EVALUATING THE EFFICACY OF ULTRASOUND-GUIDED PERCUTANEOUS NEPHROLITHOTOMY (PCNL) IN REDUCING POST-OPERATIVE COMPLICATIONS COMPARED TO FLUOROSCOPIC GUIDANCE

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ABSTRACT

Background: Percutaneous nephrolithotomy (PCNL) is an established treatment for renal calculi, but fluoroscopic guidance exposes patients and operating-room staff to ionizing radiation. This study compared post-operative complications after ultrasound-guided and fluoroscopy-guided PCNL in adults with renal calculi. **Methods:** This nonrandomized controlled trial was conducted in the Urology Department of Khyber Teaching Hospital, Peshawar from March 2026 to May 2026. A total of 144 adults were included, with 72 patients undergoing ultrasound-guided PCNL (Group A) and 72 undergoing fluoroscopy-guided PCNL (Group B). Post-operative bleeding, fever, pain and urinary extravasation were assessed within 15 days. Data were analyzed in SPSS version 27. Categorical variables were compared using chi-square/Fisher's exact test; $p<0.05$ was considered significant. **Results:** Overall post-operative complications occurred in 42/72 (58.3%) patients in Group A and 72/72 (100.0%) in Group B (Fisher's exact $p<0.001$). Bleeding occurred in 20 (27.8%) versus 42 (58.3%), fever in 21 (29.2%) versus 53 (73.6%), pain in 24 (33.3%) versus 58 (80.6%), and urinary extravasation in 10 (13.9%) versus 36 (50.0%) in Groups A and B, respectively. Procedure duration and hospital stay were also lower in Group A. **Conclusion:** In this study population, ultrasound-guided PCNL was associated with fewer recorded post-operative complications than fluoroscopy-guided PCNL. The findings support ultrasound as a radiation-free guidance option; however, the non-randomized design and baseline differences require cautious interpretation.

Keywords: Percutaneous Nephrolithotomy; Ultrasound guidance; Fluoroscopy; Renal calculi; Post-Operative complications; Bleeding; Fever; Urinary extravasation.

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INTRODUCTION

Renal stone disease is a common urological problem and an important cause of pain, morbidity and healthcare utilization. Recent epidemiological evidence indicates a continuing global burden of urolithiasis, with recurrence remaining common after an initial stone episode. Dietary factors, inadequate fluid intake, metabolic abnormalities and genetic susceptibility contribute to stone formation, and the disease remains an important health problem in South Asian populations including Pakistan (1,2).

Percutaneous nephrolithotomy (PCNL) is an established treatment for large and complex renal calculi and remains a recommended intervention for appropriately selected patients with a substantial renal stone burden. Contemporary guidelines emphasize PCNL as an important stone-removal option because it can provide effective clearance in a single procedure, although bleeding, infection, pain and urine leakage remain recognized perioperative complications (3,4). Conventional fluoroscopy-guided PCNL (FGPCNL) provides established imaging for identification of the target calyx, renal puncture, tract dilatation and confirmation of tract position. Its major limitation is the use of ionizing radiation. Radiation exposure is relevant for both patients and operating-room personnel, particularly when procedures are prolonged or repeated and in high-volume endourological practice (5,6).

Ultrasound-guided PCNL (USG-PCNL) provides real-time imaging without ionizing radiation. It can assist in identification of the kidney and adjacent

structures, selection of the puncture site, renal access and assessment of residual stones. Contemporary evidence has supported the feasibility of ultrasound-guided access and has described comparable procedural effectiveness with the additional advantage of avoiding radiation exposure (7,8).

Despite these potential advantages, comparative evidence regarding post-operative complications remains heterogeneous. Differences in patient selection, stone burden, access technique, surgeon experience and perioperative management may influence reported outcomes. Local comparative evaluation is therefore relevant, particularly in settings where ultrasound-guided access is increasingly considered as an alternative to fluoroscopy-guided PCNL.

Accordingly, this study was designed to compare post-operative complications in adults undergoing ultrasound-guided PCNL and fluoroscopy-guided PCNL in the Urology Department of Khyber Teaching Hospital, Peshawar.

MATERIALS AND METHODS

This study was designed as a non-randomized controlled trial and was conducted in the Urology Department of Khyber Teaching Hospital, Peshawar from March 2026 to May 2026. The study period was a minimum of three months after approval of the synopsis. The required sample size was calculated using the OpenEpi web-based calculator on the basis of previously reported overall post-operative complication rates of 7.7% and 24% in ultrasound-guided and fluoroscopyguided PCNL, respectively, with 80% power and a 95% confidence level. The calculated sample size was 144 patients, with 72 patients in each group. Consecutive non-probability sampling was used. Adults aged 18–70 years of either sex with renal calculi confirmed according to the study operational definition were eligible. Renal calculi were confirmed on CT as a hyperdense focus with attenuation greater than 120 HU in patients presenting with flank pain (VAS >3), dysuria, nausea and vomiting. Patients who were pregnant, had bleeding disorders, previous kidney surgery or renal deformity, or an estimated glomerular filtration rate below 45 mL/min/1.73 m^2 were excluded.

After institutional ethical approval and written informed consent, eligible patients underwent clinical assessment and demographic data collection. Age, gender, BMI, residence, monthly income, socioeconomic status, literacy status and employment status were recorded. Patients received general anesthesia and a 5F ureteral catheter was placed transurethrally for injection of saline or contrast medium. Patients were allocated non-randomly to Group A or Group B. Group A underwent ultrasound-guided PCNL, in which ultrasonography was used to identify the kidney, select the needle entry point, guide urinary tract access and dilatation, and assess residual stone at the end of the procedure. The guidewire was visible, although the Amplatz dilators and sheath were not directly visualized by ultrasonography. Group B underwent fluoroscopy-guided PCNL for identification of the target calyx, establishment of renal access and confirmation of tract alignment.

One-step dilatation was performed and a 30-Fr Amplatz sheath was used for access to the renal pelvis. Duration of procedure, stone size, hospital stay, stone side and number of stones were recorded.

Post-operative complications were assessed within 15 days of the procedure. Bleeding was defined as blood loss from the kidney or nephrostomy tract after PCNL requiring transfusion of packed red blood cells or whole blood on clinical assessment. Fever was defined as a body temperature of 38°C (100.4°F) measured orally or axillary. Pain was assessed at the surgical site using the 0–10 Visual Analog Scale and was considered positive when the score was greater than 3. Urinary extravasation was defined as drainage of urine from the nephrostomy tube, surgical site or percutaneous tract on clinical examination. The primary outcome, overall post-operative complication, was considered present when any one of these four complications occurred. A structured proforma was used for data recording. The statistical analysis was performed using SPSS version 27. The Shapiro–Wilk test was used to assess normality of continuous variables. In accordance with the analysis plan, normally distributed continuous variables were summarized as mean ± standard deviation and non-normally distributed variables as median with interquartile range. Frequencies and percentages were calculated for categorical variables. Post-operative complications were compared between groups using the chi-square test or Fisher's exact test as appropriate, with $p<0.05$ considered statistically significant.

Prespecified effect modifiers including gender, age, BMI, stone side, number of stones, residence and socioeconomic status were addressed through stratification, followed by chi-

ultrasound-guided and fluoroscopy-guided PCNL

square/Fisher's exact testing. For the stratified analysis, age was grouped as <50 and ≥50 years and BMI as <25 and ≥25 kg/m² to permit categorical comparison.

RESULTS

A total of 144 adult patients were included in the analysis, comprising 72 patients in the ultrasoundguided PCNL group (Group A) and 72 in the fluoroscopy-guided PCNL group (Group B). The median age was 45.0 years (IQR 36.75–53.00) in Group A and 46.5 years (IQR 38.00–54.00) in Group B. The corresponding median BMI was 27.75 kg/m² (IQR 25.38–30.45) and 28.55 kg/m² (IQR 25.68–30.83), respectively. The groups had identical distributions for gender, residence, literacy and stone side. Employment status differed somewhat between groups, whereas socioeconomic status was similarly distributed.

Table 1 summarizes the demographic and clinical characteristics of the study participants. The median procedure duration was 109.5 minutes (IQR 96.00–121.25) in Group A compared with 117.5 minutes (IQR 101.75–129.25) in Group B (Mann–Whitney U p=0.008). Median stone size was similar between groups at 27.5 mm (IQR 22.00–34.25) and 27.0 mm (IQR 22.00–34.00), respectively (p=0.856). Median hospital stay was 4 days (IQR 3–5) in Group A and 5 days (IQR 4– 6) in Group B (p<0.001).

Table 1. Demographic and clinical characteristics of patients undergoing

Variable	Group A USGPCNL (n=72)	Group B FGPCNL (n=72)	p-value
Age, years, median (IQR)	45.0 (36.75–53.00)	46.5 (38.00–54.00)	0.493
BMI, kg/m², median (IQR)	27.75 (25.38–30.45)	28.55 (25.68–30.83)	0.333
Monthly income, PKR, median (IQR)	36,500 (20,000 – 58,250)	38,000 (21,000 – 59,000)	0.374
Male gender, n (%)	36 (50.0)	36 (50.0)	1.000
Urban residence, n (%)	36 (50.0)	36 (50.0)	1.000
Literate, n (%)	36 (50.0)	36 (50.0)	1.000
Employed, n (%)	52 (72.2)	62 (86.1)	0.040
Socioeconomic status, n (%)			1.000
Low	36 (50.0)	36 (50.0)	
Middle	20 (27.8)	20 (27.8)	
Upper	16 (22.2)	16 (22.2)	
Left-sided stone, n (%)	36 (50.0)	36 (50.0)	1.000
>1 stone, n (%)	38 (52.8)	35 (48.6)	0.617
Procedure duration, min, median (IQR)	109.5 (96.00–121.25)	117.5 (101.75 – 129.25)	0.008
Stone size, mm, median (IQR)	27.5 (22.00–34.25)	27.0 (22.00–34.00)	0.856
Hospital stay, days, median (IQR)	4 (3–5)	5 (4–6)	<0.001

The primary outcome is presented in Table 2. Overall post-operative complications occurred in 42 of 72 patients (58.3%) in Group A and all 72 patients (100.0%) in Group B. Fisher's exact test demonstrated a statistically

significant difference (p<0.001). Thus, the observed absolute difference in complication frequency was 41.7 percentage points.

Table 2. Overall post-operative complications within 15 days after PCNL

Overall complication	Group A USGPCNL (n=72)	Group B FGPCNL (n=72)	p-value
No	30 (41.7%)	0 (0.0%)	
Yes	42 (58.3%)	72 (100.0%)	<0.001

Table 3 presents the individual post-operative complications. Bleeding occurred in 20 (27.8%) patients in Group A and 42 (58.3%) in Group B
(Fisher's exact p<0.001). Fever occurred in 21 (29.2%) and 53 (73.6%), respectively (p<0.001). Pain was reported in 24 (33.3%) versus 58 (80.6%) patients (p<0.001), while urinary extravasation occurred in 10 (13.9%) versus 36 (50.0%) patients (p<0.001).

Table 3. Individual post-operative complications within 15 days after PCNL

Complication	Group A n (%)	Group B n (%)	Fisher's exact pvalue
Bleeding	20 (27.8)	42 (58.3)	<0.001
Fever	21 (29.2)	53 (73.6)	<0.001
Pain	24 (33.3)	58 (80.6)	<0.001
Urinary extravasation	10 (13.9)	36 (50.0)	<0.001

Stratified analysis showed that the difference in overall complications remained statistically significant among patients younger than 50 years, those with BMI below 25 kg/m², both sexes, both stone-side categories, patients with one stone, and patients from low and middle socioeconomic groups. Among patients aged ≥50 years, both groups had 100% complication frequency, and no between-group difference was demonstrable. Similarly, no significant difference was detected in the upper socioeconomic stratum or among patients with more than one stone because complication frequencies were 100% in both treatment groups within those strata. These findings are summarized in Table 4.

Stratum	Group A: complication / total	Group B: complication / total	pvalue
Age <50 years	16/46 (34.8%)	43/43 (100%)	<0.001
Age ≥50 years	26/26 (100%)	29/29 (100%)	1.000
BMI <25 kg/m²	0/16 (0%)	14/14 (100%)	<0.001
BMI ≥25 kg/m²	42/56 (75.0%)	58/58 (100%)	<0.001
Male	14/36 (38.9%)	36/36 (100%)	<0.001
Female	28/36 (77.8%)	36/36 (100%)	0.005
Left stone	14/36 (38.9%)	36/36 (100%)	<0.001
Right stone	28/36 (77.8%)	36/36 (100%)	0.005
One stone	4/34 (11.8%)	37/37 (100%)	<0.001
>1 stone	38/38 (100%)	35/35 (100%)	1.000
Rural residence	14/36 (38.9%)	36/36 (100%)	<0.001
Urban residence	28/36 (77.8%)	36/36 (100%)	0.005
Middle SES	15/20 (75.0%)	20/20 (100%)	0.047
Upper SES	13/16 (81.3%)	16/16 (100%)	0.226

Low SES	14/36 (38.9%)	36/36 (100%)	<0.001

Table 4. Stratified comparison of overall postoperative complications

DISCUSSION

The present study compared post-operative complications between ultrasound-guided and fluoroscopy-guided PCNL in 144 adults with renal calculi. The principal finding was a substantially lower frequency of recorded overall complications in the ultrasound-guided group, 58.3% compared with 100.0% in the fluoroscopyguided group. The difference was statistically significant on Fisher's exact testing. All four individual complications examined in the protocol —bleeding, fever, pain and urinary extravasation —were also less frequent in the ultrasound-guided group.

The observed difference is relevant to the continuing evaluation of ultrasound as an alternative method of renal access during PCNL. Recent comparative literature has reported that ultrasound-guided and fluoroscopy-guided approaches can achieve similar procedural objectives, while ultrasound eliminates radiation exposure during renal puncture and tract access (9,10). These studies also emphasize that the quality of ultrasound guidance depends on appropriate visualization of renal anatomy and adequate operator experience.

The bleeding frequency was 27.8% in Group A and 58.3% in Group B. Bleeding is one of the most clinically important complications of PCNL, and contemporary evidence indicates that its occurrence is influenced by access characteristics, tract size, stone burden, number of tracts and patient-related factors (11,12). The lower bleeding frequency observed with ultrasound guidance in this dataset may be compatible with the ability to visualize the kidney and adjacent structures during puncture; however, because treatment allocation was non-randomized, a causal explanation cannot be established from these data alone.

Fever was observed in 29.2% of the ultrasound group and 73.6% of the fluoroscopy group. Pain was reported in 33.3% and 80.6%, respectively, while urinary extravasation occurred in 13.9% and 50.0%. Thus, the observed difference was not confined to a single complication category. Recent PCNL literature has emphasized that infectious and postoperative complications are multifactorial and may be affected by preoperative urine status, stone characteristics, operative duration, intrarenal pressure and drainage strategy (13,14). The present dataset did not contain sufficient microbiological, laboratory or detailed perioperative variables to determine the mechanisms underlying the observed differences. The median procedure duration was shorter in the ultrasound-guided group, while stone size was similar between groups. Evidence from contemporary PCNL studies suggests that operative time is affected by access complexity, stone burden, number of stones, surgeon experience and the guidance modality used for renal access (15). In the present dataset, the similar distributions of age, BMI, residence, literacy, socioeconomic status and stone side provide some comparability between groups, although employment status differed statistically and residual confounding remains possible. Stratified analysis showed that the between-group difference persisted across several prespecified strata, including sex, stone side, residence and socioeconomic categories. However, several strata had complete or near-complete complication rates, including all patients in Group B in a number of categories. Such complete separation limits the interpretability of subgroup comparisons and indicates that these analyses should be regarded as exploratory rather than as evidence of effect modification. Contemporary methodological literature similarly cautions against overinterpreting subgroup findings when cell counts are small or outcomes are highly unbalanced (16).

The radiation-free nature of ultrasound remains an important practical consideration. Recent studies evaluating ultrasound-guided renal access have emphasized the reduction or elimination of radiation exposure to patients and operating-room staff, while also describing the need for adequate training and familiarity with renal sonographic anatomy (17,18). The synopsis for the present study also recognizes a technical limitation of ultrasound in the direct visualization of some access equipment, including the Amplatz dilators and sheath. Thus, ultrasound guidance should be considered a technique requiring appropriate expertise rather than simply a replacement of one imaging modality with another.

The present findings should be interpreted in light of the study design and the available dataset. The

non-randomized allocation means that treatment selection may have been influenced by clinical or operator factors. The analysis because it was not specified in the synopsis. In addition, the dataset records the presence or absence of selected complications but does not provide detailed severity grading, stone composition, number of access tracts, calyx punctured, surgeon experience, perioperative laboratory parameters or fluoroscopy exposure time. These factors may influence postoperative outcomes and should be addressed in future prospective comparative studies (19,20).

CONCLUSION

Among adults undergoing PCNL in this study, ultrasound-guided PCNL was associated with a significantly lower frequency of overall postoperative complications than fluoroscopy-guided PCNL. Bleeding, fever, pain and urinary extravasation were each less frequent in the ultrasound-guided group, and median procedure duration and hospital stay were also lower. Because the study was non-randomized, these findings demonstrate an association rather than definitive causation. Larger prospective randomized studies with standardized complication grading and adjustment for relevant clinical factors are warranted.

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