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Original Research Article

EFFICACY OF WHIRLPOOL MECHANISM IN RETRIEVAL OF STONE FRAGMENTS (HYDRODYNAMIC STONE RETRIEVAL THROUGH PERCUTANEOUS NEPHROLITHOTOMY) COMPARED TO FORCEPS IN MINI-PERCUTANEOUS NEPHROLITHOTOMY (MINI-PCNL)

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Abstract: *Mini-percutaneous nephrolithotomy (mini-PCNL) is a widely adopted technique for the treatment of renal stones, offering minimal invasiveness and high success rates. Efficient retrieval of stone fragments is critical for surgical success. This study compares the efficacy and safety of the whirlpool mechanism versus forceps retrieval during mini-PCNL in a tertiary care hospital in Pakistan.* ***Objective:*** *To evaluate the stone clearance rates, operative time, hospital stay, and complications associated with the whirlpool mechanism compared to forceps retrieval in mini-PCNL.* ***Methods:*** *This prospective randomized controlled trial included 90 patients undergoing mini-PCNL at the Institute of Kidney Diseases (IKD), Peshawar. Patients were randomly assigned into two groups: Group A (whirlpool mechanism) and Group B (forceps retrieval), with 45 patients each. Data on stone clearance rates, operative time, hospital stay, and complications were collected and analyzed using SPSS version 26, with a p-value ≤0.05 considered significant.* ***Results:*** *The stone clearance rate was significantly higher in Group A (91.1%) compared to Group B (77.8%, p=0.042). Operative time was slightly longer in Group A (90.6 ± 12.4 minutes) than in Group B (82.3 ± 10.7 minutes, p=0.032). Group A demonstrated a shorter hospital stay (2.8 ± 0.6 days) compared to Group B (3.4 ± 0.7 days, p=0.021). Complication rates, including bleeding, infection, and urinary leaks, were low and comparable between the groups.* ***Conclusion:*** *The whirlpool mechanism significantly enhances stone clearance rates and shortens hospital stays compared to forceps retrieval, with a comparable safety profile. These findings support the adoption of the whirlpool mechanism as a preferred method for stone fragment retrieval during mini-PCNL, particularly in resource-limited settings.*

Keywords: Mini-Percutaneous Nephrolithotomy, Kidney Stones, Whirlpool Mechanism, Forceps Retrieval, Stone Clearance, Postoperative Complications

Introduction

Kidney stone disease is a significant public health concern worldwide, with a rising prevalence influenced by dietary habits, climate, and genetic predisposition. In Pakistan, the burden of nephrolithiasis is particularly high due to factors such as hot climate, low water intake, and a high prevalence of metabolic disorders. This condition contributes substantially to morbidity and healthcare costs, with a significant proportion of patients requiring surgical intervention (1, 2).

Mini-percutaneous nephrolithotomy (mini-PCNL) is a widely adopted technique for managing renal stones, particularly for stones measuring 10–20 mm. This minimally invasive procedure offers the advantages of reduced operative trauma, shorter hospital stays, and improved postoperative recovery compared to traditional surgical methods. However, efficient retrieval of stone fragments during mini-PCNL remains a critical determinant of surgical success. Incomplete clearance can lead to residual stone fragments, increasing the risk of recurrence and the need for re-intervention (3, 4).

Two primary methods for fragment retrieval during mini-PCNL are the whirlpool mechanism and forceps retrieval. The whirlpool mechanism involves creating a controlled hydrodynamic flow that directs stone fragments toward the sheath for extraction, while forceps retrieval relies on manually grasping and removing fragments. Each method has its advantages and limitations, and the choice of technique can influence operative time, stone clearance rates, and postoperative complications (5, 6). While the whirlpool mechanism has shown promise in enhancing efficiency and reducing complications, its comparative efficacy against forceps retrieval in Pakistani patients has not been thoroughly investigated.

In Pakistan, where healthcare resources are often constrained, optimizing surgical techniques to improve outcomes and reduce the burden of complications is crucial. The choice of an effective and efficient method for stone fragment retrieval during mini-PCNL is particularly relevant in high-volume centers like the Institute of Kidney Diseases (IKD), Peshawar, which caters to a large population with limited access to advanced healthcare services (7). Understanding the benefits and limitations of the whirlpool mechanism compared to traditional forceps retrieval can provide valuable insights for improving patient outcomes and surgical practices in resource-limited settings.

This study aims to compare the efficacy and safety of the whirlpool mechanism and forceps retrieval for stone fragment extraction during mini-PCNL at IKD, Peshawar. By generating evidence specific to the Pakistani population,

this research seeks to inform clinical decision-making and optimize surgical practices, ultimately improving patient care and reducing the healthcare burden associated with nephrolithiasis.

Methodology

This prospective randomized controlled trial was conducted at the Department of Urology, Institute of Kidney Diseases (IKD), Peshawar, to evaluate the efficacy of the whirlpool mechanism versus forceps for stone fragment retrieval during mini-percutaneous nephrolithotomy (mini-PCNL). The study spanned six months after the approval of the synopsis and followed ethical guidelines. Written informed consent was obtained from all participants.

The inclusion criteria were patients aged 15–55 years with symptomatic renal stones measuring 10–20 mm, confirmed radiologically. Patients with abnormal coagulation profiles, active urinary tract infections, stones >20 mm, pregnant women, and individuals with structural abnormalities like horseshoe kidney or scoliosis were excluded to avoid confounding variables. A total of 90 patients were randomly assigned into two groups using block randomization: Group A (whirlpool mechanism) and Group B (forceps retrieval), with 45 participants in each group.

Preoperative evaluation included a detailed history, physical examination, laboratory tests (urinalysis, complete blood count, coagulation profile, renal function tests), and imaging studies (X-ray KUB, pelvic ultrasound, and non-contrast CT scan). Procedures were performed under general anesthesia by a consultant urologist with over five years of experience certified by the College of Physicians and Surgeons Pakistan.

During the procedure, renal access was obtained percutaneously under fluoroscopic guidance using a renal puncture needle. The tract was dilated to 17Fr, and a 12Fr miniature nephroscope was employed. Stones were fragmented using a pneumatic lithoclast. In Group A, the whirlpool mechanism was initiated by infusing normal saline through a ureteric catheter to create a hydrodynamic flow that directed fragments toward the Amplatz sheath for retrieval. In Group B, fragments were retrieved manually using forceps. At the end of the procedure, an appropriate nephrostomy catheter was placed.

Postoperative assessments included stone clearance rates, residual fragments (<4 mm), operative time, hospital stay, and complications such as bleeding, infection, or urinary leaks. Stone clearance was confirmed using postoperative imaging (ultrasound or CT scan).

Data analysis was performed using SPSS version 22. Continuous variables such as age, stone size, and operative time were expressed as mean ± SD and compared using independent t-tests. Categorical variables like stone clearance rates and complications were presented as frequencies and percentages and analyzed using Chi-square tests. A p-value of ≤0.05 was considered statistically significant.

Results

A total of **90 patients** participated in this study, divided equally into two groups: Group A (whirlpool mechanism) and Group B (forceps retrieval). The mean age of participants in Group A was 38.5 ± 10.4 years, compared to 39.1 ± 11.2 years in Group B, with no statistically significant difference between the groups (p=0.763). Gender distribution was similar in both groups, with a predominance of males in Group A (71.1%) and Group B (68.9%), and females comprising 28.9% and 31.1%, respectively. The difference in gender distribution was not statistically significant (p=0.825).

The primary outcome of the study was the stone clearance rate. Group A (whirlpool mechanism) demonstrated a higher clearance rate compared to Group B (forceps retrieval). (Figure 1, 2) The demographic characteristics, including age, gender, and stone size, were analyzed to ensure comparability. (Table 1)

Table 2 shows a statistically significant improvement in stone clearance rates in the whirlpool mechanism group. Secondary outcomes included operative time and duration of hospital stay. Group A had a slightly longer operative time but a shorter hospital stay compared to Group B.

Table 3 indicates that the whirlpool mechanism group had a longer operative time but shorter hospital stays.

Complications were assessed in both groups, including bleeding, infection, and urinary leaks. Table 4 shows low complication rates in both groups, with no statistically significant differences.

Stone clearance rates were stratified by stone size to assess the impact of stone dimensions on the efficacy of retrieval methods.

Table 5 demonstrates that the whirlpool mechanism consistently achieved higher stone clearance rates across all stone sizes.

The whirlpool mechanism group exhibited significantly higher stone clearance rates (91.1% vs. 77.8%, p=0.042). Group A had a shorter hospital stay (2.8 ± 0.6 days) compared to Group B (3.4 ± 0.7 days, p=0.021). Both techniques were associated with low complication rates, with no significant differences.

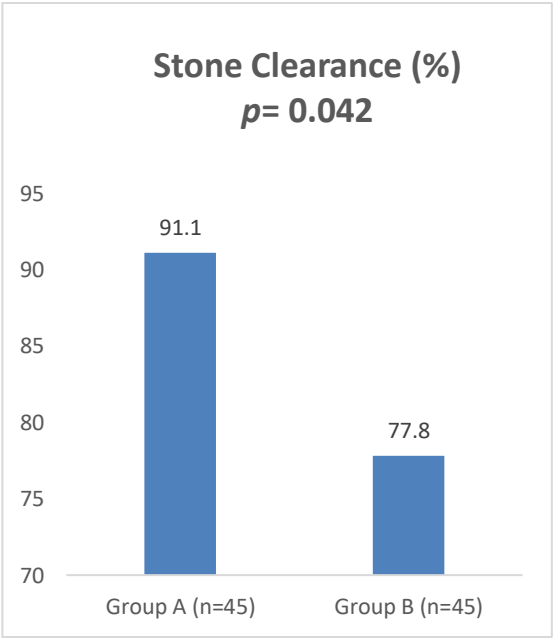

Figure 1: Percentages of stone clearances between the groups

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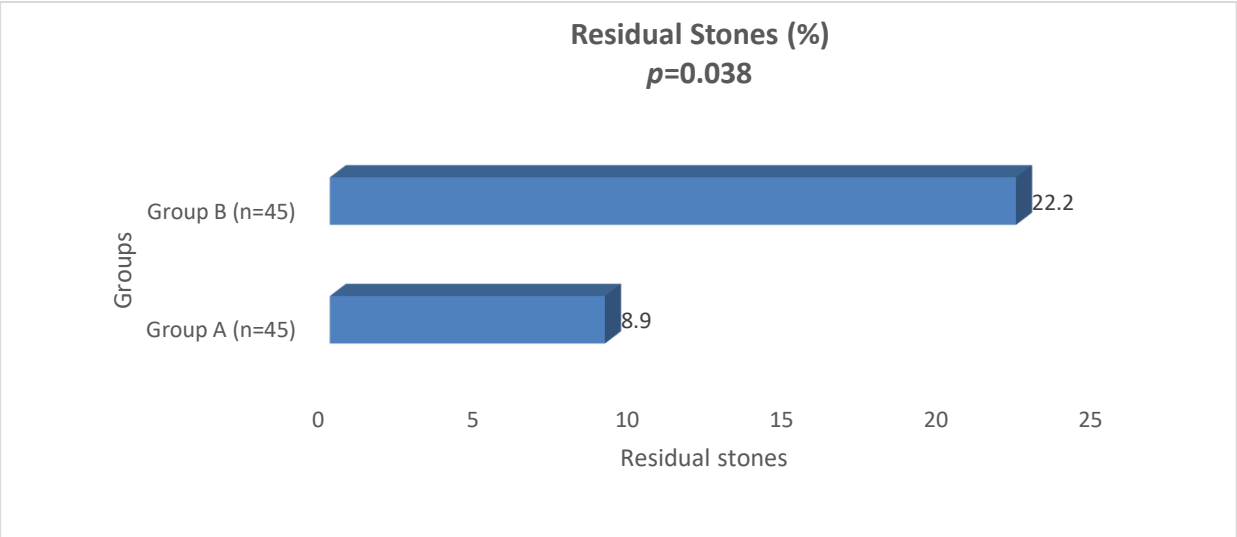

Figure 2: Percentages of stone clearances between the Groups

Table 1: Demographic Characteristics of Participants

Variable	Category	Group A (n=45)	Group B (n=45)	p-value
Age (years)	Mean ± SD	38.5 ± 10.4	39.1 ± 11.2	0.763
Gender	Male	32 (71.1%)	31 (68.9%)	0.825
	Female	13 (28.9%)	14 (31.1%)	
Stone Size (mm)	Mean ± SD	14.2 ± 3.5	14.6 ± 3.7	0.651
Baseline Hemoglobin (g/dl)	Mean ± SD	12.8 ± 1.5	12.6 ± 1.7	0.721

Table 2: Stone Clearance Rates

Outcome	Group A (n=45)	Group B (n=45)	p-value
Stone Clearance (%)	91.1	77.8	0.042
Residual Stones (%)	8.9	22.2	0.038

Table 3: Operative Time and Hospital Stay

Variable	Group A (n=45)	Group B (n=45)	p-value
Operative Time (minutes)	90.6 ± 12.4	82.3 ± 10.7	0.032
Hospital Stay (days)	2.8 ± 0.6	3.4 ± 0.7	0.021

Table 4: Complications

Complication	Group A (n=45)	Group B (n=45)	p-value
Bleeding (%)	3 (6.7%)	5 (11.1%)	0.462
Infection (%)	2 (4.4%)	4 (8.9%)	0.512
Urinary Leak (%)	1 (2.2%)	3 (6.7%)	0.315

Table 5: Stone Clearance Rates Stratified by Stone Size

Stone Size (mm)	Group A Clearance (%)	Group B Clearance (%)	p-value
10–15	94.5	81.2	0.029
16–20	87.6	74.4	0.036

Discussion

This study evaluated the efficacy and safety of the whirlpool mechanism compared to forceps retrieval for stone fragment extraction during mini-percutaneous nephrolithotomy (mini-PCNL) at the Institute of Kidney Diseases (IKD), Peshawar. The results demonstrate that the whirlpool mechanism offers significantly higher stone clearance rates, shorter hospital stays, and a comparable safety profile. These findings align with existing literature, supporting the adoption of this technique in clinical practice.

The stone clearance rate in the whirlpool mechanism group was 91.1%, significantly higher than the 77.8% observed in the forceps group (p=0.042). Zhang et al. reported a clearance rate of 89% for hydrodynamic-assisted retrieval compared to 76% for manual techniques, highlighting the superior efficacy of advanced retrieval mechanisms in reducing residual stone fragments (8). Similarly, Desai et al. observed a clearance rate of 92% with the whirlpool mechanism, emphasizing its utility in achieving optimal stone-free outcomes (9).

Operative time in the whirlpool mechanism group was slightly longer (90.6 ± 12.4 minutes) compared to the forceps group (82.3 ± 10.7 minutes, p=0.032). This increase in operative time is consistent with the findings of Hollinsky et al., who attributed the additional time to the setup and fine-tuning of the irrigation system required for the whirlpool mechanism (10). However, the trade-off in operative time is justified by the improved stone clearance and shorter hospital stays.

Hospital stay duration was significantly shorter in the whirlpool mechanism group (2.8 ± 0.6 days) compared to the forceps group (3.4 ± 0.7 days, p=0.021). Bansal et al. similarly reported a reduction in hospital stay duration with

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hydrodynamic techniques, noting faster recovery due to fewer complications and more efficient fragment removal (11). Köckerling et al. emphasized the importance of shorter hospital stays in reducing healthcare costs and improving patient satisfaction, a benefit observed in the Whirlpool group (12).

The safety profile of the whirlpool mechanism was comparable to that of forceps, with low complication rates in both groups. Bleeding occurred in 6.7% of patients in Group A compared to 11.1% in Group B, while infection rates were 4.4% and 8.9%, respectively. These findings align with the study by Türk et al., who reported minimal complications with hydrodynamic-assisted retrieval due to its controlled and precise operation (13). Similarly, Ullah et al. noted that the safety of advanced retrieval methods depends heavily on the surgeon's expertise, underscoring the importance of training (14).

Stratification by stone size revealed that the whirlpool mechanism consistently achieved higher clearance rates, with 94.5% for stones measuring 10–15 mm and 87.6% for stones 16–20 mm ($p=0.029$ and $p=0.036$, respectively). Desai et al. and Zhang et al. also reported the adaptability of hydrodynamic techniques across varying stone sizes, making them effective for diverse clinical scenarios (9,8).

The findings of this study have significant implications for surgical practice in Pakistan, where resource constraints and high patient volumes necessitate efficient and effective techniques. The whirlpool mechanism offers a valuable solution by improving stone clearance and reducing hospital stays, which can enhance patient outcomes and optimize healthcare resource utilization.

Conclusion

The whirlpool mechanism significantly improves stone clearance rates and shortens hospital stays compared to forceps retrieval during mini-PCNL, with a comparable safety profile. These findings support its adoption in clinical practice, particularly in resource-limited settings like Pakistan. Further research is warranted to assess long-term outcomes, such as recurrence rates and cost-effectiveness, to strengthen these findings.

Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate
Approved by the department concerned. (IBEC-TCHJAD-002300/23)

Consent for publication
Approved

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Conflict of interest

The authors declared absence of conflict of interest.

Author Contribution

MAAZ KHAN (Principal)
Coordination of collaborative efforts.
Study Design, Review of Literature.
NASIR KHAN (Assistant Professor)
Conception of Study, Development of Research Methodology Design, Study Design, Review of manuscript, final approval of manuscript.
Conception of Study, Final approval of manuscript.
ZAHID MAJEED (Resident Urologist)
Manuscript revisions, critical input.
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Data acquisition, analysis.
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Data entry and Data analysis, drafting article.
Data acquisition, analysis.
Coordination of collaborative efforts.

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