ORIGINAL ARTICLE

Is percutaneous nephrolithotomy an effective and minimally invasive technique in the treatment of staghorn kidney stones?

La néphrolithotomie percutanée est - t - elle une technique efficace et mini-invasive dans le traitement des calculs rénaux coralliformes ?

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Abstract

Introduction: With the advent of percutaneous nephrolithotomy (PCNL), the use of traditional surgery for the treatment of staghorn kidney stones has become rarer.

Objective: The objective of this study was to report the outcomes of percutaneous nephrolithotomy in the treatment of staghorn kidney stones.

Methods: This is a retrospective longitudinal descriptive and analytical study. It included all patients treated for a staghorn stone who underwent PNL between January 2015 and December 2021.

Results: We included 44 patients. Six patients experienced intraoperative bleeding. We reported the occurrence of postoperative infectious complications in 15 patients. The stone-free rate was 42%. Predictive factors for residual fragments were complete staghorn stone (p=0.02) and large stone volume (p=0.001). Predictive factors for hemorrhagic complications were the use of anticoagulant therapy (p=0.01), renal cavity dilation (p=0.01), complete staghorn stone (p=0.02), and large stone mass (p<0.001). Predictive factors for postoperative infectious complications were diabetes (p=0.048), positive preoperative urine culture (p=0.03), renal cavity dilation (p=0.04), complete staghorn stone (p=0.02), and postoperative drainage by ureteral stent (p<0.001).

Conclusion: PCNL is a minimally invasive and effective technique when safety conditions are met, and it has become the standard in the treatment of staghorn stones.

Key words: Kidney stones, Percutaneous nephrolithotomy, Staghorn stones.

Résumé

Introduction: Avec l'avènement de la néphrolithtomie percutanée (NLPC), le recours à la chirurgie classique dans le traitement de ces calculs rénaux coralliforme est devenu plus rare.

Objectif: L'objectif de cette étude était de rapporter les résultats de la néphrolithotomie percutanée dans le traitement des calculs rénaux coralliformes.

Méthodes: Il s'agit d'une étude longitudinale rétrospective descriptive et analytique. Elle a concerné tous les patients pris en charge pour un calcul coralliforme, ayant eu une NLPC pratiquées entre Janvier 2015 à Décembre 2021.

Résultats: Nous avons inclus 44 patients. Six patients ont présenté un saignement per-opératoire. Nous avons signalé la survenue d'une complication infectieuse postopératoire chez 15 patients. Le taux de stone free était de 42%. Les facteurs prédictifs de persistance des fragments résiduels était le caractère coralliforme complet du calcul (p=0,02) et un volume lithiasique important (p=0,001). Les facteurs prédictifs de survenue des complications hémorragiques étaient la prise d'un traitement anticoagulant (p=0,01), la dilatation des cavités rénales (p=0,01), le caractère coralliforme complet du calcul (p=0,02) et une importante masse lithiasique (p<0,001). Les facteurs prédictifs de survenue des complications infectieuses post opératoires étaient le diabète (p=0,048), un examen cytobactériologique des urines préopératoire positif (p=0,03), la dilatation des cavités rénales (p=0,04) le caractère coralliforme complet du calcul (p=0,02) et le drainage post opératoire par une endoprothèse urétérale (p<0,001).

Conclusion: La NLPC est une technique mini-invasive, et efficace sous réserve de respecter les conditions de sécurité, devenant actuellement le standard dans le traitement des calculs coralliformes.

Mots clés: Lithiase rénale, Néphrolithotomie percutanée, Coralliforme

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Introduction

Staghorn calculi are kidney stones that radiologically resemble coral or, as referred to by Anglo-Saxon terminology, have a "staghorn" shape. This definition encompasses a wide variety of stones differing in size and the number of branches and calyces they occupy. A stone is classified as staghorn when it is located in the renal pelvis and has at least two calyceal extensions (1–5). It is considered partial if it occupies the renal pelvis with two calyceal extensions and complete if it involves the renal pelvis with three or more calyceal extensions. Staghorn calculi are a distinct and relatively uncommon entity, accounting for 10–15% of all urinary stones in industrialized countries (6). These stones require aggressive treatment, even in the absence of symptoms, due to their significant potential morbidity. Without intervention, there is progressive renal function deterioration, a high rate of infection, and long-term mortality. The treatment of staghorn calculi is typically surgical, as untreated stones can lead to severe complications. Since the advent of percutaneous nephrolithotomy (PCNL), first described in 1976 by Ferstrom and Johansson (7), and subsequently standardized by Alken (8, 9), Segura (10), and Smith (11), this procedure has become the first-line treatment for complex renal stones, including staghorn calculi (12, 13).
In this study, we aimed to report the outcomes of PCNL in the management of staghorn renal calculi.

Methods

This was a longitudinal, retrospective, descriptive, and analytical study that included all patients managed for staghorn calculi who underwent PCNL over a five-year period, from January 2015 to December 2021. Patients with staghorn calculi were excluded if they had contraindications to general anesthesia and/or percutaneous surgery. These contraindications included uncontrolled coagulopathy, untreated urinary tract infections (bacteriuria was treated preoperatively for a minimum of 48 hours based on antibiogram results), and untreated or conservatively managed transitional cell carcinoma of the ipsilateral upper urinary tract. Patient records were selected based on archived operative reports categorized by year. Data were collected from medical records, including information obtained during patient interviews, physical examinations, laboratory tests (urine culture and sensitivity, renal function tests), and imaging studies (plain abdominal X-rays and abdominopelvic CT scans with or without contrast). Operative reports and follow-up assessments after treatment were also reviewed.
Comparisons of means between two independent groups were performed using the Student's t-test. When the assumptions for the t-test were not met, the Mann-Whitney test (a nonparametric equivalent for independent samples) or the Kruskal-Wallis test (a nonparametric equivalent of ANOVA) was applied. Nonparametric tests assess the equality of medians rather than means. Percentage comparisons for independent series were conducted using Pearson's chi-squared test or Fisher's exact test (bilateral) when the chi-squared test was not valid. For all statistical analyses, the significance threshold was set at 0.05.

Results

A total of 44 patients were included in the study. The median age of the patients was 47 years [40–62 years], with a male-to-female ratio (M/F) of 0.9. Previous PCNL for ipsilateral calculi was noted in 6 patients (14%). Prior treatment with semirigid ureteroscopy (URS) for ipsilateral calculi was recorded in 2 patients (4%), while open surgery for ipsilateral calculi had been performed in 6 patients (14%). Five patients (11%) had undergone prior extracorporeal shock wave lithotripsy (ESWL) for ipsilateral calculi. Additionally, 8 patients (18%) had been treated for ipsilateral acute obstructive pyelonephritis. The calculi were located on the left side in 24 patients (55%). Complete staghorn calculi were present in 17 patients (39%). The mean renal stone volume was 4133.25 ± 135 mm^3, and the median stone density was 1050 HU [747–1200 HU]. Preoperative urine culture was positive in 9 patients (21%), with the most commonly isolated organisms being Escherichia coli in 5 patients, Klebsiella pneumoniae in 3 patients, and Enterococcus faecalis in 1 patient. All 9 patients received appropriate preoperative antibiotic therapy and underwent surgery only after achieving sterile urine cultures. In all cases, puncture was performed in the posterior lower calyx group, and ballistic energy was used for stone fragmentation. At the end of the procedure, a double-J stent was placed in 33 patients (75%). Perioperative bleeding occurred in 6 patients (14%), of which 5 cases required blood transfusions: Two units for 2 patients and 4 units for 3 patients, along with catecholamine support. All cases had favorable outcomes. Postoperative infectious complications were observed in 15 patients (34%). Among these, 8 patients (54%) had isolated fever, 3 patients (20%) developed acute pyelonephritis, 3 patients (20%) experienced sepsis, and one patient (6%) presented with septic shock. Intensive care unit admission was required for 3 patients. Among those with infectious complications, 65% required antibiotic therapy. The initial stone-free rate was 42%. To improve outcomes and achieve stone-free status, a second PCNL was performed in 7 patients, complementary ESWL was conducted in 15 cases, and open surgery was performed in 3 cases. One patient with residual stones measuring 0.7 cm, 0.8 cm, and 1 cm developed postoperative lumbar ureteral stone impaction. This was managed with URS, resulting in the fragmentation and complete elimination of all stones. The final stone-free rate was 86%. Predictive factors for residual fragments included complete staghorn calculi ($p = 0.02$) and large stone volume ($p = 0.001$) (Table 1).
Predictive factors for hemorrhagic complications included anticoagulant therapy ($p = 0.01$), renal cavity dilation ($p = 0.01$), complete staghorn calculi ($p = 0.02$), and large stone burden ($p < 0.001$) (Table 2).

Table 1. Univariate Analysis of Stone-Free Status

Variables	*Stone Free*		p value
	Yes (N = 18)	**No (N = 26)**	
Median Age (years), IQR	51 [38 – 59]	43 [34 – 66]	0.54
Diabetes N (%)			
Yes	5(12)	9(19)	0.63
No	13(30)	17(39)	
Hypertension (%)			
Yes	5(12)	11(25)	0.32
No	13(30)	15(33)	
Gender N (%)			
Male	9(21)	12(27)	0.8
Female	9(21)	14(31)	
ASA Score N (%)			
ASA1	12(27)	12(27)	0.33
ASA2	6(13)	13(30)	
ASA3	0	1(3)	
Previous PCNL treatment N (%)			
Yes	2(4)	4(9)	0.68
No	16(37)	22(50)	
Previous ureteroscopy treatment N (%)			
Yes	0	2(4)	0.5
No	18(41)	24(55)	
Previous lethotripsy treatment N (%)			
Yes	2(4)	3(6)	0.9
No	16(37)	23(53)	
Previous surgery N (%)			
Yes	1(2)	5(11)	0.37
No	17(39)	21(48)	
Laterality N (%)			
Right	9(21)	11(25)	0.61
Left	9(21)	15(33)	
Stone location N (%)			
Complete staghorn	7(16)	10(22)	**0,02**
Renal pelvis with inferior and medial calyceal extension	4(9)	6(14)	
Renal pelvis with superior and medial calyceal extension	2(5)	8(18)	
Renal pelvis with inferior and superior calyceal extension	5(11)	2(5)	
Calculi size (mm3) ± SD	3975±159	4712±356	**0.001**
Median Stone Density (UH), SD	950	1200	0.42
Preoperative urine culture N (%)			
Positive	2(5)	7(16)	0.27
Négative	16(35)	19(44)	
Effect on renal cavities N (%)			
Slightly or non-dilated excretory cavities	8(18)	13(30)	0.71
Moderate to severe dilation of the excretory cavities	10(22)	13(30)	
Average operative time (min) ± SD	100±20	90±15	0.8

Predictive factors for postoperative infectious complications included diabetes (p = 0.048), positive preoperative urine culture (p = 0.03), renal cavity dilation (p = 0.04), complete staghorn calculi (p = 0.02), and postoperative drainage with a ureteral stent (p < 0.001) (Table 3).

Table 2. Univariate analysis of predictive factors for hemorrhagic complications

Variables	*Postoperative hemorrhagic complications*		p value
	Yes (N = 6)	**No (N = 38)**	
Median age (years), IQR	42 [28 – 52]	43 [35 – 67]	0.7
Diabetes N (%)			
Yes	3(6)	12(28)	0.1
No	3(6)	26(60)	
Hypertension N (%)			
Yes	2(4)	13(30)	0.64
No	4(9)	25(57)	
Anticoagulant treatment N (%)			
Yes	5(11)	2(4)	**0.01**
No	1(3)	36(82)	
ASA Score N (%)			
ASA1	1(3)	23(51)	0.4
ASA2	4(9)	15(34)	
ASA3	1(3)	0	
Previous PCNL Treatment N (%)			0.7
Yes	2(4)	4(9)	
No	4(9)	34(78)	
Previous ureteroscopy treatment N (%)			0.836
Yes	2(4)	0	
No	4(9)	38(87)	
Previous lithotripsy treatment N (%)			
Yes	4(9)	1(3)	0.732
No	2(4)	37(84)	
Previous surgery N (%)			
Yes	3(7)	3(7)	0,1
No	3(7)	35(79)	
Laterality N (%)			
Right	4(9)	16(37)	0.36
Left	2(4)	22(50)	
Stone location N (%)			
Complete staghorn	5(11)	12(27)	**0.02**
Partial staghorn	1(3)	26(59)	
Mean volume (mm³) ± SD	3879.45±165	2978.15±210	**< 0.001**
Median stone density (UH), IQR.	910 [600–1200]	860 [640 –1300]	0.7
Preoperative urine culture N (%)			
Positive	3(7)	6(14)	0.3
Negative	3(7)	32(72)	
Effect on renal cavities N (%)			
Slightly or non-dilated excretory cavities	5(11)	17(39)	**0.01**
Moderate to severe dilation of the excretory cavities	1(3)	21(47)	
Average operative time (min) ± SD	72±12	69±18	0.68

Table 3. Univariate analysis of predictive factors for postoperative infectious complications

Variables	*Complications infectieuses post opératoires*		p value
	Yes (N = 15)	**No (N = 29)**	
Median age (years), IQR	40 [35 – 62]	41 [38 – 65]	0.6
Diabetes N (%)			
Yes	7(16)	14(32)	0.9
No	8(19)	15(34)	
Hypertension N (%)			
Yes	5(11)	10(23)	0.76
No	11(25)	18(41)	
Anticoagulant treatment N (%)			
Yes	2(5)	12(27)	**0.048**
No	13(30)	17(38)	
ASA Score N (%)			
ASA1	10(23)	14(32)	0.13
ASA2	4(9)	15(34)	
ASA3	1(2)	0	
Previous PCNL Treatment N (%)			
Yes	1(2)	5(11)	0.64
No	14(32)	24(55)	
Previous ureteroscopy treatment N (%)			
Yes	1(2)	1(2)	0.57
No	14(32)	28(64)	
Previous lithotripsy treatment N (%)			
Yes	1(2)	4(9)	0.6
No	14(32)	25(57)	
Previous surgery N (%)			
Yes	1(2)	5(11)	0.64
No	14(32)	24(55)	
Laterality N (%)			
Right	7(16)	13(31)	0.9
Left	8(18)	16(35)	
Stone location N (%)			
Complete staghorn	7(16)	10(23)	**0.02**
Renal pelvis with inferior and medial calyceal extension	2(5)	6(14)	
Renal pelvis with superior and medial calyceal extension	1(2)	4(9)	
Renal pelvis with inferior and superior calyceal extension	5(11)	9(20)	
Mean volume (mm³) ± SD	3352.25±92	3259 ±85	0.2
Median stone density (UH), IQR.	950 [647–1180]	890 [690–1300]	0.4
Preoperative urine culture N (%)			
Positive	4(9)	5(11)	**0.03**
Negative	11(25)	24(55)	
Effect on renal cavities N (%)			
Slightly or non-dilated excretory cavities	6(14)	15(34)	**0.04**
Moderate to severe dilation of the excretory cavities	9(20)	14(32)	
Average operative time (min) ± SD	90±15	84±10	0.42
Postoperative drainage N (%)			
Yes	13(30)	20(45)	**<0.001**
No	2(5)	9(20)	

Discussion

Urinary lithiasis is a common condition worldwide, with a marked increase in its incidence and prevalence. The epidemiological characteristics of urinary lithiasis (13, 14) have evolved significantly in recent years due to changes in dietary habits, sanitary conditions, environmental factors, and the prevalence of conditions predisposing to stone formation, such as obesity, diabetes, and metabolic syndrome. Traditionally, staghorn calculi have been predominantly composed of struvite (15); however, their prevalence has decreased in industrialized countries. This reduction reflects improved medical care and higher standards of sanitation (16). Until the 1980s, staghorn calculi were treated primarily with open surgery, involving complex techniques for cooling and locating calculi in the depths of calyces. The advent of percutaneous nephrolithotomy (PNL) revolutionized stone management (17). This technique is now recommended as the first-line approach by most scientific societies for managing staghorn calculi (13). Recently, flexible ureteroscopy, either alone or combined with PNL, has been described as an alternative therapeutic option for treating staghorn calculi in specific patients with particular anatomical conditions (e.g., solitary kidney, horseshoe kidney, or obesity) (13). The prone position remains the classical positioning for PNL, as first described by Alken (8). All our patients underwent surgery in the prone position. Valdivia et al. were the first to propose the modified supine position to reduce the anesthetic challenges associated with prone positioning (18). Both positions have their respective advantages and drawbacks. In our study, the approach used was a posterior inferior calyceal puncture. This access is sufficient to achieve favorable outcomes for pyelic stones extending into the lower calyx (19, 20). Cink Yücel Billen (19) demonstrated that a posterior inferior approach is adequate for such cases but is not ideal for staghorn calculi. Supracostal access and multiple punctures provide excellent approaches for treating staghorn calculi (21). The management of staghorn calculi using PNL monotherapy has been extensively studied. Stone-free rates range from 63% to 90%, according to Healy and Ogan (22). PNL as monotherapy for staghorn or complex stones has been reported in pediatric populations in recent years. Aron (23) published results from a series of 19 children aged five years with complete staghorn calculi treated with PNL, achieving an 89% stone-free rate. Results from Al-Kohlany (24) showed an initial stone clearance rate of 49% in the PNL group compared to 67% in the open surgery group, with no statistically significant difference ($p = 0.238$). Desai (25) demonstrated that the stone-free rate increased from 89.9% with PNL monotherapy to 96% when combined with adjunctive extracorporeal shock wave lithotripsy (ESWL). In the comparative study by Goel (26), stone clearance was achieved in 66% of patients in the open surgery group versus 59% in the combined PNL/ESWL group. For many authors, stone morphology does not impact the risk of hemorrhagic complications during PNL, as demonstrated by Kessaris in a series of 2200 PNL procedures (27). However, the size and complexity of the stone increase the risk of intraoperative bleeding due to the more extensive nephroscopic manipulations required (28). In the literature, the postoperative urinary infection rate reaches up to 32.7%, with 0.2% of cases progressing to sepsis (29). The most commonly isolated pathogens include Escherichia coli, Streptococcus spp., and Staphylococcus spp. The study by Marippan (30) highlighted a higher infectious risk for stones larger than 2 cm and obstructive stones.

Conclusion

In terms of outcomes, PNL is a technique that ensures favorable results in the management of staghorn calculi. It represents an attractive alternative to open surgery. However, it is not without complications. Improved patient selection, advances in instrumentation, and increased technical expertise will contribute to better outcomes in the surgical treatment of staghorn calculi.

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