristics (Guy's stone score, laterality) were summarized. Intraoperative parameters such as location of puncture site (upper, mid, inferior calyces), number of tracts (single vs. multiple), operative time, estimated blood loss (EBL) and length of hospital stay (LOS) were analyzed. The primary endpoints were stone-free and complication rates according to the Clavien-Dindo (CD) classification

Ethical Consideration

This study was conducted in accordance with ICH GCP guidelines and regulations and approved by the NKTI REC with approval number NKTI REC 2017-117

1. Informed consent

This study was limited to chart review and there was no interaction with the participant therefore informed consent was not obtained.

2. Confidentiality

Patients were assigned case numbers to ensure anonymity. Only the authors had access to any data obtained in the study. In the event of any publication, all information collected from the charts will be kept confidential.

Statistical Analysis

Counts and percentages were used to summarize the data in categorical form, while means and its standard error (SEM) for data in quantitative form. Fisher's exact test was used to associate the anomaly with gender, comorbidity, laterality, Guy's classification of stone, tract, and Modified Calvien score. Analysis of variance (ANOVA) was used to compare the duration of surgery and hospital stay according to anomaly.

P-values less than 0.05 indicate significant differences. All statistical tests were performed in R.

Results

A total of 1,657 PCNLs were performed during the study period, of which 42 had anatomical variants. The mean age was 45.2±8.8 (R= 28-65) with a male to female ratio of 3:1. There were 18 horseshoe (42.9%), 15 bifid (35.7%), 7 malrotated (16.7%) and 2 renal allografts (4.8%.); Laterality wise, 28 (67%) were left-sided, 12 (29%) were right-sided and 2 (5%) had right-sided pelvic kidneys (allografts). The Guy Stone scores were 3 and 4 in 13 (30%) and 29 (70%) patients, respectively. (Table 1)

The mean stone diameter was 3.8±0.6 cms. (R=2.5-5.5). Majority, n=37 (88%) were treated with an upper pole access. Thirty-six (86%) needed a single tract and while six (14%) required multiple tracts (bifid pelvis). (Table 2)

The mean operative time was 111.5±28.1 mins. (R=65-188), EBL was 461±278.4 cc (R=200-1300). LOS was 3.6±0.94 days (R=2-7). The stone-free rate was 95% and was assessed using neephroscopy and post PCNL fluoroscopy. Twenty-five (59.5%) complications were documented. Fifteen (35.7%) had fever: Grade I CD, and 10 (23.8%) required transfusion: Grade II CD. There was no mortality. (Table 3)

Table 1. Demographics of patients with renal anatomical variations who underwent PCNL.

Total	Anomaly				
	Allograft Kidney	Horseshoe	Malrotated Kidney	Bifid pelvis	
Number of Patients	42	2	18	7	15	p-value
Gender:						
Male	28 (66.7%)	2 (100%)	12 (66.7%)	3 (42.9%)	11 (73.3%)	0.460
Female	14 (33.3%)	0 (0%)	6 (33.3%)	4 (57.1%)	4 (26.7%)	
Comorbidity:						
Diabetes Mellitus	10 (23.8%)	2 (100%)	5 (27.8%)	2 (28.6%)	1 (6.7%)	0.180
Hypertension	6 (14.3%)	0 (0%)	3 (16.7%)	1 (14.3%)	2 (13.3%)	
Laterality:						
Right	15 (35.7%)	0 (0%)	6 (33.3%)	4 (57.1%)	5 (33.3%)	0.570
Left	25 (59.5%)	0 (0%)	12 (66.7%)	3 (42.9%)	10 (66.7%)	
Guy's classification of stone:						
(4)	31 (73.8%)	0 (0%)	17 (94.4%)	4 (57.1%)	10 (66.7%)	0.007
(3)	11 (26.2%)	2 (100%)	1 (5.6%)	3 (42.9%)	5 (33.3%)	

Table 2. Intra-operative factors of patients with renal anatomical variations who underwent PCNL.

		Total	Anomaly			
			Allograft Kidney	Horseshoe	Malrotated Kidney	Bifid Pelvis
Access:	Upper	37 (88.1%)	2 (100%)	18 (100%)	5 (71.4%)	12 (80%)
	Mid	4 (9.5%)	0 (0%)	0 (0%)	1 (14.3%)	3 (20%)
	Inferior	3 (7.1%)	0 (0%)	0 (0%)	1 (14.3%)	2 (13.3%)
Tract:	Single	36 (85.7%)	2 (100%)	18 (100%)	7 (100%)	9 (60%)
	Multiple	6 (14.3%)	0 (0%)	0 (0%)	0 (0%)	6 (40%)

Table 3. Outcome of PCNL on patient with renal anatomical variations.

	Total	Anomaly				p-value
		Allograft Kidney	Horseshoe	Malrotated Kidney	Bifid Pelvis	
Duration of Surgery (min)	111.5 ± 28.2	95.0 ± 10.0	114.0 ± 4.8	107.1 ± 8.8	112.7 ± 10.1	0.808
Duration of Hospital Stay (days)	3.6 ± 1.2	4.0 ± 0.0	3.8 ± 0.3	3.0 ± 0.4	3.5 ± 0.4	0.520
Modifed Calvien Score: 2 (Requiring Blood Transfusion)	10 (23.8%)	0 (0%)	5 (27.8%)	1 (14.3%)	4 (26.7%)	0.940

Discussion

In this study, the incidence of patients with anatomical variations who underwent PCNL is 0.02% and majority had Horseshoe Kidneys (43%). PCNL is still the considered standard of care for renal anatomical variations with kidney stones more than 2 cms and the upper pole access is still the preferred access especially in patients with a horseshoe-kidney or pelvic-kidney, owing to the inferior displacement away from the pleura and majority (88%) used the upper pole access.

Percutaneous nephrolithotomy (PCNL) is considered as treatment of choice for renal stones, and some upper ureteric stones. It has been performed since 1980s, with overall success rates exceeding 90%.[1] Improvements in technique and instruments have diminished complication rates associated with this procedure.[1] PCNL is technically very challenging in anomalous kidneys because the abnormal pelvicaliceal system results in difficulty in access. An abnormal relationship to the surrounding structures increases the incidence of visceral and vascular injuries. Fusion and malrotation anomalies are the most common types of renal abnormalities presenting with stones in clinical practice. The horseshoe kidney is the most common renal fusion anomaly.

Extracorporeal Shock Wave Lithotripsy (ESWL) and PCNL are the 2 most commonly used modalities for managing the stones in horseshoe kidneys. Ureteroscopy is used less often because of the technical challenges encountered with the altered renal anatomy. ESWL is the preferred modality for stones 2 cm in anomalous kidneys because the stone-free rate has varied from 72% to 92% in different series, and PCNL remains the reference standard for large stone burdens and ESWL-resistant stones.[2] The upper pole access is relatively safe in patients with a horseshoe-kidney

or pelvic-kidney, owing to the inferior displacement away from the pleura.[3] Osther et al. reported that access-failure for PNL was significantly more in patients with renal anomalies (5 %) when compared to normal kidneys (1.7%).[4] Mosavi-Bahar reported mild pleural injury in two patients[5], while Gupta et al.[2], and Ozden et al.[6], reported intercostal tube drainage in one patient. Similarly, pneumothorax was reported by Raj et al. in 6 %.[7] On the other hand, Shokeir et al. and Viola et al.[8] reported no pleural complications in patients with upper pole PCN in a horseshoe-kidney.

In a study done by Gupta et al (2009), all patients with renal congenital anomaly had complete clearane, , 89% via single tract and 11% via multiple tracts, with a mean operating time of 82 minutes and hospital stay of 3.2 days. In a study done by Osther, outcomes of PCNL in normal vs with renal anomalies were similar in terms of frequency of common complications but noted longer duration of surgery and multiple access tracts in renal malformation. They also noted longer duration of surgery for horseshoe kidneys compared to other renal anomalies, and longer hospital stay for ectopic kidneys.[9]

Osther et al. reported that access-failure for PNL was significantly more in patients with renal anomalies (5 %) when compared to normal kidneys (1.7 %) and according to Mosavi-Bahar, mild pleural injury was reported in PCNL in horseshoe kidneys while Gupta et al.[2], and Ozden et al.[6], reported intercostal tube drainage in one patient who had horseshoe kidney who underwent PCNL Similarly, pneumothorax was reported by Raj et al. in 6%. Due to this, different centers in the country often times opt to do the open approach for renal stones due to limited experience in doing endoscopic procedures in such anatomic variants. In the present study, all patients were treated with PCNL and no major complications were noted and ten out of the forty required blood transfusion.

Conclusion

Nephrolithiases in kidneys with variations in anatomy and position are challenging. The urologist should be prepared to apply minimally invasive techniques to remedy this. The present study provides additional support that PCNL still persists as the treatment of choice for nephrolithiasis in patients with this clinical condition. A high stone clearance rate can be achieved effectively while minimizing complications.

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