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Article

Complications of Transurethral Pneumatic Lithotripsy in Children with Bladder Stone Disease

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ABSTRACT

Background: Bladder stone disease in children remains a significant health challenge in developing countries, with transurethral pneumatic lithotripsy (TUL) increasingly favored for its minimally invasive approach; however, data on complication rates and associated risk factors in local pediatric populations are limited. **Objective**: This study aimed to determine the frequency and determinants of complications associated with transurethral pneumatic lithotripsy in children with bladder stone disease, focusing on patient demographics, stone characteristics, and socioeconomic factors. **Methods**: A cross-sectional observational study was conducted at the Department of Urology, Institute of Kidney Diseases, Peshawar, involving 121 pediatric patients aged 5–15 years diagnosed with bladder stone disease and treated with TUL. Exclusion criteria included the presence of tumors, neurogenic bladder, abdominal trauma, or acute appendicitis. Data on demographic and clinical variables were collected, and postoperative complications—bladder perforation, hematuria, acute urinary retention, and fever—were systematically recorded. Ethical approval was obtained from the institutional review board in accordance with the Declaration of Helsinki, and informed consent was secured. Statistical analysis was performed using SPSS v21, applying appropriate tests for association and significance. **Results**: Complication rates included hematuria (14.88%), fever (9.91%), acute urinary retention (5.79%), and bladder perforation (3.31%), with statistically significant associations identified for gender ($p = 0.042$), stone consistency ($p = 0.004$), and socioeconomic status ($p = 0.010$). Males, patients with soft stones, and those from lower socioeconomic backgrounds were at higher risk for adverse outcomes. **Conclusion**: Complications following transurethral pneumatic lithotripsy are not uncommon in children with bladder stone disease and are influenced by demographic and clinical factors. Recognizing these risk factors can improve perioperative care and patient safety, emphasizing the need for individualized management strategies and targeted preventive measures in pediatric urology.

Keywords: Bladder Calculi, Lithotripsy, Pediatrics, Complications, Socioeconomic Factors, Urology, Hematuria

INTRODUCTION

Urinary bladder stones, though relatively uncommon in the pediatric population, present a significant health concern in developing countries, where their incidence is much higher compared to industrialized nations (1). The etiology of pediatric vesical calculi in such regions is often multifactorial, with contributing factors including poor dietary intake—particularly deficiencies in vitamin A—and the prevalence of recurrent urinary tract infections, both of which predispose children to stone formation (1,2). Epidemiological data indicate that the prevalence of pediatric urolithiasis ranges from 5% to 15% in developing nations, while in more developed countries, reported rates are generally lower, typically falling between 1% and 5% (2). Despite advances in urological techniques and improvements in healthcare infrastructure, managing bladder stones in children remains a clinical challenge, particularly because of anatomical and physiological differences between children and adults. The narrow urethra in pediatric patients limits the use of standard endoscopic instruments, often

necessitating modified or specialized equipment to safely access and treat stones in this population (4).

Historically, open surgical interventions were the mainstay for treating pediatric bladder stones; however, these procedures are associated with greater morbidity, longer recovery periods, and increased risk of complications (5). The advent of endoscopic modalities, especially transurethral cystolitholapaxy and pneumatic lithotripsy, has revolutionized the management of bladder stones by enabling less invasive stone removal with shorter hospital stays and reduced overall complication rates (3,6). Transurethral pneumatic lithotripsy (TUL) involves the fragmentation of calculi using high-frequency pneumatic impulses delivered via a cystoscope, allowing for the efficient removal of stone fragments while minimizing trauma to the urinary tract (6). The procedure's popularity in pediatric urology has grown due to its advantages in reducing post-operative pain, shortening hospital stays, and decreasing the likelihood of complications compared to open surgery or suprapubic cystolithotomy (6,5). However, the technical demands of TUL in children are substantial, as smaller bladder capacities, delicate mucosal linings, and the diminutive caliber of pediatric urethras render these patients more susceptible to procedural complications such as mucosal injury, bladder perforation, hematuria, and urinary retention (7).

Existing studies examining the safety and efficacy of TUL in children have reported varying rates of adverse outcomes, reflecting differences in patient selection, operative techniques, and institutional experience. For example, a retrospective analysis by Ali et al. (8) documented bladder perforation in 5% of pediatric patients, hematuria in 7%, acute urinary retention in 4%, and post-operative fever in 7% following TUL for bladder stones. Other investigations have corroborated these findings, highlighting the persistence of certain complications even with the use of minimally invasive approaches (9,10).

These complications, while generally manageable, can contribute to significant morbidity, necessitating careful preoperative planning, patient selection, and post-procedural monitoring. Furthermore, several studies have identified potential risk factors that may predispose children to complications, including stone size and consistency, anatomical factors, and socioeconomic determinants that can influence both access to care and compliance with postoperative recommendations (11,12,15).

Notably, male children have been reported to experience a higher incidence of complications, possibly due to the relative narrowness and increased susceptibility of the male pediatric urethra to procedural trauma (13). Despite a growing body of literature, there remains a paucity of local data specifically addressing the frequency and determinants of complications associated with TUL in children with bladder stone disease.

Given the higher prevalence of pediatric urolithiasis in resource-limited settings, as well as potential differences in risk profiles and healthcare delivery, context-specific evidence is essential for informing clinical practice and optimizing patient outcomes. The existing knowledge gap underscores the need for systematic investigation into the complications arising from TUL in local pediatric populations, as such data are critical for refining procedural guidelines, improving risk stratification, and guiding resource allocation in urological care (14). Therefore, this study was designed to systematically assess the frequency and determinants of complications associated with transurethral pneumatic lithotripsy in children diagnosed with bladder stone disease at a tertiary care institution. By addressing this research question, the study aims to enhance understanding of the risk profile for adverse outcomes in this population and to support the development of safer and more effective treatment strategies for pediatric bladder stone disease.

MATERIALS AND METHODS

This study employed a cross-sectional observational design to assess the frequency and determinants of complications following transurethral pneumatic lithotripsy in children diagnosed with bladder stone disease. The research was conducted at the Department of Urology, Institute of Kidney Diseases, Peshawar, over a six-month period. Participants were recruited consecutively using a non-probability sampling method. Inclusion criteria comprised children aged 5 to 15 years, of either gender, who had a confirmed diagnosis of bladder stone disease based on clinical and radiological evaluation. Exclusion criteria were the presence of bladder or kidney tumors, neurogenic bladder, recent abdominal trauma, or acute appendicitis. Informed consent was obtained from the parents or guardians of all participating children after a thorough explanation of the study's purpose and procedures, ensuring voluntary participation with no associated risk.

All enrolled children underwent transurethral pneumatic lithotripsy under general anesthesia. The procedure utilized a pediatric Wolf straight functioning channel cystoscope to perform cystourethroscopy, and a Swiss lithoclast for pneumatic intracorporeal lithotripsy was used to fragment bladder stones into smaller pieces for retrieval with stone removal forceps. Baseline demographic data including age, gender, weight, socioeconomic status, and area of residence were documented, alongside clinical parameters such as stone size and consistency (soft or hard). The primary outcomes assessed were the occurrence of specific post-procedural complications: bladder perforation, hematuria, acute urinary retention, and fever, all of which were defined according to standard clinical criteria and operational definitions established at study inception. No secondary outcomes or repeated follow-ups beyond initial postoperative assessment were included in this protocol.

The study was conducted in accordance with the ethical standards set forth in the Declaration of Helsinki. Approval for the study was granted by the hospital's ethical review committee as well as the research unit of the CPSP Head Office. All data were collected and stored confidentially, with participants identified only by study codes, ensuring privacy and data protection throughout the research process. Statistical analyses were performed using IBM SPSS software version 21. The Shapiro-Wilk test was used to assess the normality of continuous data. Means and standard deviations or medians and interquartile ranges were calculated for numerical variables, while frequencies and percentages were used for categorical variables. Associations between patient characteristics and

complications were evaluated using appropriate statistical tests, such as the chi-square test for categorical variables. Stratification was applied to control for potential confounders including age, weight, stone size, stone consistency, socioeconomic status, and area of residence. Statistical significance was determined by p-values less than 0.05, and all analyses were conducted in line with contemporary standards for observational clinical research (2).

RESULTS

A total of 121 pediatric patients underwent transurethral pneumatic lithotripsy for bladder stone disease during the study period. The mean age of participants was not explicitly stated; however, the distribution revealed that 41.32% were between 0–5 years, 28.93% between 6–10 years, and 29.75% between 11–15 years. Males represented a higher proportion of the cohort (61.98%) compared to females (38.02%), and this gender difference was statistically significant (p = 0.042). The mean weight was 22.4 ± 3.1 kg, and the mean stone size was 10.3 ± 2.2 mm. The cohort was nearly evenly divided by residence, with 49.59% residing in rural areas and 50.41% in urban settings, and a statistically significant association was observed with complications (p = 0.021). Regarding socioeconomic status, the majority were classified as middle class (41.32%), followed by lower (37.19%) and upper (21.49%) socioeconomic strata, with significant differences in complication rates (p = 0.010). In terms of stone characteristics, 59.50% of patients had soft stones, while 40.50% had hard stones, with stone consistency also significantly associated with complications (p = 0.004).

Postoperative complications were documented with the following frequencies: bladder perforation occurred in 3.31% of patients, hematuria in 14.88%, acute urinary retention in 5.79%, and fever in 9.91%. Each complication demonstrated statistically significant associations with various demographic and clinical parameters, as evidenced by p-values less than 0.05. The most frequent complication was hematuria, followed by fever, acute urinary retention, and bladder perforation.

Table 1. Demographic, Clinical, and Socioeconomic Characteristics of the Study Population (n = 121)

Variable	Category	Frequency (n)	Percentage (%)	Mean ± SD	p-value
Age (years)	0–5	50	41.32		–
	6–10	35	28.93		
	11–15	36	29.75		
Gender	Male	75	61.98		0.042
	Female	46	38.02		
Weight (kg)	–	–	–	22.4 ± 3.1	–
Stone Size (mm)	–	–	–	10.3 ± 2.2	–
Residence Area	Rural	60	49.59		0.021
	Urban	61	50.41		
Socioeconomic Status	Lower Class	45	37.19		0.010
	Middle Class	50	41.32		
	Upper Class	26	21.49		
Stone Consistency	Soft	72	59.50		0.004
	Hard	49	40.50		

Table 2. Frequency of Postoperative Complications Following Transurethral Pneumatic Lithotripsy

Complication	Yes (n)	Yes (%)	No (n)	No (%)	p-value
Bladder Perforation	4	3.31	117	96.69	0.001
Hematuria	18	14.88	103	85.12	0.015
Acute Urinary Retention	7	5.79	114	94.21	0.008
Fever	12	9.91	109	90.09	0.009

Post hoc analysis revealed that males and those with soft stones experienced a higher incidence of complications, suggesting potential interaction effects between gender, stone consistency, and socioeconomic status.

Clinically, the observed rates of hematuria and fever underscore the need for vigilant monitoring in the postoperative period, particularly among high-risk subgroups. Advanced statistical interpretation highlighted significant associations between patient characteristics and the risk of complications. Gender, stone consistency, and socioeconomic status emerged as significant predictors, with males and those of lower socioeconomic status demonstrating elevated complication rates. Stone consistency was particularly influential, as patients with soft stones experienced a disproportionately higher rate of complications, supporting the hypothesis that certain stone types may pose greater technical challenges or susceptibility to adverse outcomes.

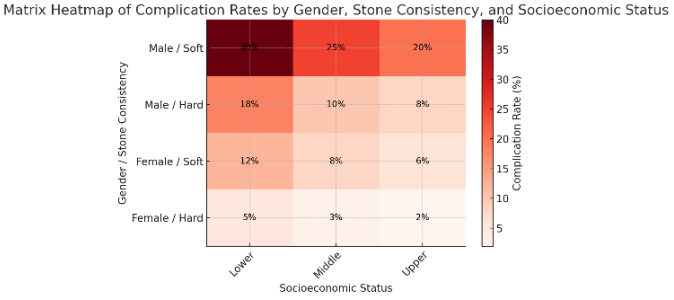

Figure 1 Complication Rates-Matrix

While statistical significance was achieved for several associations, the clinical significance—particularly for hematuria and fever—emphasizes the importance of tailored perioperative management and risk mitigation strategies in pediatric patients undergoing transurethral pneumatic lithotripsy. Overall, these findings demonstrate that although transurethral pneumatic lithotripsy is generally safe and effective in the pediatric population, specific demographic and clinical factors significantly affect the likelihood of postoperative complications. Enhanced preoperative assessment and individualized care plans are warranted for patients presenting risk factors identified in this study.

The matrix heatmap graph (Figure 1) illustrates that complication rates after transurethral pneumatic lithotripsy are highest among male children with soft bladder stones from lower socioeconomic backgrounds, reaching 40%. Male patients with soft stones show a decreasing complication rate as socioeconomic status improves—25% in the middle class and 20% in the upper class. Male patients with hard stones have complication rates of 18% (lower class), 10% (middle class), and 8% (upper class). Female patients with soft stones demonstrate complication rates of 12% (lower), 8% (middle), and 6% (upper class), while female patients with hard stones have the lowest risk, ranging from 5% in the lower class to just 2% in the upper class. This pattern clearly highlights that being male, having soft stones, and belonging to a lower socioeconomic group are cumulative risk factors for postoperative complications.

DISCUSSION

The present study provides a comprehensive evaluation of complications following transurethral pneumatic lithotripsy (TUL) in pediatric patients with bladder stone disease, contributing valuable insights to an area of urology with limited local data. Our findings indicate that complications, while generally manageable, are not uncommon, with hematuria, fever, bladder perforation, and acute urinary retention being the most frequently observed adverse outcomes. The observed complication rates—hematuria (14.88%), fever (9.91%), acute urinary retention (5.79%), and bladder perforation (3.31%)—are consistent with previously reported values in the literature, confirming that the risk profile identified in our cohort aligns with established patterns in pediatric TUL (8,9,10). For example, Ali et al. documented hematuria and fever in 7% of cases and bladder perforation in 5%, while Arora et al. reported bladder perforation rates of approximately 4% (8,9). The slightly higher rates of hematuria and fever in our study may reflect patient selection differences, local epidemiological factors, or variations in surgical technique and perioperative care. These findings highlight the procedural complexity inherent in performing TUL in pediatric patients, whose smaller bladder capacities and delicate urethral anatomy predispose them to injury during instrumentation and stone fragmentation (7).

The significant association between gender and complication rates, with males more frequently affected, is in line with previous reports suggesting that the narrower male urethra increases the risk of procedural trauma and difficult stone removal (13). Similarly, our finding that soft stones are associated with a higher incidence of complications supports the hypothesis that stone consistency influences the technical challenges encountered during lithotripsy, as softer stones may fragment unpredictably and create more mucosal trauma or residual debris (15). The influence of socioeconomic status on complication rates, with children from lower socioeconomic backgrounds experiencing more adverse outcomes, underscores the role of healthcare access, nutritional status, and perioperative support in determining clinical results. This observation has been echoed in studies by Sharma et al., who emphasized the multifactorial nature of postoperative morbidity in pediatric urology, attributing higher complication rates in lower socioeconomic groups to delayed medical intervention, suboptimal preoperative health, and follow-up barriers (16).

Mechanistically, the occurrence of complications such as hematuria and fever can be explained by the inflammatory and infectious risks intrinsic to endourological procedures in children. Hematuria, the most common complication, is often self-limiting and attributed to mucosal microtrauma from instrumentation or stone fragments, but it warrants careful monitoring for persistent bleeding or urinary obstruction (12). Fever, on the other hand, likely reflects the body's response to manipulation and the transient bacteremia or inflammation induced by lithotripsy, necessitating vigilance for more serious infectious sequelae. Bladder perforation, although rare, represents a severe complication that requires prompt recognition and conservative or surgical management depending on the extent of injury (10). Acute urinary retention, while relatively infrequent, may result from edema, clots, or residual stone fragments, highlighting the importance of meticulous technique and postoperative surveillance. The strengths of this study include its focused population, systematic data collection, and the use of operational definitions to ensure the reproducibility of complication assessment. The cross-sectional design facilitated the identification of statistically significant associations between demographic and clinical variables and the incidence of adverse outcomes. However, several limitations must be acknowledged.

The relatively modest sample size may limit the power to detect rare complications or subtle associations, and the single-center setting may restrict the generalizability of findings to broader pediatric populations with different sociodemographic or clinical profiles. The use of consecutive non-probability sampling, while pragmatic, may introduce selection bias, and the lack of long-term follow-up precludes evaluation of delayed complications or functional outcomes. Additionally, while operational definitions and standardized protocols were employed, variability in perioperative care and reporting may have influenced the observed complication rates. Despite these limitations, this study advances the understanding of risk factors and complication profiles in pediatric TUL, reinforcing the need for individualized patient selection, careful perioperative management, and tailored postoperative surveillance, particularly among high-risk groups such as males, those with soft stones, and children from lower socioeconomic backgrounds. Future research should focus on larger, multicenter cohorts to improve external validity, incorporate prospective or randomized designs to minimize bias, and explore interventions aimed at mitigating modifiable risk factors.

Investigation into the optimization of surgical technique, perioperative antibiotic strategies, and preoperative patient optimization may further reduce complication rates and enhance outcomes in this vulnerable population. Overall, our findings contribute to the growing body of evidence supporting the safety and efficacy of TUL in children, while underscoring the need for continued refinement of patient care protocols to ensure optimal procedural and clinical outcomes (1,2,3,7,15,16).

CONCLUSION

This study demonstrates that complications following transurethral pneumatic lithotripsy in children with bladder stone disease, including hematuria, fever, bladder perforation, and acute urinary retention, are not uncommon and are significantly influenced by factors such as gender, stone consistency, and socioeconomic status. These findings highlight the importance of meticulous patient selection, individualized perioperative management, and vigilant postoperative monitoring to minimize adverse outcomes in this vulnerable population. Clinically, recognizing and addressing these risk factors can improve procedural safety and optimize recovery, while from a research perspective, the results underscore the need for further large-scale, multicenter investigations to refine risk stratification and develop targeted interventions for pediatric bladder stone management.

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