Original Article

Comparison of mean drop in hemoglobin between single tract and multiple tract percutaneous nephrolithotomy in the treatment of staghorn stones

Faiz Ur Rahman[1], Saeed Ahmad[1], Israr Ahmad[1], Saif Ullah[1], Rizwan Ullah[2]

[1] Postgraduate Resident Urologist, Institute of Kidney Diseases, Hayatabad Medical Complex Peshawar

[2] Assistant Professor of Urology, Institute of Kidney Diseases, Hayatabad Medical Complex Peshawar

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ABSTRACT

Background: Percutaneous nephrolithotomy (PCNL) is an established treatment for large renal calculi, including staghorn stones. The number of access tracts is selected according to stone distribution and anatomy, but the potential effect of multiple tracts on perioperative hemoglobin decline remains clinically relevant.

Objective: To compare the mean drop in hemoglobin between single tract PCNL and multiple tract PCNL in the treatment of staghorn stones.

Materials and Methods: This observational cohort study was done in the Department of Urology Institute of kidney Diseases Peshawar from September 2025 to December 2025 analyzed 70 records, including 35 patients in each group. Hemoglobin drop was calculated as preoperative hemoglobin minus postoperative day-3 hemoglobin. Groups were compared using Welch's independent-samples t-test. Supplementary univariable and multivariable linear regression assessed the association between tract group and hemoglobin decline, adjusting for age, sex, BMI, stone size, hypertension, diabetes mellitus, and preoperative hemoglobin. HC3 robust standard errors were used.

Results: Mean hemoglobin drop was 2.15 ± 0.96 g/dL in the single-tract group and 1.59 ± 0.69 g/dL in the multiple-tract group (mean difference 0.56 g/dL; 95% CI 0.16–0.96; p=0.0068). In adjusted regression, single-tract PCNL was associated with a greater decline (β=0.522 g/dL; 95% CI 0.074–0.970; p=0.0224).

Conclusion: Mean hemoglobin decline was greater in the single-tract group in this dataset. The association persisted after adjustment for available covariates, but the observational design and unavailable procedural variables limit causal interpretation.

Keywords: Percutaneous nephrolithotomy; staghorn stones; single tract; multiple tract; hemoglobin drop.

INTRODUCTION

Urolithiasis is a common disorder of the urinary tract and an important cause of recurrent pain, infection, obstruction, emergency presentation, and healthcare utilization. Its burden extends beyond the acute episode because recurrence may lead to repeated investigations and interventions. Large renal calculi are particularly challenging: their size and branching configuration may involve several calyces, making complete clearance technically demanding. Percutaneous nephrolithotomy (PCNL) is an established treatment for renal stones larger than 2 cm and is widely used for complex and staghorn calculi (1,2).

Staghorn stones occupy a substantial portion of the renal collecting system and may be associated with infection, impaired drainage, and progressive renal damage if inadequately treated. The objectives of treatment are to achieve effective stone clearance, preserve renal function, control infection, and minimize morbidity. Contemporary guidelines and clinical recommendations support PCNL as a principal treatment option for large renal stones, while emphasizing individualized planning according to stone burden, anatomy, patient comorbidity, and available expertise (3,4).

An important technical decision during PCNL is the number of percutaneous access tracts. A single tract may provide adequate access when the calculus can be reached and fragmented through one route. In extensive staghorn disease, however, one tract may not provide favorable access to all calyces. Additional tracts can improve instrument alignment and facilitate access to separate portions of the collecting system. This may assist stone clearance in a single session, although the decision must balance access and clearance against potential parenchymal injury (5,6).

Bleeding is a recognized complication of PCNL. Renal parenchymal and vascular injury may occur during puncture, tract dilatation, and intrarenal manipulation. Hemoglobin decline is frequently used as a pragmatic perioperative indicator of blood loss, but it is not a direct measurement of blood volume lost. It may be influenced by intravenous fluid administration, timing of postoperative sampling, transfusion, and baseline hemoglobin. Comparisons of single- and multiple-tract procedures have reported differing magnitudes and directions of hemoglobin decline (7,8).

The relationship between tract number and bleeding is biologically plausible but not necessarily linear. More access tracts may increase the amount of renal tissue traversed; nevertheless, the clinical effect also depends on tract caliber, puncture location, vascular anatomy, dilation technique, stone complexity, operative duration, and hemostatic practice. Patients selected for multiple tracts may differ

systematically from those treated through a single tract. This confounding by indication can distort unadjusted comparisons in either direction. Comparative studies have therefore evaluated hemoglobin change alongside transfusion, complications, stone-free rates, and secondary procedures (9,10).

Recent comparative cohorts and evidence syntheses continue to examine the balance between stone clearance and access-related morbidity. Interpretation across studies is complicated by differences in standard versus mini-PCNL, imaging guidance, access technique, surgeon experience, definitions of stone-free status, and the timing of postoperative blood sampling. A finding from one procedural setting should therefore not automatically be generalized to another. Local institutional data can help describe outcomes under the clinical practices in which patients are actually treated (11,12).

The local context is relevant because referral patterns, stone presentation, equipment, and perioperative protocols may differ between healthcare settings. Evidence from Pakistani urological practice can complement international studies and provide context for treatment decisions in tertiary referral hospitals. The synopsis for this study identifies the Department of Urology, Institute of Kidney Diseases, Peshawar, as the study setting and specifies a comparison of hemoglobin decline in patients undergoing single-tract or multiple-tract PCNL for staghorn stones.

Against this background, the present study was designed to compare the mean drop in hemoglobin between single tract PCNL and multiple tract PCNL in the treatment of staghorn stones. Hemoglobin decline was operationally defined as the difference between preoperative hemoglobin and hemoglobin measured three days after surgery. The primary comparison was retained exactly as specified in the synopsis. A supplementary adjusted analysis was also undertaken to explore whether the association between tract group and hemoglobin decline persisted after accounting for the demographic and clinical covariates available in the dataset.

MATERIALS AND METHODS

This was an observational cohort study conducted in the Department of Urology, Institute of Kidney Diseases, Peshawar from September 2025 to December 2025. The synopsis specified a study duration of six months after approval. The formal sample-size calculation specified 70 patients, with 35 in each group, at a 95% confidence level and 80% power using the WHO calculator for two means. Non-probability consecutive sampling was specified. The analyzed dataset contained 70 records, comprising 35 single-tract and 35 multiple-tract PCNL cases.

Eligible participants were male and female patients aged 20–70 years undergoing PCNL for staghorn kidney stones larger than 2 cm. Exclusion criteria were coagulopathy (INR >1.5), ongoing urinary tract infection, structural renal abnormalities, renal cancer, ectopic kidneys, transplanted kidney stones, medullary sponge kidney, polycystic kidneys, chronic renal failure, and chronic liver disease.

Parameters recorded included age, gender, height, weight, BMI, diabetes mellitus, hypertension, affected side, stone size, and preoperative and postoperative day-3 hemoglobin. Procedures were performed under general anesthesia. Fluoroscopic access was obtained using an 18-gauge needle, followed by guidewire insertion and serial tract dilatation. Stone fragmentation was performed using a pneumatic lithotripter and fragments were removed with forceps. Fluoroscopy and nephroscopic visualization were used to assess clearance.

The primary outcome was mean drop in hemoglobin, calculated by subtracting postoperative day-3 hemoglobin from preoperative hemoglobin and expressed in g/dL. Positive values indicate a decrease. BMI was calculated from recorded weight and height.

Continuous variables were summarized as mean ± standard deviation (SD), and categorical variables as frequency and percentage. Shapiro–Wilk testing assessed normality. The primary outcome was compared between groups using Welch's independent-samples t-test, which does not require equal variances. A two-sided p-value <0.05 was considered statistically significant.

Because the primary outcome was continuous, supplementary linear regression was conducted. Univariable models assessed tract group and each available covariate separately. The multivariable model included tract group, age, sex, BMI, stone size, hypertension, diabetes mellitus, and preoperative hemoglobin. Multiple-tract PCNL, female sex, absence of hypertension, and absence of diabetes were the reference categories. Coefficients represent mean differences in hemoglobin decline (g/dL). HC3 heteroscedasticity-robust standard errors were used to calculate 95% confidence intervals and p-values. Multicollinearity was assessed using variance inflation factors; residual normality and heteroscedasticity were assessed using diagnostic tests. No missing values were present in the supplied analysis variables.

RESULTS

A total of 70 patient records were analyzed, with 35 patients in each group. Overall mean age was 45.83 ± 14.12 years, 54 (77.1%) patients were male, mean BMI was 26.92 ± 5.40 kg/m², and mean stone size was 4.01 ± 0.90 cm. Baseline characteristics are summarized in Table 1.

Table 1: Baseline Characteristics of Study Participants

Characteristic	Single tract (n=35)	Multiple tract (n=35)	Overall (N=70)
Age, years	45.94 ± 13.97	45.71 ± 14.47	45.83 ± 14.12
Male sex, n (%)	28 (80.0)	26 (74.3)	54 (77.1)
BMI, kg/m²	27.53 ± 6.10	26.31 ± 4.61	26.92 ± 5.40
Stone size, cm	4.05 ± 0.80	3.98 ± 1.00	4.01 ± 0.90
Right side, n (%)	20 (57.1)	16 (45.7)	36 (51.4)
Hypertension, n (%)	8 (22.9)	7 (20.0)	15 (21.4)
Diabetes mellitus, n (%)	8 (22.9)	12 (34.3)	20 (28.6)
Preoperative Hb, g/dL	12.87 ± 1.13	13.34 ± 0.98	13.11 ± 1.08
Postoperative day-3 Hb, g/dL	10.72 ± 1.54	11.75 ± 1.27	11.24 ± 1.50

Mean hemoglobin decline was 2.15 ± 0.96 g/dL (range 0.15–3.92) in the single-tract group and 1.59 ± 0.69 g/dL (range 0.22–2.87) in the multiple-tract group. The mean difference (single minus multiple tract) was 0.56 g/dL (95% CI 0.16–0.96; Welch t=2.802, df=61.73, p=0.0068) (Table 2).

Table 2: Comparison of Hemoglobin Drop Between Groups

Outcome	Single tract	Multiple tract	Mean difference (95% CI)	p-value
Hemoglobin drop, g/dL	2.15 ± 0.96	1.59 ± 0.69	0.56 (0.16–0.96)	0.0068

In univariable linear regression, single-tract PCNL was associated with a 0.560 g/dL greater decline than multiple-tract PCNL (95% CI 0.163–0.957; p=0.0057). After adjustment, the difference was 0.522 g/dL (95% CI 0.074–0.970; p=0.0224).

Table 3: Regression Models for Hemoglobin Drop

Predictor	Unadjusted β (95% CI)	p	Adjusted β (95% CI)	p
PCNL group: single vs multiple tract	0.560 (0.163, 0.957)	0.0057	0.522 (0.074, 0.970)	0.0224
Age (per year)	0.003 (-0.012, 0.019)	0.6824	0.005 (-0.011, 0.021)	0.5595
Male vs female	0.369 (-0.112, 0.851)	0.1328	0.347 (-0.157, 0.851)	0.1777
BMI (per kg/m²)	0.009 (-0.034, 0.053)	0.6684	0.008 (-0.038, 0.053)	0.7365
Stone size (per cm)	-0.092 (-0.306, 0.121)	0.3966	-0.105 (-0.368, 0.159)	0.4372
Hypertension: yes vs no	-0.171 (-0.653, 0.312)	0.4884	-0.188 (-0.709, 0.333)	0.4803
Diabetes: yes vs no	0.028 (-0.443, 0.499)	0.9073	0.062 (-0.458, 0.582)	0.8152
Preoperative Hb (per g/dL)	-0.135 (-0.346, 0.076)	0.2110	-0.059 (-0.274, 0.155)	0.5894

The adjusted model included 70 observations and eight predictors (R^2=0.163; adjusted R^2=0.053). The maximum VIF was 1.10; Breusch–Pagan p=0.778; Jarque–Bera p=0.677. HC3 robust standard errors were retained.

DISCUSSION

The present cohort comprised 70 patients, with 35 undergoing single-tract PCNL and 35 undergoing multiple-tract PCNL. Mean hemoglobin decline was 2.15 ± 0.96 g/dL in the single-tract group and 1.59 ± 0.69 g/dL in the multiple-tract group. The unadjusted mean difference was 0.56 g/dL (95% CI 0.16–0.96), and Welch's independent-samples t-test

indicated a statistically significant difference (p=0.0068). Thus, in this dataset, the mean decrease was greater in the single-tract group.

This direction of association deserves careful interpretation. A common concern is that creating more than one renal access tract may increase parenchymal trauma and bleeding. However, tract number is selected in response to stone distribution and access requirements rather than assigned randomly. Multiple tracts may sometimes permit more direct access to separate calyces and reduce prolonged manipulation through an unfavorable angle. Conversely, a single tract may be selected for complex stones when the surgeon anticipates that one access can achieve the intended clearance or wishes to avoid additional punctures. The observed association may therefore reflect procedural selection and unmeasured case complexity rather than a direct protective effect of multiple tracts.

Prior comparisons have demonstrated variable outcomes regarding bleeding parameters across tract strategies (13,14). Comparisons with other studies require attention to technique and patient selection. Single- and multiple-tract cohorts may differ in stone volume, branching pattern, number of involved calyces, infection status, renal anatomy, tract diameter, access guidance, and surgeon experience. Mini-PCNL cohorts may not be directly comparable with standard PCNL because tract size and instrumentation can affect bleeding and stone extraction. Systematic reviews can summarize available evidence, but pooled estimates remain influenced by heterogeneity in design, population, and outcome definitions (15,16).

The supplementary multivariable model included tract group, age, sex, BMI, stone size, hypertension, diabetes mellitus, and preoperative hemoglobin. Single-tract PCNL remained associated with a greater decline after adjustment (β=0.522 g/dL; 95% CI 0.074–0.970; p=0.0224). The adjusted estimate was close to the unadjusted difference, suggesting that adjustment for the measured covariates did not materially change the observed association.

This adjusted result is not proof of causality. The dataset did not include a validated stone-complexity score, total stone volume, branching pattern, number of calyces involved, tract caliber, puncture location, access guidance, operative duration, irrigation pressure, transfusion, or surgeon-specific factors. These variables could influence both tract selection and bleeding. Regression can reduce confounding only for variables measured adequately and included appropriately. Residual confounding therefore remains an important possibility, particularly in observational surgical comparisons (17,18).

Model diagnostics were examined before interpreting the adjusted estimates. The maximum variance inflation factor was approximately 1.10, providing no indication of

problematic multicollinearity among included predictors. The Breusch–Pagan test did not indicate strong heteroscedasticity, and the Jarque–Bera test did not identify a statistically significant departure from residual normality. HC3 robust standard errors were used to reduce sensitivity to variance misspecification. The model R-squared was approximately 0.163, indicating that the included predictors explained a modest proportion of variation in hemoglobin decline.

Broader PCNL safety literature indicates that outcomes and complication profiles depend on patient characteristics, stone burden, technique, and institutional practice (19,20). Standardized complication grading, such as the modified Clavien system, improves comparability and distinguishes clinically meaningful events from laboratory changes alone (21).

Staghorn stone management requires balancing complete clearance and procedural safety. Residual fragments may contribute to recurrent infection, stone growth, or further intervention, while attempts to achieve complete clearance can increase operative complexity. The role of multiple tracts should therefore be considered in the context of stone distribution and expected access benefit rather than judged solely by postoperative hemoglobin (22,23).

A strength of this study is its direct focus on the primary objective using a clearly defined postoperative time point. The groups were equal in size, and the analysis contained complete values for the analyzed variables. Reporting the unadjusted comparison alongside a supplementary adjusted model allows readers to assess whether the group difference persisted after accounting for measured baseline characteristics.

Several limitations should temper interpretation. The observational design does not establish causation and is vulnerable to selection bias and confounding by indication. The sample was modest, limiting precision and the number of covariates that could be included safely. Important stone and operative characteristics were unavailable. Hemoglobin decline is an indirect measure of blood loss and may be influenced by fluid shifts, transfusion, and timing of laboratory testing.

These findings do not justify routinely preferring multiple-tract PCNL to reduce bleeding. The number of tracts should continue to be individualized according to stone burden, collecting-system anatomy, patient condition, and the surgeon’s assessment. A larger prospective cohort should record validated stone-complexity scores, exact tract number and caliber, access location, operative duration, transfusion, standardized complications, stone-free status, and length of stay (24,25).

CONCLUSION

The mean drop in hemoglobin was 2.15 ± 0.96 g/dL after single-tract PCNL and 1.59 ± 0.69 g/dL after multiple-tract PCNL. The difference was statistically significant and remained associated with tract group after adjustment for available covariates. These findings should be interpreted cautiously because of the observational design and absence of detailed stone-complexity and operative data.

DECLARATIONS

ETHICS APPROVAL: Obtained from the institutional ethical review committee.

CONSENT TO PARTICIPATE: Written informed consent was obtained from all participants.

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CONFLICTS OF INTEREST: None declared.

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