The evolution of percutaneous nephrolithotomy: Analysis of a single institution experience over 25 years

Jennifer Bjazevic[1]; Linda Nott[1]; Philippe D. Violette[2]; Thomas Tailly[3]; Marie Dion[4]; John D. Denstedt[1]; Hassan Razvi[1]

[1]Division of Urology, Western University, London, ON, Canada; [2]Division of Urology, McMaster University, Hamilton, ON, Canada; [3]Division of Urology, Ghent University, Ghent, Belgium; [4]Niagara Health System, ON, Canada

Cite as: *Can Urol Assoc J* 2019 February 7; Epub ahead of print.
http://dx.doi.org/10.5489/cuaj.5725

Published online February 7, 2019

***

Abstract

Introduction: Over time, the incidence of nephrolithiasis has risen significantly, and patient populations have become increasingly complex. Our study aimed to determine the impact of changes in patient demographics on percutaneous nephrolithotomy (PCNL) outcomes.
Methods: A retrospective analysis of a prospectively collected database was carried out from 1990–2015. Patient demographics, comorbidities, stone and procedure characteristics were analyzed. Multivariate logistic regression was used to evaluate differences in operative duration, complications, stone-free rate, and length of stay.
Results: A total of 2486 patients with a mean age of 54±15 years, body mass index (BMI) of 31±8, and stone surface area of 895±602 mm^2 were analyzed; 47% of patients had comorbidities, including hypertension (22%), diabetes mellitus (14%), and cardiac disease (13%). Complication rate was 19%, including a 2% rate of major complications (Clavien grade III–V). There was a statistically significant increase in patient age, BMI, and comorbidities over time, which was correlated with an increased complication rate (odds ratio [OR] 1.15; p=0.010). The overall transfusion rate was 1.0% and remained stable (p=0.131). With time, both OR duration (mean Δ 16 minutes; p<0.001) and hospital length of stay (mean Δ 2.4 days; p<0.001) decreased significantly. Stone-free rate of 1873 patients with available three-month followup was 87% and decreased significantly over time (OR 1.09; p<0.001), but was correlated with an increased use of computed tomography (CT) scans for followup imaging.
Conclusions: Despite an increasingly complex patient population, PCNL remains a safe and effective procedure with a high stone-free rate and low risk of complications.

Introduction

Urinary stone disease is a very common condition with incidence rates ranging from 7 to 13% in North America.[1] The prevalence of stone disease is rising, with recent evidence demonstrating an increase from 5.2 to 8.8% in American adults over the past twenty years.[2] This has been attributed to increasing rates of medical conditions associated with the development of kidney stones including obesity, diabetes mellitus (DM), metabolic syndrome, gout, and hypertension.[3] Specifically, the prevalence of obesity and DM have risen 5.2% and 3.7% respectively over the past ten years, and it is estimated that if this trend continues obesity and DM will contribute to a further 1.1% increase in stone prevalence by 2030.[4]

Apart from their impact on the development of stone disease, rising rates of medical comorbidities may also have an important influence on surgical outcomes. This is particularly important when considering the substantial increase of patient age and comorbidities over the years.[5] Multiple series have demonstrated an association between percutaneous nephrolithotomy (PCNL) complications and the presence of patient comorbidities.[6-11]

Following its introduction in 1976, PCNL has become the mainstay of surgical treatment for large and complex renal calculi.[12] Over the past several decades, many innovations have led to advances in the techniques and equipment utilized to perform PCNL.[13] Despite the increasing prevalence of urinary stone disease, the utilization of PCNL has been relatively constant in North America.[14,15] Few long-term longitudinal studies have provided insight into independent predictors and the effect over time on PCNL outcomes. We examined the impact of changes in patient demographics and surgical techniques on PCNL outcomes and complications at a single high-volume academic institution over a period of 25 years.

Methods

Patient selection

A prospective database of all consecutive PCNLs performed between July 1990 and July 2015 was maintained, and no patients were excluded from analysis. Study approval was obtained from Western University's institutional ethics review board.

Patient demographics included age, sex, body mass index (BMI), American Society of Anaesthesiologists' (ASA) classification, comorbidities, and presence and type of urinary tract abnormality. Patient comorbidities were assessed dichotomously as either the presence or absence of disorders. Imaging, with intravenous pyelography (IVP), ultrasound (US), or computed tomography (CT) was used to identify urinary tract abnormalities.

Stone characteristics included stone size, composition, location, and presence of partial or complete staghorn calculi. Stone burden was approximated by the sum of elliptical surface area (length x width x pi)/4 for each stone, and categorized into size categories (<500mm^2, 500 to 1000mm^2, 1001 to 1500mm^2, >1500mm^2) for analysis.[16] Partial staghorn stones were defined as a renal pelvic stone branching into one calyx; where complete staghorn stones were classified as branching into more than one calyx. Procedural data included operative time, number and location of tracts, dilation method, lithotripter type, and method of post-operative drainage.

Data on surgical outcomes included length of hospital stay, perioperative complications, rate of secondary interventions, and stone-free status at discharge and 3-months post-PCNL. Perioperative complications were categorized according to the Clavien-Dindo classification system. Secondary interventions included either second look nephroscopy, ureteroscopy or extracorporeal shock wave lithotripsy (SWL) treatment. Stone-free status at the time of discharge and 3-months post-PCNL was defined as no residual fragments present on imaging, determined by a combination of plain film x-ray kidneys ureters bladder (KUB), US, non-contrast CT, or IVP. The imaging modality preformed was based on surgeon discretion and individualized to patient and stone characteristics.

Detailed surgical steps

All PCNL cases were performed by two different surgeons. Surgeon A performed cases over the time period of 1995-2015, comprising 33.9% of the total cases included in the analysis. Surgeon B performed the remainder of the cases. PCNLs were performed with patients in the prone position. Single stage PCNL with renal access was achieved using fluoroscopic guidance in the operating room in 97% of cases. The remaining 3% required either US or CT guidance in the interventional radiology suite due to inability to access the ureter in a retrograde fashion, or anatomical factors such as organomegaly, scoliosis or retrorenal colon which precluded safe access. The details of our PCNL technique have previously been published.[17] If required, second look nephroscopy was performed in a clinic cystoscopy suite under local anesthesia or in the operating room during the patient's inpatient hospital stay.

Statistical analysis

Retrospective analysis of the prospectively maintained database was performed. Patients were divided into chronological equal terciles of 852 consecutive procedures each (tercile one: July 1990-February 2000, tercile two: March 2000-March 2007, tercile three: April 2007-July 2015) in order to allow for analysis of changes in variables over time. Chi squared test was used to evaluate changes in patient characteristics and surgical techniques. A multivariate logistic regression was used to identify the effect of time on operative duration, adverse events, stone-free rate, and hospital length of stay. Statistical analyses were carried out using SPSS v.20 (Armonk, NY: IBM Corp.).

Results

Patient characteristics

Our cohort included 2554 consecutive PCNL treatments in 2486 patients. The mean age was 54 ± 15 years (range 4-91 years), 55.6% of patients were male (n=1382), and the mean BMI was 31 ± 8 kg/m^2 (15-61 kg/m^2). Almost half, 46.9% (n=1166) of patients had medical comorbidities,

DRAFT

most commonly hypertension (21.9%, n=545), DM (14.2%, n=352), or cardiac (13.0%, n=322) conditions. Patient characteristics are detailed in table 1.

Analysis comparing patient characteristics between terciles revealed significant changes in patient age, BMI, ASA score, and the presence of comorbidities over time. The mean patient age increased from 53 to 56 years (p=0.009) and mean BMI increased from 30 to 33 kg/m^2 (p=0.032) when compared over terciles. Over time, there was a significant increase in patients with an ASA score of III, which was associated with a corresponding decrease in the number of ASA score I and II patients (p<0.001). There was a significant increase in the prevalence of medical comorbidities, specifically the overall rate of medical comorbidities increased from 20.2% to 38.8% over time (p<0.001). The largest increases were observed in the rates of hypertension (11.5% to 35.1%, p<0.001) and DM (10.6% to 19.6%, p<0.001). There was no difference observed in the rates of renal anomalies over the compared terciles.

Stone characteristics

54.1% (n=1,381) of treated stones were left-sided, and 5.3% of cases (n=135) involved bilateral PCNL. The mean stone burden was 895 ± 602 mm^2, with 54.3% (n=1,387) of treated stones measuring less than 500 mm^2. Stone composition was primarily calcium oxalate (74.2%), with a smaller proportion of stones being calcium phosphate (29.9%) or uric acid (20.0%) in composition. Comparison between terciles of time did not demonstrate any differences in stone burden or composition (Table 2).

Surgical characteristics

The mean operative time for PCNL was 86±37 minutes (range 17-290 mins). Operative time was calculated based on procedural start and stop times. There was a significant change in operative time between terciles, with operative time decreasing a mean of 16 minutes between the first and third tercile (p<0.001). A single tract was utilized in the vast majority of cases (92.4%). No difference in the number of tracts utilized was noted over time. The majority of tracts were placed in the lower calyx (64.8%), compared with the mid calyx (21.9%) and upper calyx (13.3%). There was an increased number of mid calyceal access tracts over time, with a corresponding decreased number of lower calyceal tracts (p<0.001). Tract dilation was primarily preformed with a balloon dilator (94.1%), compared to the sequential amplatz dilators (5.9%). Over time, there was a significant decrease in the utilization of the amplatz dilators (p<0.001).

An ultrasonic lithotripter was the primary modality utilized for stone fragmentation (55.1%) and its use increased over time (p<0.001). Comparatively, pneumatic (28.2%) and electrohydraulic (12.9%) lithotripters were used to a lesser extent and their use was observed to decrease over time (p<0.001). A laser was utilized in the minority of cases (3.8%) and there was a trend towards increased use of the laser over time. A post-operative nephrostomy tube was placed in the majority of cases (99.1%). A ureteric stent was placed in 23.4% of cases and there was a significant increase in the use of ureteric stents over time (p<0.001) (Table 3).

Outcomes

The mean length of hospital stay was 4.1 days (median = 3 days, range 1-30), however this varied significantly with time. Patients in the first tercile had a mean hospital stay of 5.6±2.1 days, while those in the third tercile had a mean stay of 3.2±1.2 days, demonstrating a relative decrease of -2.4 days in hospital stay (p<0.001) (Table 4).

At the time of discharge 86.0% (n=2090) of patients were stone free on imaging. Three-month follow-up data was available for 73.3% (n=1873) of patients and these patients were observed to have a stone free rate of 86.7%. The imaging modality performed at follow-up was observed to change significantly over time, specifically an increased number of CTs were performed with a corresponding decreasing in the number of IVPs (p<0.001, Table 4). The stone free rate decreased statistically over time (OR 1.09, p<0.001); however, this was correlated with the increased use of CT scans for follow-up imaging. Multi-variable analysis failed to demonstrate any other factors significantly correlated with stone free rate.

22.2% (n=567) of patients required a secondary procedure to address residual stones, including 16.3% (n=416) who underwent secondary nephroscopy, 2.7% (n=69) who underwent SWL, and 1.6% (n=41) who required ureteroscopy. The rate of secondary procedures decreased over time due primarily to a significant decrease in the number of patients requiring a second look nephroscopy (p<0.001, Table 4).

The overall rate of complications was 18.9% (n=483) and the majority of complications (16.6%, n=424) were noted to be minor (Clavien grade I-II). There was an increased rate of complications noted over time (OR 1.15, p=0.010); however, this was correlated with the increased rate of medical comorbidities observed on multi-variable analysis. The majority of complications that increased over time were Clavien grade I and II, and there was no statistical difference in the rate of major complications (Clavien grade III-V) over time (Table 5). The overall rate of blood transfusion was 1.0% and did not change through-out the terciles. Two mortalities were reported in the series, including one from a pulmonary embolus and one from intra-abdominal sepsis.

Discussion

Since its inception, PCNL has aimed to provide effective management of large and complex renal stones by achieving a high stone free rate with minimal complications. However, there have been significant changes in the demographics and characteristics of patients undergoing PCNL. However, limited data exists on the effect of changes to PCNL outcomes. Through a retrospective review of a prospectively collected database from a high-volume single academic centre, we evaluated the effect of changing patient and procedural characteristics on the outcomes of PCNL.

DRAFT

Our patient population was observed to become more medically complex over the twenty-five-year period, as demonstrated by increases in age, BMI, ASA score, and the presence of comorbidities. Prior series have shown similar results, with increasing patient age, rates of obesity, and Charlson comorbidity index being observed over time.[18-22] In our series, the rates of hypertension and DM demonstrated the largest increase over time; this is consistent with a previous study which also observed a significant increase in the rates of hypertension and DM in patients undergoing PCNL.[18]

The overall complication rate reported in our series was 18.9%, with a 2.3% rate of major complications (Clavien grade III-V). This is consistent with prior literature; for instance, the CROES study reported an overall 20.5% complication rate among an international series of 5803 consecutive PCNLs.[23] The rate of bleeding requiring blood transfusion in our series was 1.0% and did not change significantly over the twenty-five-year period. This is significantly lower than the transfusion rate observed in other studies, which ranges from 4-11%; specifically the CROES series reported a 7.8% rate of significant bleeding and a transfusion rate of 5.7%.[21-26] A higher reported transfusion rate may be accounted for by an increased proportion of PCNLs requiring multiple tracts for access in some series, as this has been established as a risk factor for bleeding.[24-25] We observed a 0.5% rate of angioembolization for bleeding in our series which was stable over time, and consistent with previous studies that have demonstrated embolization rates of 0.3 to 0.9%.[27-29]

Over the twenty-five-year period our complication rate increased significantly and was correlated with the increased rate of medical comorbidities present within the patient population. This is consistent with several previous published reports which have also demonstrated increased complication rates with increased patient age, and the presence of medical comorbidities.[8,18,20-21,30] A recent study determined that complications following PCNL were 2.5 times more common in patients with hypertension, and 2.7 times more common in patients with DM.[31] This further correlates with a recent series which demonstrated a 2.2 times increased risk of PCNL complications in patients with a Charlson comorbidity index of three or greater.[18]

Over time there was a significant decrease in both operative time and hospital length of stay; with operative time decreasing a mean of 16 minutes between the first and third terciles and length of hospital stay decreasing 2.4 days. While the precise reasons for these observations are speculative, we believe the shorter operative time reflects an increased level of efficiency developed by all team members over time. In addition, the adoption of ultrasonic lithotripsy as the primary modality of intracorporeal lithotripsy likely accelerated stone removal and shortened OR times, compared with pneumatic lithotripy which was more commonly utilized earlier in the series. The reduction in hospital length of stay is felt to be the result of a clinical care pathway that is communicated to patients preoperatively, implemented by nursing and house staff experienced with post-PCNL care, and includes early post-operative imaging. The increased utilization of a post-operative stent observed throughout the series was felt to be due to a combination of factors including increased upper calyx access, a larger number of tubeless procedures, and more complex patients.

In our series, the stone free rate at three-month follow-up was 86.7%, which compares favourably to previous reports which demonstrate a stone free rate of 76 to 92%.[23,32-33] The variation in stone free rates published in the literature can be attributed to differences in the definition of stone-free, timing, and type of imaging modalities utilized. Our motivation was to provide a pragmatic approach to outcome assessment that would reflect reasonable clinical practice. As a result, follow-up imaging modality was performed at the discretion of the surgeon and was primarily a combination of KUB and US with selective use of CT. We believe that routine CT follow-up for all patients is unnecessary and is associated with higher costs and radiation exposure.

In our series, there was minimal difference in stone free rates at the time of discharge and three-month follow-up. This can likely be attributed to use of second look nephroscopy in order to treat residual stones during the same inpatient hospital admission. In addition, a considerable proportion of our patients are referred from urologists outside our centre. As a result, three-month follow-up data was only available in 73.3% of our patients which may limit the accuracy of the three-month stone free rate.

The stone free rate in our series was noted to decrease significantly over time, and this was correlated with the increased use of CT scans for follow-up imaging. This is likely secondary to the increased detection of residual fragments with the higher sensitivity of CT compared with KUB and ultrasound. Considerable debate exists within the literature regarding the optimal timing and modality for imaging following PCNL and the definition of clinically significant residual fragments. While up to 26% of patients with residual fragments following PCNL require additional surgical intervention, the risk of this depends on the size and location of the residual fragment.[34] However, multiple other series have demonstrated that the presence of small, 'insignificant' fragments is not associated with increased rates of reintervention.[35-37]

The decreased stone free rate observed over time in our series may also be partially attributable to the increased rates of obesity and medical comorbidities. Prior CROES analysis demonstrated a decreased stone free rate and significantly higher re-treatment rates in obese compared with normal weight patients.[38] Furthermore, an increased rate of secondary procedures following PCNL has been observed in patients with both DM and metabolic syndrome.[31]

Over time, we have trended toward using more ureteral stents post- PCNL although the majority of patients even in the most recent tercile did not have a stent placed. Our explanation for this observation is our greater use of an upper pole/supracostal tract in more recent times. To minimize the risks of pleural effusion exacerbated by ureteral obstruction we typically place a stent in these patients. Our use of nephrostomy tube placement post-PCNL remains almost universal, and reflects our philosophy of providing renal access in case second look nephroscopy is required and a preference of providing a short period of renal drainage without a stent when possible to reduce patients' stent-related morbidity. When deemed appropriate however, we are adopting tubeless PCNL and in select cases an ambulatory protocol.

There are several limitations to this study which warrant discussion. As a retrospective review there is inherent observation bias and association between factors cannot prove causation. In addition, changes in personnel staffing, trainee involvement, and the introduction of new equipment were not specifically accounted for in the series. Finally, variation in the imaging modality used to assess for residual stone fragments may have resulted in deviation of the SFR over time. Over the course of the study period there was an increase in the use of CT imaging at follow-up, which may have artificially lowered the SFR earlier in the series.

Conclusion

PCNL remains the gold standard treatment for the management of large and complex renal calculi. Trends over time have demonstrated increasing patient age, BMI, and medical comorbidities; which have corresponded with increased complication and decreased stone free rates. However, despite an increasingly complex patient population PCNL remains a safe and effective procedure, resulting in a high stone free rate and low risk of complications.

DRAFT

References

1. Scales CD, Smith AC, Hanley JM, et al. Prevalence of kidney stones in the United States. *Eur Urol* 2012;62:160–5.
2. Stamatelou KK, Francis ME, Jones CA, et al. Time trends in reported prevalence of kidney stones in the United States: 1976-1994. *Kidney Int* 2003;63:1817-3.
3. Sorkin I, Mamoulakis C, Miyazawa K. Epidemiology of stone disease across the world. *World J Urol* 2017;35:1301-20.
4. Antonelli JA, Maalouf NM, Pearle MS, et al. Use of the National Health and Nutrition Examination Survey to calculate the impact of obesity and diabetes on cost and prevalence of urolithiasis in 2030. *Eur Urol* 2014;66:724-9.
5. Makdad AH, Bowman BA, Ford ES et al. The Continuing epidemics of obesity and diabetes in the United States. *JAMA* 2001;286:1195-200.
6. Unsal A, Resorlu B, Atmaca AF, et al. Prediction of morbidity and mortality after percutaneous nephrolithotomy by using the Charlson comorbidity Index. *Urology* 2012; 79:55-60.
7. Michel MS, Trojan L, Rassweiler JJ. Complications in percutaneous nephrolithotomy. *Eur Urol* 2007;51:899-906.
8. Olvera-Posada D, Tailly T, Alenezi H, et al. Risk factors for postoperative complications of percutaneous nephrolithotomy at a tertiary referral center. *J Urol* 2015;194:1646-51.
9. Seitz C, Desai M, Hacker A, et al. Incidence, prevention, and management of complications following percutaneous nephrolitholapaxy. *Eur Urol* 2012;61:146-58.
10. Labate G, Modi P, Timoney A, et al. The percutaneous nephrolithotomy global study: classification of complications. *J Endourol* 2011;25:1275-80.
11. Moreno-Palacios J, Maldonado-Alcaraz E, Montoya-Martinez G, et al. Prognostic factors of morbidity in patients undergoing percutaneous nephrolithotomy. *J Endourol* 2014; 28:1078-84.
12. Fernstrom I, Johansson B. Percutaneous pyelolithotomy. A new extraction technique. *Scand J Urol* Nephrol 1976;10:257-9.
13. Ghani KR, Andonian S, Bultitude M, et al. Percutaneous nephrolithotomy: Update, trends, and future directions. *Eur Urol* 2016;70:382-96.
14. Ordon M, Urbach D, Mamdani M. The surgical management of kidney stone disease: A population based time series analysis. *J Urol* 2014;192:1450-6.
15. Geraghty RM, Jones P, Somani BK. Worldwide trends of urinary stone disease treatment over the last two decades: A systematic review. *J Endourol* 2017;31:547-56.
16. Lam HS, Lingeman JE, Barron M, et al. Staghorn calculi: analysis of treatment results between initial percutaneous nephrostolithotomy and extracorporeal shock wave lithotripsy monotherapy with reference to surface area. *J Urol* 1992;147:1219–25.
17. Ko R, Soucy F, Denstedt JD, et al. Percutaneous nephrolithotomy made easier: a practical guide, tips and tricks. *BJU Int* 2008;101:535–9.
18. Mirheydar HS, Kerrin LP, Derweesh IH, et al. Percutaneous nephrolithotomy use is increasing in the United States: An analysis of trends and complications. *J Endourol* 2013;27:979-83.

DRAFT

19. Stern KL, Tyson MD, Abdul-Muhsin HM, et al. Contemporary trends in percutaneous nephrolithotomy in the United States: 1998-2011. *Urology* 2016;91:41-5.
20. Leow JJ, Meyer CP, Wang Y, et al. Contemporary trends in utilization and perioperative outcomes of percutaneous nephrolithotomy in the United States from 2003 to 2014. *J Endourol* 2017;31:742-50.
21. Ghani KR, Sammon JD, Bhojani N, et al. Trends in percutaneous nephrolithotomy use and outcomes in the United States. *J Urol* 2013;190:558-64.
22. Trudeau V, Karakiewicz PI, Boehm K, et al. The effect of obesity on perioperative outcomes following percutaneous nephorlithotomy. *J Endourol* 2016;30:864-70.
23. Rosette J, Assimos D, Desai M, et al. The clinical research office of the Endourological Society percutaneous nephrolithotomy global study: Indications, complications, and outcomes in 5803 patients. *J Endourol* 2011;25:11-7.
24. Kukreja R, Desai M, Patel S, et al. Factors affecting blood loss during percutaneous nephrolithotomy: prospective study. *J Endourol* 2004;18:715–22.
25. Akman T, Binbay M, Sari E, et al. Factors affecting bleeding during percutaneous nephrolithotomy: single surgeon experience. *J Endourol* 2011;25:327–33.
26. Lee JK, Kim BS, Park YK. Predictive factors for bleeding during percutaneous nephrolithotomy. *Korean J Urol* 2013;54:448–53.
27. Yamaguchi A, Skolarikos A, Buchholz N-PN, et al. Operating times and bleeding complications in percutaneous nephrolithotomy: a comparison of tract dilation methods in 5,537 patients in the Clinical Research Office of the Endourological Society Percutaneous Nephrolithotomy Global Study. *J Endourol* 2011;25:933–9.
28. Kessaris DN, Bellman GC, Pardalidis NP, et al. Management of hemorrhage after percutaneous renal surgery. *J Urol* 1995;153:604–8.
29. Keoghane SR, Cetti RJ, Rogers AE, et al. Blood transfusion, embolisation and nephrectomy after percutaneous nephrolithotomy (PCNL). *BJU Int* 2013;111:628–32.
30. Okeke Z, Smith A, Labate G, et al. Prospective comparison of outcomes of percutaneous nephrolithotomy in elderly patients versus younger patients. *J Endourol* 2012;26:996-1001.
31. Tefekli A, Kurtoglu H, Tepeler K, et al. Does the metabolic syndrome or its components affect the outcome of percutaneous nephrolithotomy? *J Endourol* 2008;22:35-40.
32. De S, Autorino R, Kim FJ, et al. Percutaneous nephrolithotomy versus retrograde intrarenal surgery: a systematic review and meta-analysis. *Eur Urol* 2015;67:125–37.
33. Skolarikos A, Alivizatos G, Rosette J. Percutaneous nephrolithotomy and its legacy. *Eur Urol* 2005;47:22-8.
34. Raman JD, Bagrodia A, Gupta A, et al. Natural history of residual fragments following percutaneous nephrostolithotomy. *J Urol* 2009;181:1163-8.
35. Gokce MI, Ozden E, Suer E, et al. Comparison of imaging modalities for detection of residual fragments and prediction of stone related events following percutaneous nephrolithotomy. *Int Braz J Urol* 2015:41:86-90.
36. Thomas K, Smith NC, Hegarty N, et al. The Guy's stone score – Grading the complexity of percutaneous nephrolithotomy procedures. *Urology* 2011;78:277-81.

DRAFT

37. Vicentini FC, Marchini GS, Mazzuchhi E, et al. Utility of the Guy's stone score based on computed tomogrpahic scan findings for percutenaous nephrolithotomy outcomes. *Urology* 2014;83:1248-53.
38. Fuller A, Razvi H, Denstedt JD, et al. The CROES percutaneous nephrolithotomy global study: The influence of body mass index on outcome. *J Urol* 2012;188:138-44.

DRAFT

Figures and Tables

Table 1. Patient characteristics stratified by tercile

Characteristic	Overall	Tercile			p
		First	Second	Third	
Age (years)*	54±15	53±13	53±12	56±12	0.009
BMI (kg/m^2)*	31±8	31±6	30±6	33±6	0.032
ASA score*					
ASA I	12.4	14.6	16.8	7.8	<0.001
ASA II	50.0	51.5	53.2	46.6	<0.001
ASA III	32.8	6.2	23.3	37.8	<0.001
ASA IV	4.8	0.6	3.4	5.9	<0.001
Overall comorbidities*	27.8	20.2	24.4	38.8	<0.001
Hypertension*	21.9	11.5	17.4	35.1	<0.001
Diabetes mellitus*	14.2	10.6	11.2	19.6	<0.001
Cardiac disease	13.0	13.8	10.9	13.0	ns
Pulmonary disease*	7.3	4.9	4.7	11.8	<0.001
Neurologic disease*	7.4	6.3	4.9	10.2	<0.001
Orthopedic condition	5.6	6.1	4.2	6.1	ns
Gastrointestinal disease*	5.5	2.7	4.4	9.0	<0.001
Renal insufficiency*	2.8	1.6	2.0	4.6	<0.001
Renal anomalies	13.7	12.9	14.7	13.6	ns
Calyceal diverticulum	4.5	4.6	5.3	3.2	ns
Solitary kidney	4.0	4.0	4.5	3.2	ns
Horseshoe kidney	2.7	3.1	1.9	2.8	ns
Urinary diversion	2.1	1.2	2.2	2.7	ns
Ectopic kidney	0.7	0.0	0.4	1.7	ns
Transplant kidney	0.2	0.1	0.5	0.1	ns

Values presented as percentage of patients or mean ± standard deviation. *p<0.05 for the difference between terciles. ASA: American Society of Anaesthesiologists' classification; BMI: body mass index; ns: non-significant.

DRAFT

Table 2. Stone characteristics stratified by tercile

Characteristic	Overall	Tercile			p
		First	Second	Third	
Stone burden					
≤500 mm^2	54.3	54.9	51.7	55.9	ns
501–1000 mm^2	26.2	25.1	28.7	25.0	ns
1001–1500 mm^2	9.1	9.9	8.2	9.3	ns
≥1500 mm^2	4.8	10.0	11.4	9.8	ns
Staghorn stones					
Partial staghorn	18.5	27.1	11.4	15.4	ns
Complete staghorn	14.2	11.3	11.5	18.6	ns
Stone composition					
Calcium oxalate monohydrate	37.5	29.9	50.0	51.2	ns
Calcium oxalate dihydrate	30.5	21.7	41.1	39.8	ns
Calcium phosphate	29.9	20.3	31.3	37.4	ns
Uric acid	20.0	18.3	21.8	20.0	ns
Struvite	13.4	14.0	14.4	13.1	ns
Cystine	6.4	7.5	7.2	4.9	ns

Values presented as percentage of patients. ns: non-significant.

DRAFT

Table 3. Procedural characteristics stratified by tercile

Characteristic	Overall	Tercile			p
		First	Second	Third	
Tract number					
1	92.4	91.1	90.6	93.7	ns
2	6.7	8.0	6.3	5.6	ns
≥ 3	0.8	0.7	1.2	0.6	ns
Tract location					
Upper calyx	13.3	10.7	12.7	15.6	ns
Mid calyx*	21.9	12.8	23.7	27.7	<0.001
Lower calyx*	64.8	73.6	59.9	56.3	<0.001
Dilation method					
Amplatz dilators*	5.9	8.1	9.0	0.6	<0.001
Balloon dilator*	94.1	91.9	91.0	99.4	<0.001
Lithotripter					
Ultrasound*	55.1	21.3	69.8	88.5	<0.001
Pneumatic*	28.2	47.5	33.0	11.3	<0.001
Electrohydraulic*	12.9	20.8	10.5	10.8	<0.001
Laser	3.8	3.1	2.4	6.8	ns
Postoperative drainage					
Nephrostomy tube	99.1	99.9	99.2	98.1	ns
Ureteric stent*	23.4	12.1	14.5	43.6	<0.001
Operative duration (mins)*	86±37	95±28	76±23	80±28	<0.001

Values presented as percentage of patients or mean ± standard deviation. *p<0.05 for the difference between terciles. ns: non-significant.

DRAFT

Table 4. Clinical outcomes stratified by tercile

Outcome	**Overall**	**Tercile**			**p**
		First	**Second**	**Third**	
Hospital stay (days)*	4.1±2.5	5.6±2.1	3.7±1.4	3.2±1.2	<0.001
Ancillary procedures*	20.6	39.2	9.0	13.4	<0.001
Second look* nephroscopy	16.3	35.3	6.0	7.5	<0.001
Shockwave lithotripsy	2.7	2.8	1.5	3.6	ns
Ureteroscopy	1.6	1.1	1.5	2.2	ns
Followup imaging					
IVP*	6.7	16.0	6.7	0.0	<0.001
Ultrasound	18.8	24.2	19.2	13.1	ns
X-ray KUB*	77.3	68.0	76.1	85.3	<0.001
CT*	4.3	0.4	4.0	7.3	<0.001
Stone-free rate*	86.7	95.0	89.7	73.5	<0.001

Values presented as percentage of patients or mean ± standard deviation. *p<0.05 for the difference between terciles. CT: computed tomography; IVP: intravenous pyelogram; KUB: kidneys ureter bladder; ns: non-significant.

DRAFT

Table 5. Complications stratified by tercile

Outcome	Overall	Tercile			p
		First	Second	Third	
Overall complications*	18.9	9.9	13.9	32.9	0.010
Clavien-Dindo I*	13.8	7.0	10.6	23.8	0.007
Clavien-Dindo II*	2.8	1.8	1.8	4.8	0.019
Clavien-Dindo IIIA	1.5	0.8	1.4	2.2	ns
Clavien-Dindo IIIB	0.53	0.0	0.1	1.5	ns
Clavien-Dindo IVA	0.2	0.1	0.0	0.5	ns
Clavien-Dindo IVB	0.03	0.0	0.0	0.1	ns
Clavien-Dindo V	0.07	0.2	0.0	0.0	ns
Specific complications					
Urosepsis	2.4	0.5	0.5	1.3	ns
Transfusion	1.0	0.8	0.7	1.4	ns
Embolization	0.6	0.7	0.1	0.8	ns
Pneumothorax	1.1	0.9	1.2	2.8	ns
Colon injury	0.1	0.2	0.0	0.1	ns
DVT/PE	0.4	0.4	0.1	0.6	ns
Death	0.1	0.2	0.0	0.0	ns

Values presented as percentage of patients or mean ± standard deviation. *p<0.05 for the difference between terciles. DVT: deep vein thrombosis; ns: non-significant; PE: pulmonary embolism.

DRAFT