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Success Rate and Complications of Percutaneous Nephrolithotomy (PCNL) in Nephrolithiasis Patients

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Abstract

Percutaneous Nephrolithotomy (PCNL) is the standard management method for kidney stones due to its high success rates. This process is associated with risks, including complications such as infection and bleeding. This study aimed to evaluate the complications and success rates of PCNL in nephrolithiasis patients and provide important insights for clinical decision-making. Data were collected from patients undergoing PCNL for nephrolithiasis at Dr. Hasan Sadikin General Hospital Bandung, Indonesia, in the form of demographic data, stone parameters, and postoperative complications. Data were then analyzed statistically to identify the associated factors. This study was conducted at the Urology Department of the hospital from January to December 2023, involving 80 nephrolithiasis cases. Predominantly, 67.5% of patients were males, with 63.7% in the age group of above 50 years. Multiple stones were the most common (55%), with stone sizes of ≥1.5 cm prevalent in 95% of cases. Left-sided stones (43.8%) were most frequent, followed by right-sided (36.2%) and bilateral stones (20%). Hydronephrosis complications were present in 36.2% of cases, with 100% stone clearance found in Guy Stone Score (GSS) grade 1 cases, while GSS grade 4 cases exhibited the lowest stone clearance rate at 45.4%. This study provided insights into nephrolithiasis demographics, stone characteristics, and postoperative outcomes. Male predominance, multiple stones, high rates of stone clearance, and postoperative complications, particularly in the Guy's score system, underscore the need for proper management strategies and further research in this field.

Keywords: Complication, nephrolithiasis, percutaneous nephrolithotomy, success rate

Introduction

Nephrolithiasis is a urological disorder potentially leading to fatal kidney failure, with a considerable morbidity rate.[1] The prevalence of this disease in the United States has risen from approximately 3% to 10% between 1980 and 2010. However, in Indonesia, nephrolithiasis affects six per 1,000 individuals, which makes the disease the third most common urological condition. Individuals aged 30 to 50 years are most vulnerable to kidney stones, with males being more affected than female.[2-3] While not all kidney stone episodes require treatment, surgical intervention is necessary when stones are symptomatic, causing obstruction, infection, or jeopardizing kidney function.

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Percutaneous Nephrolithotomy (PCNL) is the preferred method for removing kidney stones, specifically those larger than 20 mm or complex ones resistant to other treatments. [1,5-6] Despite the effectiveness, PCNL accounts for only 5% of stone-related procedures due to the invasive nature, higher complication rates, and technical demands compared to other methods, namely ureteroscopy or Extracorporeal Shock Wave Lithotripsy (ESWL). PCNL is associated with various complications ranging from mild, such as fever or nephrostomy tube leakage, to severe, including organ and pleural injuries, as well as bleeding and infection. [1,7-8]

Understanding the success rates and complications of PCNL is crucial for clinicians in selecting the appropriate surgical methods. The modified Clavien complication scale is an effective tool for assessing complex levels. Furthermore, the Guy score system aids in educating patients about stone-free rates and surgical prognosis.[9] PCNL has the highest stone-free rate and lower rates of additional

procedures, including retreatment, compared to ESWL or other methods.[4,9] A study conducted on 174 patients in Bandung reported stone-free rates following percutaneous nephrolithotomy (PCNL) of 94.7% in the prone position and 91.3% in the supine position.[10] Another study reported stone-free rates ranging from 85% to 93%.[5] Given the variation in reported outcomes, the present research aimed to evaluate the complications and success rates of PCNL in patients with nephrolithiasis. Further investigation was considered necessary, as previous studies did not provide detailed descriptions of the success rates and associated complications.

Methods

This study is a descriptive observational design using a cross-sectional approach, with data collection and measurement conducted at a single point in time. The research was carried out at the Department of Urology, Dr. Hasan Sadikin General Hospital (RSHS), Bandung, from January to December 2023. The inclusion criteria encompassed all patients scheduled to undergo percutaneous nephrolithotomy (PCNL) who provided informed consent. Exclusion criteria included patients undergoing open surgery, individuals with radiolucent stones, pregnant women, patients with comorbid conditions or bleeding disorders, and those who declined to participate.

The minimum sample size of 72 was calculated using the formula for Estimating Population Proportion with Specified Absolute Precision. The subjects comprised all patients diagnosed with nephrolithiasis who met the inclusion criteria and were scheduled to undergo PCNL at the Hospital. The following laboratory tests, creatinine, bleeding, and clotting time, including urine culture, were conducted. Radiological evaluation was performed using various imaging modalities such as Kidney Ureter and Bladder X-ray (KUB), Intravenous urography (IVU), computed tomography intravenous urogram (CT IVU), ultrasonography, or Non-Contrast Computerized Tomography (NCCT) when necessary.

Data collection involved obtaining relevant demographic and clinical information from medical records, including age, gender, stone size and location, comorbidities, intraoperative findings, postoperative outcomes, and complications. Stone size and location were assessed through radiographic imaging and classified using the Guy's Stone Score (GSS). Postoperative evaluation was conducted using a kidney, ureter, and bladder (KUB) X-ray on the first postoperative day. Stone clearance was defined as residual fragments smaller than 4 mm, along with the absence of significant hematuria, and indicated eligibility for nephrostomy tube removal within 48 to 72 hours after the procedure. Foley catheter removal was considered if no urinary leakage was observed from the nephrostomy site after 48 hours postoperatively. Ethical approval for this study was obtained from the Health Research Ethical Committee of Dr. Hasan Sadikin General Hospital, Bandung (Approval Number: DP.04.03/D.XIV.6.5/28/2024). Data processing included verification, coding, entry, sorting, and normalization. Key variables such as age, gender, GSS score, postoperative stone clearance, and operation duration were analyzed. Statistical analysis was performed using SPSS version 22 to identify factors associated with the success of PCNL (stone-free rate) and related complications.

Results

This study examined patient characteristics, including gender, age, stone count, size, location, and the presence of hydronephrosis. The research was conducted over a one-year period, from January to December 2023, at the Department of Urology, Faculty of Medicine, Universitas Padjadjaran/Dr. Hasan Sadikin General Hospital, Bandung. The study sample comprised 80 individuals diagnosed with nephrolithiasis who underwent PCNL within the specified timeframe and met the predetermined inclusion and exclusion criteria. The table below presents the general characteristics of the study population.

From January to December 2023, a total of 80 nephrolithiasis cases at the Department of Urology, Dr. Hasan Sadikin General Hospital, Bandung, met the inclusion criteria and did not fulfill the exclusion criteria. Among these cases, the majority of patients were male, accounting for 54 individuals (67.5%), while 26 patients (32.5%) were female. The age distribution showed that most patients were over 50 years old, comprising 51 individuals (63.7%). This was followed by 21 patients (26.3%) aged between 40 and 49 years, and 3 patients (3.8%) aged between 18 and 29 years.

The data also showed that the most common stone count was multiple stones, which suffered

Table 1 General Characteristics of the Research

Variables	n (%)	Mean
Gender		
Male	54 (67.5)	(-)
Female	26 (32.5)	
Age		
18-29 Years	3 (3.8)	
30-39 Years	5 (6.2)	
40-49 Years	21 (26.3)	52.85
>50 Years	51 (63.7)	
Stone Count		
Single	36 (45)	
Multiple	44 (55)	
Stone Size		
<1.5 cm	4 (5)	
≥1.5 cm	76 (95)	
Stone Burden	88.196	
Stone Location		
Right	29 (36.2)	
Left	35 (43.8)	
Bilateral	16 (20)	
Hydronephrosis		
Present	29 (36.2)	
Absent	51 (63.8)	
Body mass index		
Underweight	2 (1.3)	23.57
Normoweight	49 (61.3)	
Overweight	24 (30.1)	
Obesity	5 (6.3)	
Stone Composition		
Urea		31.52
Creatinine		2
Calcium		5.015
Phosphate		5.60
Uric Acid		5.67

Table 2 Postoperative Success by Comparing GSS with Stone Clearance

Grade	n (%)	Stone Clearance
1	19 (23.8%)	100
2	30 (37.5%)	66.67
3	20 (25%)	85
4	11 (13.8%)	45.45

by 55%, equivalent to 44 patients. The majority, approximately 95% or 76 patients, had stone sizes ≥1.5 cm. The most common stone location detected in 43.8% or 35 patients was on the left side, followed by the right side, suffered by 36.2% or 29 individuals, and bilateral by 20% or 16 recorded cases. In this research, approximately 36.2% or 29 patients reportedly suffered from hydronephrosis complications. The Postoperative success was examined by comparing the GSS with stone clearance, as shown in Table 2.

Urea shows the highest mean concentration at 31.52, indicating its significant presence in the stone. Uric acid and phosphate have relatively similar mean concentrations of 5.67 and 5.60, respectively, suggesting their notable contribution to the stone's makeup. Calcium has a mean value of 5.015, reflecting its importance in stone formation, while creatinine has the lowest mean concentration of 2.

This study revealed that all patients with GSS grade 1 achieved a 100% stone clearance rate. In contrast, the lowest stone clearance rate, at 45.45%, was observed in patients with GSS grade 4. Postoperative complications were systematically classified using the Clavien-Dindo grading system, a widely accepted tool for evaluating surgical complications. The distribution of these complications is detailed in Table 3, offering a comprehensive overview of postoperative outcomes among the study cohort.

According to Table 3, the majority of postoperative complications were classified as Clavien Grade I, particularly among patients with a GSS of 2, representing 37.5% of the cases. Additionally, 1.25% of patients with GSS grade 1 experienced Clavien Grade III complications. No postoperative complications were recorded under Clavien Grades II or IV.

Discussion

Age is a significant factor in the incidence of nephrolithiasis, with global data indicating the highest prevalence among individuals aged 50 to 60 years, particularly in males.[5] This trend aligns with the findings of the current study, where 63.7% of patients were over the age of 50. The increasing incidence in older age groups may be influenced by occupational factors and lifestyle choices, such as dietary habits, fluid intake, and physical activity levels. However, obesity (BMI≥30 kg/m^2) significantly increased the incidence of nephrolithiasis in the elderly, possibly due to

Table 3 Clavien Scale[11]

Grade	Description
1	Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions. Acceptable therapeutic regimens: antiemetics, antipyretics, analgesics, diuretics, electrolytes, and physiotherapy. Includes wound infections opened at the bedside.
2	Requiring pharmacological treatment with drugs other than those allowed for Grade 1 complications. Includes blood transfusions, antibiotics, and total parenteral nutrition.
3	Requiring surgical, endoscopic, or radiological intervention.
3a	Intervention under regional/local anesthesia.
3b	Intervention under general anesthesia.
4	Life-threatening complication requiring intensive care/intensive care unit (ICU) management.
4a	Single organ dysfunction.
4b	Multi-organ dysfunction.
5	Patient demise.

Table 4 Postoperative Complications According to the Clavien Scale

Guy Score	Clavien I	Clavien II	Clavien III	Clavien IV
Guy Score 1	22.5% (18)	-	1,25% (1)	-
Guy Score 2	37.5% (30)	-	-	-
Guy Score 3	25% (20)	-	-	-
Guy Score 4	13.75% (21)	-	-	-

heightened levels of uric acid nephrolithiasis in obese individuals. While most patients had a normal BMI, approximately 36.25% had a BMI above the normal range, suggesting a correlation between BMI and nephrolithiasis occurrence. Increased excretion of calcium, oxalate, and uric acid in urine raises the risk of calcium kidney stone formation, as shown by the biochemical profile in this research. [12]

The gender disparity in nephrolithiasis is significant, with a prevalence two to three times higher in men than in women globally.[12] This trend is consistent with the research findings, including investigations conducted in Korea and NHANES data from the United States. However, the prevalence gap between men and women tends to be narrowing over time, with continuous increases observed in females across various analyses and annual cycles.[12] The research findings contributed to this understanding, focusing on a stable male prevalence, but a rising occurrence in females, particularly among those below 60 years. The role of estrogen in reducing kidney stone recurrence in postmenopausal women shows the importance of hormonal factors in nephrolithiasis development. [13]

This research also elaborated on the distribution of stone characteristics, with multiple stones being the most prevalent (44%) and the majority of cases having stone sizes ≥1.5 cm. Compared with a study conducted by Alasker et al.,[15] the mean stone size was 12.2±9.91 mm.[14] In terms of laterality, left-sided stones were more frequently observed than right-sided ones, consistent with findings by Saeed et al.,[16] who reported that 55% of patients had stones on the left side and 45% on the right.Furthermore, hydronephrosis was identified in 36.25% of the patients in this study, reflecting the impact of obstruction caused by nephrolithiasis.. Four patients had bilateral stones.Kidney and ureteric stones were the most common cause of hydronephrosis. Fifty-four percent of adult hydronephrosis patients were caused by kidney and ureteric stones.[17] Stone clearance rates varied across GSS grades, with GSS grade 1 cases possessing a 100% stone clearance rate. However, the lowest, approximately 45.45%, was observed in GSS grade 4 cases, showing the influence of stone complexity on treatment outcomes.

The adoption of standardized assessment systems, such as GSS and S.T.O.N.E. nephrolithometry, was crucial for predicting

treatment outcomes and guiding patient counseling. These systems facilitated uniform reporting and comparison between different surgical methods and institutions.[13] Despite the significance of stone complexity in treatment outcomes, no significant relationship was found between stone complexity and postoperative complications, in line with previous research findings.[18] Further investigation into the predictive value of assessment systems and the impact on treatment outcomes must be conducted to enhance clinical decision-making in nephrolithiasis management.

Thomas et al. reported that GSS had suitable reproducibility with ideal inter-rater agreement. Several research have reported a strong correlation between GSS and stone-free rates. The research reported 81%, 72.4%, 35%, and 29% success rates for GSS 1, 2, 3, and 4, respectively. Other investigations reported stone-free rates ranging from 93.9% to 100%, 85.71% to 97%, 90.17% to 100%, and 60% to 77.77% for GSS 1, 2, 3, and 4. Overall success rates ranging from 62% to 97.73% had been reported in different investigations validating the GSS.[19]

In a retrospective research by Kumsar et al. that compared GSS and S.T.O.N.E., stone-free rates of 90%, 96%, and 34% were obtained in the GSS 1, 2, and 3 groups, respectively. Some investigations have also found GSS based on CT scans to be effective in predicting the success rates of PCNL. Okhunov et al. recently introduced the STONE score, which was validated by retrospective research in predicting PCNL success rates. Additionally, this was supported by only one prospective investigation. [19]

Labadie et al. conducted a retrospective comparative analysis and reported that low GSS and STONE scores were significantly associated with stone-free rates (p=0.002 and 0.004). Furthermore, both systems also correlated with blood loss and length of hospital stay. The assessment systems had effective predictive value for stone-free status. [20,21]

This research reported that most cases experienced postoperative complications at the Clavien I scale, especially 37.5% of GSS 2. Meanwhile, 1.25% of GSS 1 experienced postoperative complications on Clavien III scale. No cases of postoperative complications at the Clavien II or IV scales were found. According to Shaheem et al., [22] complications after PCNL measured based on the significantly modified Clavien Dindo scale were associated with GSS and STONE scores of p-value=0.007 and 0.005, respectively.

Thomas et al. reported no significant association between GSS and complications following PCNL. Similarly, Noureldin et al. found that neither the GSS nor the STONE score correlated with intraoperative complications. In contrast, Vicentini et al. demonstrated a significant association between GSS and post-PCNL complications. Furthermore, Singla et al. identified only a weak correlation between all three assessment systems (GSS, STONE, and CROES) and the modified Clavien-Dindo classification of complications.[19,22]

GSS is a simple and reliable tool for predicting success rates. It is mainly used in kidney, ureter, bladder (KUB), and intravenous urography (IVU) films to predict success rates after PCNL. The GSS and STONE scores effectively predicted stone-free (SF) status (AUCs: 0.68, 0.72) and correlated with perioperative complications. Overall complication rates (modified Clavien) were lower compared to Thomas et al. and Okhunov et al.[23] CROES PCNL showed 75.5% SF and 20.5% complication rates, with 3.1% requiring transfusions.

Lojanapiwat et al. reported that GSS based on KUB and intravenous urography was a valuable tool in predicting outcomes and complication rates after PCNL through the upper pole. Direct success rates, operation time, tubeless or uncomplicated procedure rate, and major complications differed significantly in each GSS group.[24]

In conclusion, this study observed a male predominance among PCNL patients, accounting for 67.5% of the study population, with the majority of cases occurring in individuals over the age of 50. Most patients presented with multiple stones, typically measuring ≥1.5 cm in size. Left-sided stones were more frequently encountered than right-sided or bilateral stones. Postoperative complications were common, with the majority classified as Clavien grade I, indicating predominantly minor surgical outcomes.

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