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Urology

KEY FACTORS INFLUENCING URINARY LEAK AFTER PERCUTANEOUS NEPHROLITHOTOMY: INSIGHTS AND IMPLICATIONS

KEY WORDS: Percutaneous nephrolithotomy, urinary leakage, hydronephrosis, parenchymal thickness, kidney stones, postoperative complications, predictive factors.

Dr Guddety Sreenivasa Reddy Senior Resident

Dr Sanjay R Pudakalkatti* Associate Professor *Corresponding Author

Dr Keshavamurthy Ramaiah Professor And HOD

ABSTRACT

Background: Percutaneous nephrolithotomy (PCNL) is the standard treatment for large or complex renal stones. Despite its high success rates, complications such as prolonged urinary leakage (PUL) are significant concerns, occurring in 5–15% of cases. This study investigates predictors of PUL following PCNL, focusing on anatomical and procedural factors. **Methods:** A retrospective cohort study of 225 PCNL patients was conducted. Data on demographic, anatomical (hydronephrosis grade, parenchymal thickness), stone characteristics (volume, location), and procedural factors (surgery time, number of punctures) were analyzed. Urinary leakage was categorized as leakage persisting >24 hours post-nephrostomy removal. Statistical analyses included t-tests, chi-square tests, and multivariate logistic regression. **Results:** Prolonged urinary leakage occurred in 23 patients (10%). Key predictors included higher hydronephrosis grade (mean: 2.39 vs. 0.98, $p<0.001$), thinner parenchymal thickness (mean: 15.97 mm vs. 20.11 mm, $p<0.001$), larger stone volume (mean: 810.14 mm³ vs. 684.56 mm³, $p=0.04$), and longer surgery time (mean: 92.4 min vs. 81.0 min, $p=0.01$). Multiple punctures and lower calyceal access were also associated with increased risk. Skin-to-parenchymal length showed no significant correlation with leakage. **Conclusion:** Higher grades of hydronephrosis, reduced parenchymal thickness, larger stones, prolonged surgery, and multiple punctures are significant predictors of urinary leakage after PCNL. Preoperative imaging and meticulous surgical planning can mitigate these risks.

INTRODUCTION

Percutaneous nephrolithotomy (PCNL), first introduced in the 1970s by Fernstorm and Johnson, has revolutionized the management of large or complex renal stones, providing a minimally invasive alternative to open surgery. It remains the standard of care for renal stones larger than 2 cm, lower pole stones resistant to shock wave lithotripsy, and stones associated with structural abnormalities of the urinary tract[1,2]. The procedure boasts high success rates, often exceeding 90%, with lower morbidity compared to open surgery[3,4].

Despite its advantages, PCNL is not devoid of complications. Prolonged urinary leakage—defined as persistent urine drainage for more than 24 hours following nephrostomy tube removal—poses a significant postoperative challenge[5,6]. The reported incidence of prolonged leakage varies widely, ranging from 5% to 15%[7,8]. This complication not only prolongs hospital stays but also delays recovery, increases healthcare costs, and reduces patient satisfaction[9,10].

The etiology of prolonged leakage is multifactorial, involving anatomical factors such as the degree of hydronephrosis, parenchymal thickness, and stone volume, as well as procedural aspects like puncture site and number of access tracts[11,12]. However, the relative contribution of each factor remains unclear. While some studies emphasize the role of preoperative imaging to assess risk factors, others highlight the need for intraoperative techniques to mitigate complications[13,14].

This study aims to identify key predictors of prolonged urinary leakage following PCNL, focusing on anatomical and procedural factors. By elucidating these predictors, this study seeks to aid in preoperative risk stratification and surgical planning, thereby minimizing the incidence of this troublesome complication.

Methodology

Study Design

The study was a retrospective cohort analysis conducted at Institute of Nephro Urology, Bangalore. The dataset comprised 225 patients who underwent PCNL between January 2022 and December 2022. The research focused on identifying factors predictive of prolonged urinary leakage, defined as leakage persisting for over 24 hours post-nephrostomy removal. The study adhered to ethical principles, Patient identifiers were anonymized, Approved by the hospital's ethics committee.

Study Population

- **Inclusion Criteria**:
- Adult patients (≥18 years old) who underwent PCNL for kidney stones.
- Complete medical records with demographic details, preoperative imaging, and postoperative outcomes.
- Single-stage PCNL procedures.

- **Exclusion Criteria**:
- Patients with missing data for key variables (e.g., hydronephrosis grade, parenchymal thickness).
- Cases involving concurrent urinary infections, multiple surgical stages, or incomplete stone clearance.

PCNL procedures were conducted under general anesthesia. Prophylactic antibiotics were given as per hospital antibiotic protocol. Initially, as a standard protocol ureteric cannulation done in modified lithotomy position using cystoscope sheath and ureteric catheter secured to Foley's catheter. The initial calyceal puncture done by 18G initial puncture needle by bull's eye technique fluoroscopic guidance, following a retrograde pyelogram to delineate the pelvicalyceal anatomy. Once access to the pelvicalyceal system was achieved, a guidewire was introduced, and tract dilatation was performed using Alken's metal dilators over a guide rod.

This process concluded with the placement of a 24F Amplatz sheath, through which a 20F rigid nephroscope was inserted. During surgery, the pelvicalyceal system and ureter were thoroughly examined under direct nephroscopic visualization. The decision to place a double J stent was based on the presence of small residual stones, prolonged renal manipulation, or significant hematuria. Such patients who had double J stent were excluded. The removal of the nephrostomy tube was determined by evaluating the urine color in the nephrostomy tube, urine output volume, and any pain associated with the catheter which is done on post operative day 2. Patients were typically discharged 24 hours postoperatively, following the removal of the nephrostomy tube. Leakage is considered when dressing gets wet noticed by patient or nurse requiring change.

Variables Recorded

Demographic Variables:

Age: Expressed in years.

Sex: Male or Female.

Anatomical Variables:

Hydronephrosis: Graded from 0 to 4 based on preoperative imaging (CT scan).

Parenchymal Thickness: Measured in millimeters along the nephrostomy tract on preoperative imaging.

Skin-to-Parenchymal Length: Distance (in millimeters) from the skin surface to the renal parenchyma.

Stone Characteristics:

Stone Volume: Calculated using imaging, expressed in cubic millimeters.

Stone Location: (Upper, middle, or lower pole).

Procedural Details:

Surgery Time: Total duration of PCNL, measured in minutes.

Number Of Punctures: Single vs. multiple.

Outcome Variable:

Urinary Leakage: Dichotomized into "Yes" (leakage >24 hours) and "No" (leakage ≤24 hours).

Statistical Methods

Non-numeric values and missing data were removed. Continuous variables were checked for normality and transformed if necessary. Mean, median, standard deviation, and range were calculated for continuous variables. Frequencies and percentages were reported for categorical variables. T-tests: Used to compare continuous variables (e.g., hydronephrosis, surgery time) between leakage and non-leakage groups. Chi-square tests: Applied to categorical variables like the number of punctures. Pearson's correlation coefficient assessed the strength of relationships between continuous variables. Multivariate logistic regression identified independent predictors of leakage. Variables with $p < 0.10$ in bivariate analysis were included in the model.

RESULTS

A total of 225 patients who underwent PCNL were analyzed, 23(10%) patients had urine leak beyond 24 hrs. Mean age of study population is 40.7 years, Males 145 (64%)Females 80 (36%).

The summary of key variables is as follows:

Hydronephrosis: The mean grade was 1.25, with a significantly higher grade observed in leakage cases (mean: 2.39) compared to non-leakage cases (mean: 0.98), **Parenchymal Thickness**: Leakage cases had a mean thickness of 15.97 mm, which was significantly thinner than in non-leakage cases (20.11 mm), **Stone Volume**: Larger stones were observed in leakage cases (mean: 810.14 mm^3 vs. 684.56 mm^3 in non-leakage cases), **Surgery Time**: Mean surgery time was longer in leakage cases (92.4 minutes) compared to non-leakage cases (81 minutes), **Skin-Parenchymal Length**: No significant difference was observed between leakage and non-leakage groups. (Table 1)

The correlation matrix reveals, **Positive Correlations:** Hydronephrosis and urinary leakage ($r = 0.63$). Stone volume and urinary leakage ($r = 0.31$). **Negative Correlation:** Parenchymal thickness and urinary leakage ($r = -0.54$).

On T- test, Significant differences were noted for: Hydronephrosis ($p < 0.001$), Surgery Time ($p = 0.01$), Stone Volume ($p = 0.04$), Parenchymal Thickness ($p < 0.001$). No significant difference was observed for skin-parenchymal length ($p = 0.57$). (Table 1)

Visual Representation

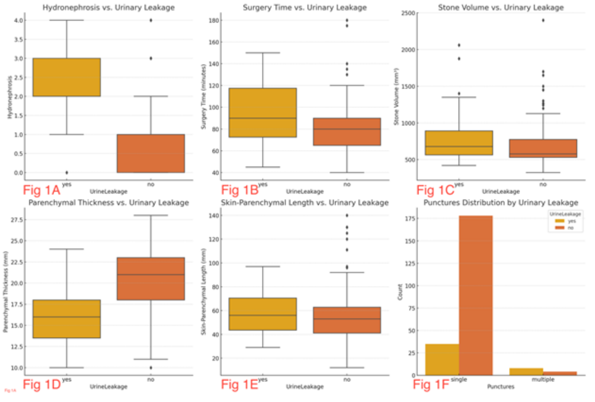
1. **Hydronephrosis**: Leakage cases exhibited significantly higher hydronephrosis grades (Figure 1A).
2. **Surgery Time**: Longer surgeries correlated with increased leakage risk (Figure 1B).
3. **Stone Volume**: Larger stones were observed in leakage cases (Figure 1C).
4. **Parenchymal Thickness**: Thinner parenchyma was a strong predictor of leakage (Figure 1D).
5. **Skin-Parenchymal Length**: No significant difference was evident (Figure 1E).
6. **Punctures Distribution**: Multiple punctures were more frequent in leakage cases (Figure 1F).

Tables And Figures

Table 1: Descriptive Statistics of Key Variables

Variable	Mean (Leakage)	Mean (No Leakage)	p-value
Hydronephrosis	2.39	0.98	<0.001**
Surgery Time (minutes)	92.4	81.0	0.01*
Stone Volume (mm^3)	810.14	684.56	0.04*
Parenchymal Thickness (mm)	15.97	20.11	<0.001**
Skin-Parenchymal Length (mm)	56.28	54.50	0.57 (NS)

Significance Levels: *$p < 0.05$, **$p < 0.001$



DISCUSSION

This study identifies critical predictors of prolonged urinary leakage (PUL) following percutaneous nephrolithotomy (PCNL), corroborating findings from prior research and providing actionable insights for surgical planning and patient care.

Hydronephrosis emerged as a significant predictor of PUL, consistent with prior findings. Studies by Othman et al. and Bozkurt et al. demonstrate that higher grades of hydronephrosis impair drainage efficiency, leading to renal pelvic distension and delayed healing of the nephrostomy tract[4,11]. El-Nahas et al. further observed that patients with grade 3 or 4 hydronephrosis are three times more likely to experience complications[18]. These findings underscore the importance of preoperative imaging to assess and address significant hydronephrosis. Parenchymal thickness plays a critical role in predicting leakage. Studies by Sahan et al. and De Sio et al. highlight that parenchymal thickness ≤13 mm is associated with prolonged urinary leakage due to reduced structural support for the nephrostomy tract[5,17]. Thinner renal parenchyma, often seen in chronic kidney disease or long-standing hydronephrosis, increases susceptibility to postoperative complications[19]. Larger stone burdens were associated with prolonged urinary leakage. Maheshwari et al. observed that patients with larger stones (>800 mm^3) required longer surgeries and more complex maneuvers, increasing the risk of tissue damage and delayed tract healing[6]. This aligns with findings by Hill et al., who reported that stone complexity and fragmentation time significantly correlate with complications, including prolonged leakage[16].

Surgical Factors- Access Site: Middle and lower calyceal accesses were significantly associated with prolonged leakage compared to upper pole access. El-Nahas et al. observed that lower pole access, although effective for stone removal, is more prone to complications due to the gravitational dependency of urine flow[18]. Number of Punctures: Multiple punctures were a strong predictor of prolonged leakage. Ansari et al. and Miller et al. highlighted that multiple tracts increase parenchymal trauma and inflammation, delaying the recovery process[7,19].

Postoperative Interventions- Double-J Stents: The use of double-J stents has been well-documented in reducing urinary leakage by maintaining ureteral patency and preventing obstruction. Kassem et al. reported a significant reduction in leakage duration and hospital stays in patients receiving stents[7]. Alpha-Blockers: Tamsulosin and similar alpha-blockers have demonstrated efficacy in alleviating ureteral edema and spasm, expediting recovery. Kim et al. observed that patients on alpha-blockers reported shorter leakage durations and better postoperative comfort[9].

Comparison With Existing Literature

Our findings align with established literature emphasizing the importance of anatomical and procedural factors in predicting PUL. Predictive tools such as scoring systems have been validated by Sahan et al. and De Sio et al., incorporating factors like hydronephrosis grade, parenchymal thickness, and nephroscopy duration[5,17]. Such tools provide clinicians with practical applications for risk stratification, improving surgical planning and patient outcomes.

Additionally, the role of postoperative interventions like tubeless PCNL has been explored by Xun et al., who reported a 30% reduction in leakage rates with tubeless techniques [10]. While promising, this approach may not be suitable for all patients, particularly those with complex stones or pre-existing urinary infections.

Clinical Implications

Preoperative Assessment

Imaging modalities like CT urography should be routinely used to evaluate hydronephrosis and parenchymal thickness. Stone volume quantification and localization are critical for surgical planning.

Surgical Strategies

Favoring upper pole access in anatomically feasible cases can reduce leakage risks.

Minimizing the number of punctures and ensuring meticulous tract dilation can reduce parenchymal trauma.

Postoperative Management

Double-J stents should be considered for high-risk patients, especially those with significant hydronephrosis or thin parenchyma.

Alpha-blocker therapy can be incorporated into standard postoperative care to expedite recovery and improve patient satisfaction.

Limitations And Future Directions

While this study provides robust evidence, the retrospective, single-center design limits generalizability. Future multicentric, prospective studies with larger cohorts and diverse populations are needed to validate these findings. Moreover, advancements in imaging technologies, such as functional MRI or 3D CT reconstructions, may enhance predictive accuracy for PUL. The role of novel pharmacological agents in promoting ureteral healing warrants further investigation.

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