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ORIGINAL ARTICLE

Evaluation of factors affecting success rate of open nephrolithotomy in adult patients

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ABSTRACT

BACKGROUND
Indonesia has a high incidence of kidney stone disease. Endoscopic procedures are the preferred first-line treatment, but' nephrolithotomy remains an option for large or complex staghorn calculi, particularly in resource-limited settings. This study aimed to determine factors associated with the success rate of open nephrolithotomy at a single tertiary center.

METHODS
This retrospective study included 92 adults who underwent open nephrolithotomy at Wonogiri Regional General Hospital from January 2018 to December 2022. We analyzed demographic, laboratory, stone-related, and operative variables. Stone characteristics were assessed on preoperative non-contrast CT. Success was defined as complete stone clearance or residual fragments <4 mm on plain abdominal radiography (Blaas Nieren Overzicht, BNO) (KUB) on postoperative day 1. Associations were tested with simple binary logistic regression. Variables with $p<0.25$ were entered in a multiple logistic regression model.

RESULTS
Among the 92 patients, 59 were men and 33 were women, with a mean age of 53.25 ± 10.25 years. Surgery succeeded in 69 patients (75.0%), and complications occurred in 14 (15.2%). In simple logistic regression, female gender (OR 3.44, 95% CI 1.06–11.20; p=0.040) and multiple stones (OR 0.026, 95% CI 0.003–0.203; p=0.001) were associated with success. In multiple logistic regression, only stone number remained independently associated with success (aOR 0.029, 95% CI 0.004–0.230; p=0.001).

CONCLUSION
Stone number was the only independent factor associated with the success of open nephrolithotomy. Patients with multiple stones had lower odds of success. This should guide preoperative planning and counseling.

Keywords: Nephrolithiasis, open nephrolithotomy, surgical outcome, stone burden

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INTRODUCTION

Indonesia is a country known to be in the stone belt area of Southeast Asia, which has a high incidence of kidney stone disease (KSD).[1] It has been reported that 6 out of 1000 people have KSD, with a higher incidence rate in the 30-50-year population group and three times more cases in men than in women. It has been reported that after 1 year an estimated 6-7% of patients come back with KSD. Besides the high incidence rate, the recurrence rate among patients is also high, [2]while the percentages are 21-53% after 3-5 years and 60-80% in lifetime patients.[3] Recurrent stone formation increases the risk of kidney injury, leading to end-stage renal disease (ESRD) and an increased risk of mortality and morbidity.[4] The study by Kim et al.[5] reported that patients with nephrolithiasis had risks of stroke and ischemic heart disease that were 1.18 times and 1.24 times those of the controls, respectively. Although kidney transplantation (KT) is the treatment of choice for end-stage renal disease (ESRD) in Indonesia, dialysis is preferred over KT. [6]

The surgical management of nephrolithiasis has evolved considerably over recent decades. Minimally invasive endoscopic procedures, including percutaneous nephrolithotomy (PCNL), retrograde intrarenal surgery (RIRS), and extracorporeal shock wave lithotripsy (ESWL), are now the preferred first-line treatments for most renal stones. A network meta-analysis by Chung et al.[7] demonstrated that PCNL achieves the highest stone-free rate among these modalities, particularly for stones larger than 2 cm, while ESWL showed the lowest stone-free rate overall. Despite these advances, open nephrolithotomy remains a relevant and commonly performed procedure for large or complex staghorn calculi, particularly in resource-limited settings where endourological infrastructure and expertise are unavailable. Nourian et al.[8] reported a stone-free rate of 91.6% for open surgery in staghorn calculi, which was numerically higher than PCNL (81.9%), reinforcing the continued viability of open nephrolithotomy for complex stone disease.

Their number being projected to double in the future, patients with renal replacement therapy (RRT) are, moreover, fully covered by national health insurance and social welfare programs. Renal replacement therapy puts pressure on the national healthcare budgets, with the challenge that patients with KSD must get therapy before they fall into end-stage renal disease (ESRD).[9,10]

Existing literature on predictors of surgical success in nephrolithiasis focuses predominantly on PCNL, and even within this body of work, reported predictors are inconsistent. Yılmaz et al.,[11] in 508 PCNL patients, identified stone size, complexity, intraoperative complications, operative time, and surgeon experience as independent predictors of stone-free status, with no significant effect of age or gender. Ali et al.,[2] in 245 Indonesian PCNL patients, instead identified stone location within the renal pelvis as the principal predictor, again with no age effect.

Stone burden and complexity are the only factors that recur consistently across these series, whereas demographic and anatomical predictors do not. Evidence specific to open nephrolithotomy is limited. One comparative series that included open surgery alongside percutaneous nephrolithotomy (PCNL) and retrograde intrarenal surgery (RIRS) reported only 13 open cases, described their outcomes (stone-free rate 69.3%), but did not analyze predictors.[12] Consequently, it remains unclear whether predictors identified in PCNL are applicable to open nephrolithotomy.

The present study differs from previous reports by focusing exclusively on open nephrolithotomy and by evaluating patient, laboratory, and stone-related factors collectively in an Indonesian setting, where this procedure remains commonly performed. The objective was to analyze factors associated with the success rate of open nephrolithotomy, defined as stone-free status or residual fragments less than 4 mm in size, at a single tertiary center in Indonesia.

METHODS

Research design

This retrospective observational study was conducted at Wonogiri Regional General Hospital, a tertiary referral center in Central Java, Indonesia, over a five-year period from January 2018 to December 2022. Data were collected and analyzed from August to November 2025.

Study subjects

A total of 92 patients aged 18 years or older, both male and female, diagnosed with nephrolithiasis and treated with open nephrolithotomy, were included. Open surgery at

this center is reserved for large or complex staghorn calculi and for obstructive renal calculi >20 mm in size with a density of >1000 Hounsfield units (HU). This indication limits annual case volume compared with endoscopic stone procedures. All consecutive eligible cases during the study period were included through total sampling. Patients with pyohydronephrosis, a history of previous open renal stone surgery, renal anatomical abnormalities (e.g., horseshoe kidney), and pediatric patients were excluded. All diagnoses were confirmed using non-contrast CT.

Preoperative evaluation

All patients underwent preoperative laboratory assessment, including complete blood count, serum electrolytes, and renal function tests (blood urea nitrogen and creatinine). Urinalysis was performed to assess for leukocyturia. Renal ultrasonography was used to detect hydronephrosis. Non-contrast CT scan confirmed the diagnosis and characterized stone number, size, and location, and served as the basis for surgical planning.

Surgical technique

All patients underwent open nephrolithotomy performed by a single experienced urologist at the study center, which minimized inter-operator variability. Stone location and number, as determined by preoperative CT, guided the operative approach. Patients were placed in the lateral flank position under general anesthesia. A flank incision was used to access the retroperitoneal space and expose the kidney. Nephrotomy or pyelotomy was performed at the site corresponding to the stone location on imaging, and stones were extracted under direct visualization. The collecting system was closed, with nephrostomy tube and/or ureteral stent placement according to intraoperative findings and the surgeon's discretion.

Postoperative evaluation

Surgical success was assessed with plain abdominal radiography (BNO) on the first postoperative day. Success was defined as complete stone clearance or clinically insignificant residual fragments of <4 mm in diameter; larger residual stones were classified as failure. Complete blood count and renal function tests were repeated on postoperative day 1 to monitor for bleeding and renal recovery.

Measurements

The following variables were analyzed in relation to success: gender, age, pre-operative hemoglobin, creatinine, and leukocyte count, stone number, hydronephrosis, leukocyturia, and operative time. For regression, variables were categorized as follows: age <60 or ≥60 years; anemia as hemoglobin <13 g/dL in men and <12 g/dL in women; leukocytosis as a leukocyte count >11 $\times 10^3/\mu L$; abnormal creatinine as >1.3 mg/dL in men and >1.1 mg/dL in women; leukocyturia as >5 white blood cells per high-power field; stone number as single or multiple; hydronephrosis as present or absent; and operative time as <100 or ≥100 minutes.

Statistical analysis

Continuous variables were assessed for normality using the Shapiro-Wilk test, where $p>0.05$ indicated a normal distribution. Normally distributed variables are reported as mean ± standard deviation (SD), non-normally distributed variables as median (interquartile range, IQR), and categorical variables as number (percentage). The association between each categorized variable and stone-free status was evaluated using simple binary logistic regression, with results presented as odds ratio (OR) and 95% confidence interval (CI). Variables with $p<0.25$ were included in a multiple binary logistic regression model, and results were reported as adjusted OR (aOR) with 95% CI. Statistical significance was defined as p-value <0.05. All analyses were conducted using SPSS software.

Ethical clearance

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Medical and Health Research Ethics Committee of the Faculty of Medicine, Universitas Islam Indonesia (Approval No. 13/Ka.Kom.Et/70/KE/V/2026, dated May 22, 2026). All study procedures were carried out in compliance with the approved protocol.

RESULTS

A total of 92 patients were included in the study, comprising 59 men and 33 women, with a mean age of 53.25 ± 10.25 years. Pre-operative hemoglobin was reported as mean ± standard deviation (13.25 ± 1.68 g/dL). Leucocyte count and creatinine level, which were not normally

distributed, were reported as median (interquartile range): 8.0 (6.53–9.60) $\times 10^3/\mu L$ and 1.04 (0.90–1.39) mg/dL, respectively. Hydronephrosis was observed in 71 patients, and leukocyturia was detected in 77 patients. Radiographic BNO (KUB) identified 45 patients with single stones and 47 with multiple stones; the median maximal stone length was 40 (30–40) mm. The median operative time was 90 (60–90) minutes, and the median hospital stay was 4 (3–5) days. Intra- and post-operative complications occurred in 14 patients (15.2%) (Table 1).

Table 1. Characteristics and clinical features of the subjects (n=92)

Variable	n (%)
Gender	
Male	59 (64.1)
Female	33 (35.9)
Age (Years)	53.25 ± 10.25
Pre-operative hemoglobin (mg/dL)	13.25 ± 1.68
Pre-operative leucocyte count (mg/dL)	8.0 (6.53 – 9.60)
Creatinine level (mg/dL)	1.04 (0.90 – 1.38)
Stone number	
Single	45 (48.9)
Multiple	47 (51.1)
Hydronephrosis	
Yes	71 (77.2)
No	21 (22.8)
Pre-operative leukocyturia	77 (83.7)
Yes	15 (16.3)
No	
Operative time (minutes)	90 (60 – 90)
Maximum stone length (mm)	40 (30 – 40)
Length of hospitalization (days)	4 (3 – 5) [b]
Complications	
Yes	14 (15.2)
No	78 (84.8)
Success rate	
Stone-free	69 (75.0)
Failure	23 (25.0)

Note : data presented as n (%), except for age and pre-opeative hemoglobin as mean ± SD, pre-operative leucocyte, creatinine level, operative time, maximum stone length, and length of hospitalization as median (interquartile range, Q1–Q3)

Among the nine variables analyzed, only gender and stone number demonstrated significant associations with stone-free status in simple logistic regression (Table 2). Female patients had higher odds of achieving stone-free status compared to male patients (OR 3.444, 95% CI 1.059–11.201; p=0.040). The presence of multiple stones was associated with lower odds of stone-free status compared to single stones (OR 0.026, 95% CI 0.003–0.203; p=0.001). Age group (p=0.677), hemoglobin (p=0.089), creatinine level (p=0.518), hydronephrosis (p=0.886), leukocyturia (p=9.871), and operative time (p=9.206) were not significantly associated with stone-free status. The odds ratio for leucocyte count could not be estimated because all nine patients with leukocytosis achieved stone-free status.

Variables with p-values less than 0.25 in univariate analysis (gender, hemoglobin, stone number, and operative time) were included in the multiple logistic regression model. Only stone number remained independently associated with stone-free status (adjusted OR 0.029, 95% CI 0.004–0.230; p=0.001), indicating that patients with single stones had approximately 34 times higher odds of achieving stone-free status compared to those with multiple stones. Gender (aOR 1.666, 95% CI 0.344–8.077; p=0.526), hemoglobin (aOR 2.232, 95% CI 0.159–31.351; p=0.552), and operative time (aOR 2.127, 95% CI 0.459–9.862; p=0.335) were not significantly associated (Table 3).

DISCUSSION

The overall stone-free rate was 75% (69 out of 92 patients), with intra- and post-operative complications recorded in 14 patients (15.2%). Among the nine variables analyzed, stone number emerged as the strongest independent predictor of surgical success. These findings are consistent with the existing literature and underscore the importance of pre-operative stone burden assessment and patient optimization in improving stone surgery outcomes.[2,11]

The relationship between age and nephrolithotomy outcomes is generally reassuring. Consistent with our findings, Haberal et al.[13] conducted a large multicenter retrospective study of 8,191 renal units and reported that stone-free rates were comparable between elderly and younger patient groups undergoing PCNL, with complication rates showing no significant difference between the two groups. Furthermore, their study demonstrated that stratification of elderly patients into young-old (65–69 years), old-old (70–79 years), and oldest-old (80+ years) subgroups revealed no

significant differences in stone-free rates or major complication rates across these subgroups, suggesting that age alone should not be a contraindication for surgical intervention in nephrolithiasis.[13] In our study, age was not associated with success rate. While elderly patients often present with comorbidities such as cardiovascular disease or diabetes that may affect perioperative risk, these factors did not independently determine stone-free outcomes in our cohort.

The data on the effect of gender on nephrolithotomy outcomes is nuanced. In our study, women had a higher stone-free rate than men (87.9% vs 67.8%), and gender was significant in simple logistic regression (OR 3.44, 95% CI 1.06–11.20), but the association did not persist after adjustment (aOR 1.67, 95% CI 0.34–8.08). However, a prior finding reveals that female gender is an independent risk factor for complications, particularly those related to bleeding requiring blood transfusion.[15] This seemingly contradictory relationship can be explained by the physiologically lower pre-operative hemoglobin levels in women compared to men, which increases their susceptibility to transfusion-related complications despite achieving comparable or better stone-free rates.[11,14,15] These findings highlight the importance of gender-specific pre-operative preparation, particularly hemoglobin optimization, to mitigate the risk of bleeding-related complications in female patients.

Table 2. Simple logistic regression of risk factors associated with stone-free status

Risk Factors	Stone Free		OR (95% CI)	p value
	Yes (N=69)	No (N=23)		
Gender				0.04$^{\beta}$
Male (ref)	40 (58.0)	19 (82.6)	1 (ref)	
Female	29 (42.0)	4 (17.4)	3.444 (1.059–11.201)	
Age group				0.677
Adult (ref)	51 (73.9)	18 (78.3)	1 (ref)	
Elderly	18 (26.1)	5 (21.7)	1.271 (.412–3.922)	
Pre-operative hemoglobin				0.089$^{\beta}$
Normal (ref)	54 (78.3)	22 (95.7)	1 (ref)	
Anemia	15 (21.7)	1 (4.3)	6.111 (.760–49.115)	
Pre-operative leukocyte count				—$^{\alpha}$
Normal (ref)	60 (87.0)	23 (100.0)	1 (ref)	
Leukocytosis	9 (13.0)	0 (0.0)	NA$^{\alpha}$	
Pre-operative creatinine				0.518
Normal (ref)	46 (66.7)	17 (73.9)	1 (ref)	
High	23 (33.3)	6 (26.1)	1.417 (.492–4.076)	
Stone number				0.001$^{\beta}$
Single (ref)	44 (63.8)	1 (4.3)	1 (ref)	
Multiple	25 (36.2	22 (95.7)	.026 (.003–.203)	
Hydronephrosis				0.886
Normal (ref)	16 (23.2)	5 (21.7)	1 (ref)	
Hydronephrosis	53 (76.8)	18 (78.3)	.920 (.295–2.870)	
Pre-operative leukocyturia				0.871
Normal (ref)	11 (15.9)	4 (17.4)	1 (ref)	
Leukocyturia	58 (84.1)	19 (82.6)	1.110 (.316–3.898)	
Operative time				0.206$^{\beta}$
<100 min (ref)	51 (73.9)	20 (87.0)	1 (ref)	
≥100 min	18 (26.1)	3 (13.0)	2.353 (.624–8.871)	

Reference categories: male, adult (<60 years), normal hemoglobin, normal leukocyte count, normal creatinine, single stone, no hydronephrosis, no leukocyturia, operative time <100 minutes. $^{\alpha}$OR for leukocyte could not be estimated due to complete separation (all 9 patients with leukocytosis were stone-free); this variable was therefore excluded from the multivariable model regardless of its nominal p-value. $^{\beta}$Variables with p<0.25 in bivariate analysis were entered as candidates into the multivariable model (gender, hemoglobin, stone number, operative time).

Table 3. Multivariable logistic regression of factors affecting the success rate

Variable	Adjusted OR	95% CI (Lower–Upper)	p value
Gender (Female vs. Male)	1.666	0.344–8.077	0.526
Hemoglobin (Anemia vs. Normal)	2.232	0.159–31.351	0.552
Stone Number (Multiple vs. Single)	0.029	0.004–0.230	<0.001
Operative Time (≥100 vs. <100 min)	2.127	0.459–9.862	0.335

Note : CI : confidence interval;Adjusted for gender, hemoglobin, stone number, and operative time simultaneously. Reference categories as in Table 2.

Preoperative hemoglobin, creatinine, leukocyte count, and leukocyturia were not independently associated with stone-free status. However, pre-operative hemoglobin is still an important predictor of blood loss and transfusion requirement.[16] Singh et al.[16] prospectively evaluated 193 patients undergoing PCNL and demonstrated that higher stone burden was significantly associated with a greater postoperative hemoglobin drop, highlighting the interplay between procedural complexity and bleeding risk. Creatinine, as a marker of baseline renal function, may not directly impact stone-free rate, but post-operative creatinine reduction can reflect successful renal recovery following stone removal, and its pre-operative assessment remains recommended particularly in patients with concurrent hydronephrosis.[11,14] Similarly, elevated leukocyte count and leukocyturia are established markers of underlying urinary tract infection, which represents one of the most significant perioperative risks in nephrolithotomy. Pre-operative leukocyturia has been reported as a strong independent risk factor for postoperative infection.[11,17] Although leukocyte count was invalid for logistic regression in our analysis, its clinical significance in infection screening warrants routine pre-operative evaluation in all patients planned for open nephrolithotomy.

In this study, we found that hydronephrosis has no association with the success rate of open nephrolithotomy. However, data from other studies appear contradictory, suggesting that patients with hydronephrosis experience fewer postoperative complications and bleeding. The resolution of this contradiction lies in an understanding of surgical anatomy.[18] Hydronephrosis causes the renal collecting system to become dilated, creating a wider space for the surgeon to navigate. This enlarged system can make surgical access easier, reducing trauma to the renal parenchyma, which in turn reduces bleeding and complications.[19,20]

Stone number was the only independent predictor of success. Single stones had a stone-free rate of 97.8% (44/45), compared with 53.2% (25/47) for multiple stones (aOR 0.029, 95% CI 0.004–0.230).This finding is consistent with the broader nephrolithiasis literature, complex stones such as staghorn calculi that fill multiple calyces or the renal pelvis have been reported to have significantly lower success rates compared to simple, single stones.[21,22]

Multiple stones contribute to a high overall stone burden, which has been consistently reported as the most influential predictor of stone-free rate.[22] This has also been reported by Atmoko et al.[23] and is strongly corroborated by our results. These findings collectively emphasize the need for thorough pre-operative stone characterization to counsel patients appropriately and set realistic surgical expectations.

This study has several limitations. Stones were characterized on NCCT before surgery, but residual stones were assessed on BNO, which is less sensitive, so the stone-free rate may be overestimated. The study sample came from a single center and included only 92 patients, which limits how far these findings generalize. We also did not apply validated stone-complexity scores such as the Guy's Stone Score or the S.T.O.N.E. score.[22] Both were built and validated for percutaneous nephrolithotomy, not open surgery, so we used stone number as a practical surrogate for stone burden instead.

The number of stones should inform preoperative counseling. Patients presenting with multiple stones have a significantly reduced likelihood of achieving stone-free status and may require a staged approach or adjunctive treatments. In resource-limited settings, the findings support open nephrolithotomy as a viable option for managing complex stone disease, provided that surgeons evaluate stone number prior to surgery. Preoperative hemoglobin optimization is also important, particularly for women, due to their increased risk of transfusion despite higher stone-free rates. Where endourological infrastructure is limited, these results further support open nephrolithotomy as a

practical intervention for complex stone disease, contingent upon thorough assessment of stone burden and correction of anemia before surgery. Future research should employ larger, multicenter cohorts, confirm stone-free status using computed tomography, and evaluate whether a complexity score specifically designed for open nephrolithotomy enhances risk prediction.

CONCLUSION

Stone number was the strongest independent predictor of surgical success in open nephrolithotomy, with single stones achieving a significantly higher stone-free rate than multiple stones. Gender and pre-operative hemoglobin level also showed significant associations in bivariate analysis. These findings emphasize the importance of pre-operative stone burden assessment and patient optimization in surgical planning and patient counseling. Future studies with larger multicenter cohorts and non-contrast computed tomography (NCCT) based evaluation are recommended to validate these findings.

Conflict of Interest

All of the authors in this study have no conflict of interest.

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Authors' Contributions

FFP: Conception and design, Critical revision of the manuscript for scientific and factual content and Supervision. AMMA : Data acquisition, Data analysis and interpretation, Drafting the manuscript, Statistical analysis. AKH : Critical revision of the manuscript for scientific and factual content and Supervision. All authors have read and approved the final anuscript.

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Data Availability Statement

The data presented in this study are available upon reasonable request from the corresponding author.

Declaration of AI Usage in Scientific Writing

The authors declare that this manuscript was prepared entirely without the use of generative AI technologies or automated text-producing tools. All ideas, narrative structure, arguments, and scientific explanations were developed solely by the authors without any AI-generated assistance.

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