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ORIGINAL ARTICLE

Efficacy of Pneumatic Lithoclast in the Management of Different Metabolic Types of Stones in Lower Ureter

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ABSTRACT

Background: Lower ureteric stones are among the most common causes of acute urological emergencies. Pneumatic lithotripsy is a widely used, cost-effective modality for their management. However, the efficacy of pneumatic lithoclast varies based on the metabolic composition of the stones, which may influence fragmentation success and complication rates.

Objective: To evaluate the efficacy and safety of pneumatic lithoclast in managing lower ureteric stones of various metabolic compositions and to determine the association between stone type and procedural outcomes.

Methods: A prospective clinical study was conducted at the Department of Urology, Jinnah Hospital, Lahore, from June 2022 to Jun 2023. A total of 100 patients with solitary lower ureteric stones were included. All patients underwent semi-rigid ureteroscopy followed by pneumatic lithotripsy. Stone composition was determined postoperatively using Fourier-transform infrared spectroscopy (FTIR). Parameters recorded included stone size, operative time, success of fragmentation, and complication rates.

Results: The most common stone type was calcium oxalate monohydrate (34%), followed by uric acid (22%), calcium oxalate dihydrate (16%), mixed stones (12%), struvite (10%), and cystine (6%). Uric acid and calcium oxalate dihydrate stones showed 100% fragmentation success with the shortest operative times (30.3 ± 4.1 min and 37.8 ± 4.5 min, respectively). Cystine and calcium oxalate monohydrate stones had lower success rates (83.3% and 91.2%, respectively) and longer operative durations. The overall fragmentation success rate was 93.4%, with a complication rate of 9.2%, mostly minor.

Conclusion: Pneumatic lithoclast is an effective and safe treatment modality for most lower ureteric stones. Stone composition significantly influences fragmentation success and operative duration. Uric acid and calcium oxalate dihydrate stones respond best to pneumatic lithotripsy, while cystine and calcium oxalate monohydrate stones are more resistant. Individualized treatment planning based on preoperative stone assessment may enhance outcomes.

Keywords: Pneumatic lithotripsy, ureteric stones, metabolic stone types, calcium oxalate, cystine, uric acid, ureteroscopy, stone fragmentation.

INTRODUCTION

Urolithiasis, the formation of urinary stones, remains a prevalent and recurrent condition affecting millions globally[1]. Among its various presentations, ureteric calculi particularly those located in the lower ureter constitute a significant proportion of urological emergencies. The obstruction caused by such calculi can lead to debilitating

pain, hematuria, hydronephrosis, infection, and even loss of renal function if left untreated [2]. The anatomical positioning of the lower ureter makes it a frequent site for stone impaction, often requiring timely and effective intervention [3].

Several treatment modalities exist for the management of ureteric stones, including medical expulsive therapy, extracorporeal shock wave lithotripsy (ESWL), ureteroscopy (URS), laser lithotripsy, and pneumatic lithotripsy[4]. Among these, pneumatic lithotripsy often executed with a pneumatic lithoclast device has emerged as a cost-effective, widely accessible, and efficient approach, particularly suited for lower ureteric stones. The mechanism of action involves the generation of rapid, high-frequency mechanical impulses that fragment the stone upon contact, facilitating its removal through ureteroscopy[5]. The advantages include shorter operative times, minimal thermal injury to the ureteral mucosa, and high fragmentation rates even for hard stones.

Importantly, the metabolic composition of stones plays a critical role in determining their hardness, fragility, response to treatment, and recurrence potential[6]. The most common types of stones include calcium oxalate (monohydrate and dihydrate), uric acid, struvite, cystine, and mixed-composition stones[7]. Each has unique physical properties such as density, crystalline structure, and brittleness that influence the efficacy of fragmentation techniques. For instance, calcium oxalate monohydrate stones are notoriously dense and hard, whereas uric acid stones are softer and more amenable to fragmentation[8].

Despite the wide use of pneumatic lithoclast in clinical urology, limited literature exists evaluating its comparative efficacy across different metabolic stone types, particularly in the context of lower ureteric stones[9]. Understanding this relationship is crucial not only for optimizing treatment protocols but also for anticipating procedural outcomes, counseling patients effectively, and minimizing operative complications. Furthermore, early identification of stone type can aid in the formulation of individualized preventive strategies to reduce recurrence, especially in metabolically active patients[10].

In this context, the present study aims to evaluate the efficacy of pneumatic lithoclast in fragmenting and managing lower ureteric stones of varying metabolic compositions. By comparing outcomes such as fragmentation success rates, operative time, complication incidence, and postoperative recovery, the study seeks to provide valuable insights into the device's performance across the biochemical spectrum of urolithiasis[2,4]. The findings have the potential to enhance clinical decision-making and guide urologists in tailoring interventions based on stone type for improved patient care.

MATERIAL AND METHOD

The present study was conducted at the Department of Urology, Jinnah Hospital, Lahore, over a period of seven months from June 2022 to Jun 2023. A total of 100 patients presenting with lower ureteric stones were included through a non-probability consecutive sampling technique. Patients aged between 18 and 70 years, irrespective of gender, who were diagnosed with solitary radio-opaque stones located in the lower third of the ureter and scheduled for pneumatic lithotripsy were enrolled after obtaining informed consent. Exclusion criteria included patients with active urinary tract infections, bleeding disorders, pregnancy, anatomical abnormalities of the urinary tract, or those undergoing other forms of lithotripsy or having undergone prior ureteral interventions.

All patients underwent a standardized preoperative assessment, including detailed clinical history, physical examination, urinalysis, renal function tests, ultrasound of the urinary tract, and non-contrast computed tomography (NCCT) to confirm stone location and size. The metabolic composition of stones was later analyzed postoperatively using Fourier-transform infrared spectroscopy (FTIR) after stone retrieval. Stones were classified into metabolic types, including calcium oxalate (monohydrate and dihydrate), uric acid, struvite, cystine, and mixed stones.

Pneumatic lithotripsy was performed under spinal or general anesthesia using a semi-rigid ureteroscope and a pneumatic lithoclast (Swiss Lithoclast). The procedure involved direct visualization and fragmentation of the stone using mechanical impulses generated by compressed air. Fragments were removed with forceps or flushed into the bladder using irrigation. A ureteral double-J stent was placed in selected cases based on surgeon discretion, particularly in patients with mucosal edema, residual fragments, or prolonged procedure time. All patients were monitored postoperatively for immediate complications and followed up for four weeks to assess stone clearance, complications, and symptom resolution. Data were collected and analyzed to compare the efficacy of pneumatic lithotripsy across different metabolic stone types based on operative time, stone fragmentation success, and any associated intraoperative or postoperative complications.

RESULTS

A total of 100 patients were included in the study, with a mean age of 43.6 ± 11.2 years. Among them, 64 were males and 36 were females. The most common stone type was calcium oxalate monohydrate (COM), followed by uric acid and mixed stones. The distribution of stone types

and procedural outcomes are summarized in the table below. The results of the study are summarized in a table that outlines the distribution of different metabolic types of lower ureteric stones and the corresponding procedural outcomes using pneumatic lithoclast in 100 patients. The most frequently encountered stone type was calcium oxalate monohydrate, seen in 34 patients. These stones had a mean size of 9.8 ± 1.7 mm and required an average operative time of 42.5 ± 5.2 minutes. The fragmentation success rate in this group was 91.2 percent, with a complication rate of 11.7 percent. Calcium oxalate dihydrate stones were identified in 16 patients, with a slightly smaller mean stone size of 9.1 ± 1.4 mm. These were more amenable to fragmentation, showing a 100 percent success rate and requiring less operative time, averaging 37.8 ± 4.5 minutes. The complication rate in this group was 6.2 percent.

Uric acid stones were observed in 22 patients and had the smallest average size of 8.6 ± 1.2 mm. These stones showed the highest ease of management with a 100 percent fragmentation success rate and the shortest mean operative time of 30.3 ± 4.1 minutes. Only 4.5 percent of these cases experienced complications. Struvite stones were present in 10 patients, with a mean stone size of 9.3 ± 1.5 mm and an average operative duration of 36.5 ± 3.8 minutes. The fragmentation success in this group was 90 percent, and the complication rate was recorded at 10 percent. Cystine stones, known for their hardness and resistance to fragmentation, were found in 6 patients. These stones had the largest mean size at 10.1 ± 2.0 mm and required the longest operative time, averaging 48.7 ± 6.4 minutes. The success rate of fragmentation in cystine stones was the lowest among all groups at 83.3 percent, and the complication rate was relatively high at 16.6 percent. Mixed composition stones were detected in 12 patients, with an average stone size of 9.5 ± 1.6 mm and an operative time of 40.1 ± 4.7 minutes. The success rate in this group was 91.7 percent, and the complication rate was 8.3 percent.

Overall, the average stone size across all patients was 9.4 ± 1.6 mm, and the mean operative time was 39.3 ± 5.8 minutes. The overall stone fragmentation success rate using pneumatic lithoclast was 93.4 percent, and the general complication rate observed was 9.2 percent. These findings indicate that pneumatic lithotripsy is highly effective in treating most types of lower ureteric stones, particularly uric acid and calcium oxalate dihydrate stones. However, its efficacy is comparatively lower in managing cystine and dense calcium oxalate monohydrate stones, which are more resistant to mechanical fragmentation. The safety profile remains acceptable, with only minor complications reported.

Table 1: Distribution of Stone Types and Procedural Outcomes with Pneumatic Lithoclast

Stone Type	No. of Patients (n = 100)	Mean Stone Size (mm)	Mean Operative Time (min)	Successful Fragmentation (%)	Complication Rate (%)
Calcium Oxalate Monohydrate	34	9.8 ± 1.7	42.5 ± 5.2	91.2%	11.7%
Calcium Oxalate Dihydrate	16	9.1 ± 1.4	37.8 ± 4.5	100%	6.2%
Uric Acid	22	8.6 ± 1.2	30.3 ± 4.1	100%	4.5%
Struvite	10	9.3 ± 1.5	36.5 ± 3.8	90.0%	10.0%
Cystine	6	10.1 ± 2.0	48.7 ± 6.4	83.3%	16.6%
Mixed Composition	12	9.5 ± 1.6	40.1 ± 4.7	91.7%	8.3%
Total / Average	**100**	**9.4 ± 1.6**	**39.3 ± 5.8**	**93.4%**	**9.2%**

Ultimately stone fragmentation success rate was 93.4%**,** with the highest success seen in uric acid and calcium oxalate dihydrate stones (100%), and the lowest in cystine stones (83.3%) due to their higher density and resistance to fragmentation. The mean operative time was longest for cystine stones (48.7 minutes) and shortest for uric acid stones (30.3 minutes). The complication rate was low overall (9.2%), with minor complications such as mucosal injury and transient hematuria being most common. These findings suggest that pneumatic lithoclast is highly effective in managing most metabolic types of lower ureteric stones, with reduced efficacy noted in dense and hard stones such as cystine and calcium oxalate monohydrate. The procedure remains safe, with an acceptable complication profile.

DISCUSSION

The present study evaluated the efficacy of pneumatic lithoclast in managing lower ureteric stones of various metabolic compositions in a cohort of 100 patients treated at Jinnah Hospital, Lahore. The findings demonstrated that pneumatic lithotripsy is a safe and highly effective modality for fragmenting most types of lower ureteric stones, with an overall success rate of 93.4% and a low complication rate of 9.2%. However, variations in efficacy and procedural outcomes were observed depending on the biochemical nature of the stones[11]. Uric acid and calcium oxalate dihydrate stones showed excellent response to pneumatic lithotripsy, with 100% fragmentation success and the shortest operative

durations. This is likely due to their relatively softer and less dense structure, making them more susceptible to mechanical disruption by the pneumatic lithoclast. Uric acid stones, in particular, are known to have low radiodensity and high fragility, which correlates with the shorter operative time and minimal complications observed in this study[12].

On the other hand, calcium oxalate monohydrate and cystine stones posed greater challenges. These stones are characterized by their high hardness and compact crystalline structure, which makes them more resistant to fragmentation[13]. Cystine stones, although less common, had the lowest fragmentation success rate (83.3%) and the highest complication rate (16.6%), along with the longest operative time. These findings align with previous reports in the literature indicating that cystine and COM stones often require more energy and multiple pulses to achieve satisfactory fragmentation, and may even necessitate alternative approaches such as Holmium: YAG laser lithotripsy for complete disintegration[14]. Mixed composition stones and struvite stones demonstrated intermediate outcomes, with success rates above 90% and acceptable operative durations. Struvite stones, often associated with infection, may present with softer textures but pose risks of recurrence if underlying infections are not addressed concurrently [15].

The moderate complication rates observed in these groups were likely due to mucosal abrasions and transient hematuria, which are commonly encountered during ureteroscopic procedures. The safety profile of pneumatic lithoclast observed in this study is consistent with existing evidence supporting its use as a cost-effective and efficient modality for lower ureteric stones[16]. No major complications such as ureteric perforation or avulsion were reported. Minor complications such as mucosal injury and hematuria were self-limiting and managed conservatively. The use of a semi-rigid ureteroscope with direct visualization during lithotripsy ensures controlled targeting of the stone and minimizes trauma to surrounding tissues[17]. An important strength of this study is its emphasis on the correlation between stone composition and treatment outcome, which is often overlooked in routine clinical practice. Early identification of stone type, either through non-contrast CT Hounsfield units or through postoperative analysis, can guide urologists in selecting the most appropriate treatment modality[18].

For example, in patients suspected of having dense COM or cystine stones, preoperative planning may include consideration of laser lithotripsy to improve outcomes. However, this study is not without limitations[16-19]. The sample size for certain stone types, particularly cystine stones, was relatively small, limiting the generalizability of findings for those subgroups. Additionally, long-term follow-up data regarding recurrence rates and metabolic evaluation were not included, which are important in the comprehensive management of urolithiasis[19-25]. Future studies with larger, multicenter cohorts and extended follow-up periods are recommended to validate these findings and explore the role of metabolic evaluation in preventing stone recurrence. In conclusion, pneumatic lithoclast proves to be an effective and safe tool for the fragmentation of lower ureteric stones, especially uric acid and calcium oxalate dihydrate types[11,25-34]. While its efficacy decreases with harder stones such as calcium oxalate monohydrate and cystine, it remains a valuable first-line modality due to its accessibility, low cost, and favorable safety profile. Individualized treatment planning based on stone composition can further enhance clinical outcomes and reduce the need for repeat procedures.

CONLUSION

This study concludes that pneumatic lithoclast is an effective, safe, and reliable modality for the management of lower ureteric stones, particularly those composed of uric acid and calcium oxalate dihydrate. The overall fragmentation success rate was high, with minimal complications observed. However, its efficacy is comparatively lower in harder stones such as calcium oxalate monohydrate and cystine, which may require alternative lithotripsy methods for optimal outcomes. The correlation between stone composition and procedural success highlights the importance of preoperative stone assessment and individualized treatment planning. Pneumatic lithotripsy remains a cost-effective option for most lower ureteric calculi, particularly in resource-limited settings.

DECLARATION

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Research Interest

The authors have a continued academic and clinical interest in endourology, minimally invasive techniques for urolithiasis management, and the role of metabolic evaluation in preventing stone recurrence. Further research is intended to evaluate long-term outcomes and recurrence rates following different lithotripsy modalities.

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