ORIGINAL ARTICLE

Profile and Outcome Differences in Kidney Stone Patients with Percutaneous Nephrolithotomy and Open Nephrolithotomy

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ABSTRACT

Introduction: Effective management of kidney stones can involve either percutaneous nephrolithotomy (PCNL) or open nephrolithotomy. This study aims to compare the profiles and outcomes of patients with kidney stones who underwent either PCNL or open nephrolithotomy. **Methods:** Conducted at Abdul Moeloek Hospital in Lampung, the research employed an observational analytical approach with a cross-sectional design from April to September 2023. A total of eighty-five patients with kidney stones participated in this study, which examined several key factors, including hemoglobin levels, transfusion requirements, stone burden, and stone type. Furthermore, the study assessed complications, surgery duration, and the stone-free rate, all of which are vital considerations. It specifically investigated the independent variables associated with the procedures of percutaneous nephrolithotomy and open nephrolithotomy. Data collection involved patient medical records and observation sheets, while data analysis employed the Mann-Whitney test. **Results:** There were differences in stone-free rate and stone type. The stone-free rate was higher in open nephrolithotomy than in PCNL, with more non-staghorn stones in open nephrolithotomy. There were no significant differences in stone burden and complications. Meanwhile, stone burden and complications were nearly equal in both groups. **Conclusion:** Both PCNL and open nephrolithotomy are effective options for treating kidney stones. The researchers recommend conducting further studies involving larger populations to enhance the understanding of these procedures.
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INTRODUCTION

Urolithiasis is a condition in which stones form in the urinary tract, including the kidneys, ureters, bladder, and urethra. The stones are formed from crystals that precipitate from urine. Urolithiasis symptoms vary based on stone location, infection severity, and urinary tract blockage (1). The lifetime prevalence of urolithiasis ranges from 1% to 15%. Age, race, gender, and geographic location cause this variation. Kidney stones that form in the kidneys are called nephrolithiasis. Kidney stones are formed from blood waste that turns into crystals and becomes harder over time. Small, asymptomatic urinary tract stones can usually pass naturally from the urinary tract and heal on their own (2).

Treatment for kidney stones depends on the size, location, and severity of the condition. Non-invasive treatments for kidney stones include Extracorporeal Shock Wave Lithotripsy (ESWL), which breaks stones into smaller pieces for easier excretion through urine (3). Besides that, minimally invasive surgical procedures, surgical procedures without incisions or with small incisions. Surgical procedures without incisions, include Ureterorenoscopy (URS) or Retrograde Intrarenal Surgery (RIRS) to detect and break up kidney stones. Advances in medical technology have shifted kidney stone surgery. The medical field has moved from open surgery to minimally invasive methods. These include ESWL, Percutaneous Nephrolithotomy (PCNL), ureteroscopy, and laparoscopic surgery (4).

The PCNL method is a minimally invasive technique for accessing the calyx or pelvis of the kidney. The surgeon employs a nephroscope or ureteroscope to remove kidney stones that are larger than 2 cm or not amenable to treatment with ESWL or cystoscopy and ureteroscopy. This procedure is also indicated when kidney stones cause infections or severe pain that cannot be managed with medication. The nephroscope, a tubular instrument equipped with a camera, is inserted directly into the

kidney through a small incision made by the surgeon in the patient's back (5).

PCNL is particularly effective for managing large or complex kidney stones and boasts a high stone-free rate, quick procedure duration, and immediate results (6). (7). However, it necessitates specialized skills from urologists (8). In contrast, open nephrolithotomy involves making a larger incision in the back and using specialized instruments to crush the kidney stones into smaller pieces for removal (9). This surgical procedure is often chosen when ESWL has failed to effectively treat the stone or when the stone exceeds 2 cm in size. (10), Currently, PCNL is the preferred choice for kidney stone treatment due to its numerous advantages.(11), Research indicates that both PCNL and open nephrolithotomy have been utilized to manage kidney stones, resulting in varying patient profiles and outcomes (12). This research focused on examining the disparities in stone-free rates, types of stones, stone burden, and complications between patients with kidney stones who underwent PCNL and those who underwent open nephrolithotomy.

MATERIALS AND METHODS

This study employed a retrospective approach to compare the profiles and outcomes of kidney stone patients treated with PCNL versus open nephrolithotomy (13). The research was submitted to the Medical Research Ethics Committee of the University of Lampung under the reference number 3467/UN26.18/PP.05.02.00/2024. Inclusion criteria consisted of patients aged 18 years and older, who had been diagnosed with kidney stones and had provided informed consent. Exclusion criteria eliminated patients with kidney abnormalities. This research was conducted at Abdul Moeloek Hospital in Lampung, between April and September 2023. The study focused on several variables, including stone-free rate, stone type, stone burden, and complications. Data collection was carried out using medical records and observation sheets (14). The Mann-Whitney and Chi-Square tests were employed to analyze the data (15).

RESULTS

Eighty-five kidney stone patients participated in this study, comprising 44 males (51.8%) and 41 females (48.2%). Among these 85 patients, 31 (36.5%) underwent Percutaneous Nephrolithotomy (PCNL), while 54 (63.5%) were treated with open nephrolithotomy. The mean age in the PCNL group was 50.60±11.27 years (ranging from 24 to 69), compared to an average age of 51.09±10.69 years (ranging from 24 to 72) in the open nephrolithotomy group. The mean duration of surgery for the PCNL group was 104.52±20.30 minutes (with a range of 60 to 120), whereas the open nephrolithotomy group averaged 69.44±19.17 minutes (also ranging from 60 to 120). In the PCNL group, there were 15 males and 16 females.

Conversely, the open nephrolithotomy group included 29 males and 25 females. Within the PCNL group, 4 patients (12.9%) exhibited stable hemoglobin (Hb) levels, while 27 (87.1%) experienced a decrease. Of these, 8 patients (25.8%) required blood transfusions, whereas 23 (74.2%) did not. In the open nephrolithotomy group, 18 patients (33.3%) maintained stable Hb levels, 35 (64.8%) showed decreased levels, and 1 (1.9%) experienced an increase. In this group, 16 patients (29.6%) received blood transfusions, while 38 (70.4%) did not. The characteristics of the patients are detailed in Table I.

Table II provides insights into the stone-free rates, stone types, stone burden, and associated complications for the two surgical techniques analyzed. The mean stone-free rate in the PCNL group was 84.03±6.11 (with a minimum of 80 and a maximum of 100), while the open nephrolithotomy group demonstrated a mean stone-free rate of 89.54±3.918 (minimum 75, maximum 100). A t-test indicated a significant mean difference in stone-free rates between the two groups (p<0.001), with a difference of 5.51; this suggests that both methods are comparably effective in removing kidney stones.

Table I: Characteristics of Patients at Abdul Moeloek Hospital, Lampung Province, in 2022

Variables	PCNL Group		Open Nephrolithotomy Group	
	Mean	Standard Deviation	Mean	Standard Deviation
Age (year)	50.6	11.27	51.09	10.69
Duration of operation (minute)	104.52	20.3	69.44	19.17
	Frequency	Percent	Frequency	Percent
Gender				
Male	15	48.4	29	53.7
Female	16	51.6	25	46.3
Hb level				
Stable	4	12.9	18	33.3
Decrease	27	87.1	35	64.8
Increase	0	0.0	1	1.9
Need for blood transfusion				
Yes	8	25.8	16	29.6
No	23	74.2	38	70.4

In the PCNL group, the distribution of stone types was as follows: non-staghorn stones accounted for 15 cases (25.4%) and staghorn stones for 16 cases (61.5%). Conversely, the open nephrolithotomy group included 44 non-staghorn stones (74.6%) and 10 staghorn stones (38.5%). A t-test analysis revealed a significant difference in stone types between the two groups (p=0.003).

Regarding stone burden, the PCNL group reported 23 cases (32.9%) in the 20-50 mm range and 8 cases (53.3%) exceeding 50 mm. In the open nephrolithotomy group, 47 cases (67.1%) fell within the 20-50 mm range, while 7 cases (46.7%) were greater than 50 mm. Statistical evaluations indicated no significant difference in stone burden between the two groups (p=0.230).

Table II: Stone-Free Rate, Stone Type, Stone Burden and Complications

Variable		Methods		Total	p-value
		PCNL	*Open Nephrolithotomy*		
Stone-Free Rate		84.03±6.11	89.54±3.918		<0.001
Stone type	Non Staghorn	15 (25.4)	44 (74.6)	59	0.003
	Staghorn	16 (61.5)	10 (38.5)	26	
Stone burden	20-50 mm	23 (32.9)	47 (67.1)	70	0.230
	>50 mm	8 (53.3)	7 (46.7)	15	
Complications	*Grade 1*	23 (39.7)	35 (60.3)	58	0.292
	Grade 2	7 (41.2)	10 (58.8)	17	
	Grade 3	0 (0.0)	0 (0.0)	0	
	Grade 4	0 (0.0)	4 (100.0)	4	
	Grade 5	1 (16.7)	5 (83.3)	6	

When it comes to complications, the PCNL group experienced first-grade complications in 23 cases (39.7%), second-grade in 7 cases (41.2%), and fifth-grade in 1 case (16.7%). The open nephrolithotomy group had first-grade complications in 35 cases (60.3%), second-grade in 10 cases (58.8%), fourth-grade in 4 cases (100.0%), and fifth-grade in 5 cases (83.3%). The study concluded that there was no significant difference in complication rates between the two surgical techniques (p=0.292).

DISCUSSION

Percutaneous nephrolithotomy (PCNL) is a minimally invasive procedure designed to remove stones from the urinary tract, gallbladder, or pancreas. This technique involves inserting a specialized instrument through a small tube directly to the location of the stone. Because PCNL does not require a large incision, it effectively minimizes postoperative pain and facilitates a faster recovery compared to open surgery. Moreover, PCNL boasts a higher success rate and a lower risk of requiring retreatment than alternative methods. In contrast, open nephrolithotomy involves making a substantial incision in the waist to access the kidney for stone removal and is typically reserved for patients with very large kidney stones (over 2 cm) (16).

5-10% of people will develop kidney stones during their lifetime, with most experiencing recurrent episodes. Kidney stones are most common between the ages of 20 and 49 and are rare in children and young adults. Men are more likely to develop kidney stones than women, although this gender gap has narrowed in recent years. Testosterone can increase oxalate levels, raising the risk of calcium oxalate stone formation. Conversely, women tend to have higher urinary citrate levels, which inhibit stone formation (17). Surgery can lead to decreased hemoglobin (Hb) levels because it may involve cutting and opening blood vessels. However, the reduction in Hb typically does not require transfusions and remains within normal limits. This is especially true for surgeries that do not involve significant blood loss. Minimally invasive procedures, which use small incisions, generally cause less bleeding than open surgeries (18). Percutaneous nephrolithotomy (PCNL) is considered the standard treatment for medium to large kidney stones. It is a safe, highly effective, and minimally invasive procedure. Nonetheless, complications may arise in patients with complex stone burdens (19).

In addition to percutaneous nephrolithotomy (PCNL), open nephrolithotomy is a surgical procedure used to remove large and hard kidney stones that are difficult to break up and extract using non-surgical methods. This procedure involves making an incision to access and remove the kidney stone. Patients may require nephrolithotomy if the stone is very large (greater than 2 centimeters) or if its location renders other treatments, such as extracorporeal shock wave lithotripsy (ESWL) or ureteroscopy, ineffective. Since nephrolithotomy is an open surgery, there are associated risks that must be carefully managed to minimize complications (20). Kidney stones most commonly develop between the ages of 40 and 60, although they can occur at any age. Research indicates that 35–50% of individuals who have had one kidney stone will develop additional stones, typically within 10 years of the first occurrence. Age and gender significantly influence the type of stone that forms (21).

The patient's age, gender, and medical history can significantly influence the outcomes of nephrolithotomy and percutaneous nephrolithotomy (PCNL) procedures (22). These factors impact the success rate of kidney stone removal, the risk of complications, and the duration of recovery (23). Generally, younger patients tend to have stronger immune systems and higher metabolic rates, which may contribute to faster recovery and a reduced risk of complications following PCNL (24). Conversely, older patients often have comorbidities that increase the likelihood of complications, and their recovery may be prolonged due to a weakened immune system and slower metabolism (25).

Several studies have shown that longer surgical durations in percutaneous nephrolithotomy (PCNL) may increase the risk of residual stones. This is because extended surgical times can indicate difficulties in accessing and clearing the stones or complications

arising during the procedure. Men may have a higher risk of bleeding complications after PCNL compared to women, possibly due to greater muscle mass, which may increase susceptibility to internal bleeding (26). Conversely, women may have a higher risk of infectious complications following PCNL, potentially because of differences in immune response that increase susceptibility to urinary tract infections (27).

Patients with a history of chronic diseases, such as diabetes or hypertension, may have an increased risk of complications following PCNL. These medical conditions can affect recovery and may also elevate the risk of infection (28). Additionally, patients with a history of allergies may be susceptible to allergic reactions from anesthesia or other medications used during PCNL. Those taking certain medications, such as anticoagulants, may face a higher risk of bleeding after the procedure (29).

Overall, it is important to understand that age, gender, and medical history can influence the outcomes of PCNL and nephrolithotomy (30). By taking these factors into account, physicians can tailor the treatment to each patient, thereby increasing the likelihood of a successful procedure and minimizing the risk of complications (31).

Stone complexity is associated with lower postoperative hemoglobin levels and can be assessed using the STONE score. Staghorn stones result in greater blood loss compared to calyceal stones, a finding consistent for both complete and partial staghorn stones. Key factors such as stone complexity, creatinine levels, complications, and surgery duration are linked to an increased risk of bleeding and the need for transfusion during percutaneous nephrolithotomy (PCNL). Larger staghorn stones require more blood transfusions during PCNL than smaller stones (32).

Patient-related factors predict postoperative bleeding and include age, diabetes, and urinary tract infections. Additionally, the preoperative hemoglobin level is important, as are the presence of large or staghorn stones, their location, hydronephrosis, and renal thickness. Prolonged operating times can also contribute to increased postoperative bleeding (33).

Bleeding during open nephrolithotomy can occur as a complication, although it is less common than in other procedures such as percutaneous nephrolithotomy (PCNL). Accurate estimation of blood loss is essential to avoid unnecessary blood transfusions. Certain factors can predict the total amount of bleeding during this procedure (34). Hydronephrosis is one such predictor of bleeding in PCNL. Blood loss during PCNL depends on three factors: the degree of hydronephrosis, the number of access channels, and the duration of the operation. Higher rates of blood transfusion are associated with lower degrees of hydronephrosis and thicker renal parenchyma. PCNL performed on horseshoe kidneys is considered safe and does not carry an increased risk of bleeding. Anatomical anomalies do not predict bleeding (35).

In the treatment of kidney stones, the stone-free rate is a crucial parameter to consider. This study found that the stone-free rate was 84.03% in the PCNL group, compared to 89.54% in the open nephrolithotomy group. Although the difference between the two groups was statistically significant ($p < 0.001$), the absolute difference was only 5.51%. Therefore, the researchers concluded that PCNL is comparable to open nephrolithotomy in terms of stone-free rate. Similarly, El-Nahas (36) reported that PCNL and open surgery had comparable stone-free rates. However, Zhang (37) found that open surgery provided a significantly higher final stone-free rate compared to PCNL (97.5% vs. 76.1%, $p < 0.001$). The stone-free rate refers to the percentage of patients with no residual kidney stones following a medical procedure and is used to measure the procedure's success in treating kidney stones. The stone-free rates for PCNL and open nephrolithotomy are similar, indicating that PCNL also achieves a favorable outcome in this regard. The stone-free condition is defined as the absence of residual stones after surgery, which is typically assessed using plain abdominal radiographs and/or ultrasonography (USG). PCNL is a minimally invasive urological procedure designed to remove kidney stones through percutaneous access to the pelvicalyceal system. Patients undergoing PCNL often have a greater stone burden (38).

In the PCNL group, the stone types were non-staghorn in 15 cases (25.4%) and staghorn in 16 cases (61.5%). In the open nephrolithotomy group, non-staghorn stones were found in 44 cases (74.6%) and staghorn stones in 10 cases (38.5%). Analysis using the t-test revealed a significant difference between the two groups ($p = 0.003$). Several factors contribute to the development of staghorn kidney stones. Intrinsic factors include heredity, age (commonly occurring between 30 and 50 years), and gender (men are affected three times more often than women). Extrinsic factors include geography, climate and temperature, water intake (insufficient hydration and high calcium mineral levels in consumed water), diet (high in purines, oxalates, and calcium), and occupation (the condition is more common in individuals with sedentary jobs). Staghorn kidney stones are characterized by branching stones that extend from the renal pelvis into two or more renal calyces. The size of staghorn stones depends on the size of the kidney. Staghorn kidney stones can be treated with PCNL surgery without radiation exposure. This technique uses ultrasound guidance to avoid radiation risks and minimize the need for radiation-related medications.

The stone burden in the PCNL group was 20–50 mm in 23 patients (32.9%) and greater than 50 mm in 8 patients (53.3%). In the open nephrolithotomy group, 47 patients (67.1%) had stones measuring 20–50 mm, and 7 patients (46.7%) had stones larger than 50 mm. Statistical analysis showed no significant difference in stone burden between the two groups. Kidney stones are considered dangerous if they exceed 10 mm (1 cm) because they can obstruct the urinary tract and cause complications. Stones of this size typically require medical intervention for removal. Conversely, kidney stones smaller than 4 mm usually pass spontaneously within 1 to 2 weeks. Larger stones may take longer to pass or may necessitate medical treatment. Generally, urinary tract stones with a diameter less than 5 mm have a higher likelihood of passing on their own. However, medical intervention may still be necessary in cases where the stone obstructs the urinary tract or causes severe symptoms. For patients requiring intervention, factors such as stone location, stone size, and kidney function must be carefully considered (39).

For stones measuring less than 2 cm in diameter (which corresponds to the maximum diameter of the urinary tract), the first-line treatment is extracorporeal shock wave lithotripsy (ESWL). The success of ESWL depends on the size, composition, and location of the stone. ESWL generates extracorporeal shock waves that are focused on the stone, fragmenting it into smaller pieces. This facilitates easier passage of the stone fragments through the urine. An advantage of ESWL is that it does not require general anesthesia, allowing the patient to go home immediately after the procedure (40).

Complications in the PCNL group were classified as follows: first grade, 23 cases (39.7%); second grade, 7 cases (41.2%); and fifth grade, 1 case (16.7%). In the open nephrolithotomy group, complications included first grade, 35 cases (60.3%); second grade, 10 cases (58.8%); fourth grade, 4 cases (100.0%); and fifth grade, 5 cases (83.3%). The study found no significant difference in complication rates between the two groups. Complications associated with the PCNL procedure include bleeding, infection, injury to surrounding organs, and ureteral obstruction. PCNL is considered a relatively low-risk surgical procedure for kidney stones. It is minimally invasive, resulting in smaller incisions, less postoperative pain, and a shorter recovery time. In contrast, complications following open nephrolithotomy for kidney stone treatment may include pain and discomfort at the incision site or around the kidney, painful urination, nausea and vomiting, hematuria, infection, anesthesia-related reactions, and constipation (41).

One of the complications of percutaneous nephrolithotomy (PCNL) is bleeding. PCNL procedures can injure the renal blood vessels, particularly the segmental and interlobar arteries. This risk arises due to direct access to the pelvicalyceal system and intrarenal manipulation. One type of kidney stone is the staghorn stone. Risk factors for staghorn stones include heredity, age (30–50 years), and gender, with men being three times more likely to develop them than women. Other contributing factors include climate, low water intake, high calcium levels, and a diet rich in purines and oxalates, as well as sedentary work (42). Previous systematic reviews and meta-analyses have found that PCNL is a viable alternative to open surgery for patients with staghorn kidney stones. It offers several advantages, such as shorter hospitalization and operation times, less blood loss and fewer blood transfusions, without increasing complications or reducing the final stone-free rate (43).

Overall, this study demonstrates that PCNL is an effective treatment for kidney stones, achieving a stone-free rate comparable to that of open nephrolithotomy. PCNL is highly successful in treating kidney stones, is minimally invasive due to a small incision in the back, and is associated with a low risk of complications, minimal postoperative pain, and a rapid recovery time. Previous studies have also reported that PCNL offers high success rates, faster recovery, shorter hospital stays, and lower morbidity (44).

CONCLUSION

Percutaneous nephrolithotomy (PCNL) and open nephrolithotomy are both effective treatment options for kidney stones. Patients who underwent PCNL achieved stone-free rates comparable to those who received open nephrolithotomy. The study's findings indicated no significant difference in complication rates between the two groups.

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