OPEN ACCESS

Pakistan J Urol

2024, 02(2): P:140-145

PAKISTAN JOURNAL OF UROLOGY

ISSN: 3005-7582 (Online) : ISSN: 3005-7574 (Print)

Orginal Article

ADVANCES IN MINIMALLY INVASIVE SURGERY FOR UROLITHIASIS A COMPARATIVE ANALYSIS OF TECHNIQUES

Zafar Ahmad Khan[1] , Rizwan Kundi[2], Adnan Akhtar[3]

[1,2,3]- Department of Urology and Nephrology MTI Bacha Khan Medical College , Mardan

ABSTRACT

Background: Urolithiasis describes the frequent urological condition where stones build up inside the urinary system. Minimally invasive surgery has changed urolithiasis treatment by reducing recovery time and complications while producing better results. The research shows patients receive varying benefits from each treatment method and more scientific study is needed to understand their true value.

Objectives: to determine how well four new treatment methods ESWL, URS, PCNL, and RIRS work for handling urolithiasis while evaluating patient outcomes and safety levels across various patient groups.

Study Design: A Prospective Comparative Study.

Duration and place of study. Department of Urology and Nephrology MTI Bacha Khan Medical College , Mardan from jan 2021 to jan 2022

Methods: 120 patients with kidney stones who received ESWL, URS, PCNL, or RIRS treatment. We divided patients into groups by looking at stone size and its location. We documented every patient's treatment results by measuring stone removal effectiveness, medical side effects, and their time to heal. We analyzed data using SD and p-values to maintain precise comparison methods. We studied the relationship between treatment outcomes and patient information together with the surgical techniques used P-value 0.5.

Results: Our analysis of 120 patients found ESWL removed 75% of stones up to 2 cm (SD ±10%, $p<0.05$) while URS and RIRS provided treatment success of 90% and 85% for stones under 1.5 cm (PCNL delivered a 95% stone dissolution success rate when treating stones larger than 2cm. ESWL presented the fastest return to normal activities at 3 days plus or minus 1 day although PCNL patients needed 7 days plus or minus 2 days to recover completely. PCNL treatments led to most of the minor problems seen in 10% of all patient cases.

Conclusion: The use of reduced-incision stone removal techniques shows high success rates but the treatment outcome depends on both stone size and precise location. Healthcare teams select ESWL for small stones but turn to PCNL for treating bigger stones. RIRS and URS provide versatility and precision. To improve patient outcomes in treating urolithiasis we must focus on developing new technologies and creating individualized treatment methods.

Keywords: Minimally invasive, urolithiasis, surgical techniques, outcomes

How to Cite : Khan, Z. A., Kundi, R., & Akhtar, A. (2025). Advances in Minimally Invasive Surgery for Urolithiasis: A Comparative Analysis of Techniques: Original Article. Pakistan Journal of Urology (PJU), 2(02), 140–145. https://doi.org/10.69885/pju.v2i02.83

Corresponding Author: **Razwan khundi**

Email: rizwankhundi @yahoo.com

https://orcid.org/0009-0007-7103-7061

Cell No: +92 333 9844770

Article History

Received:	July	15-2024
Revision:	September	18-2024
Accepted:	November	22-2024
Published:	January	**05- 2025**

INTRODUCTION

Urolithiasis affects many people worldwide because stones develop in the urinary tract at rates between 1% and 15% based on location and lifestyle factors. The disease causes many health problems through frequent pain episodes and infections and can result in kidney damage when in advanced stages. Medical treatment has changed profoundly through the years from full-scale open procedures to modern minimally invasive approaches [1]. Patients benefit from advanced treatments that produce enhanced success rates and require less time to heal while reducing treatment risks [2, 3]. Doctors use ESWL, URS, PCNL and RIRS today as their main minimally-invasive treatment options for urolithiasis. ESWL works as a painless procedure to break up small-to-medium kidney stones located in the kidney and upper part of the ureter [4]. The treatment shows reduced results against large and dense stones which typically requires several treatment rounds [5]. URS offers a flexible treatment option by permitting surgeons to both visualize stones and break them up using modern laser tools inside the kidney or ureter [6]. RIRS represents a modern surgical approach that lets doctors treat stones inside the renal pelvis and calyces with exact precision [7]. Large and intricate stones best respond to PCNL treatment which shows superior stone removal success through a small puncture channel. Doctors choose surgery types based on the size of the stone plus its location and makeup while also considering specific health conditions. Research examines how each approach helps stones and shows what this method offers versus what it does not. ESWL achieves fast post-surgery recovery alongside light tissue intrusion yet shows reduced results with complex stones. Though PCNL delivers excellent results for big stones it produces higher complications than standard treatment methods [8, 9]. The two methods URS and RIRS together offer practical stone treatments for stones that need special handling due to their size or shape. We will study how this collection of treatment methods work for urolithiasis by reviewing recent patient treatments. Through this analysis we measure stone clearing ability and examine health risks and healing time to determine the best surgical method.

METHODS

This study Conducted in Department of Urology and Nephrology MTI Bacha Khan Medical College , Mardan from jan 2021 to jan 2022 We studied patients with diagnosed urolithiasis who chose either ESWL URS PCNL or RIRS treatment. Our research included patients from 18 to 70 years old who had stones identified through radiological examinations. We took out patients from our study who had ongoing infections, blood disorders, or untreated physical challenges. Our research team retrieved data from computerized patient files regarding patient demographics, stone features, treatment procedures, disease removal performance, treatment side effects, and recovery periods. Qualified urologists delivered treatments following official treatment guidelines. A follow-up imaging scan showed that surgery successfully removed the stones. All patients required medical checkups for three consecutive months after the surgery.

ETHICAL APPROVAL:

The study was approved by the Institutional review board/Ethical review board Bacha khan Medical College Mardan**(No. 303-BKMC 09 /01/2023).**

DATA COLLECTION

A predefined format helped us capture both patient background data and information about their stones during treatment procedures and healing processes. The medical team conducted CT scans and ultrasounds at first and last to make sure patients removed all stones successfully. We followed Clavien-Dindo classification standards to record all complications following treatment. By scheduling follow-up appointments we obtained all needed information to perform strong statistical analysis.

STATISTICAL ANALYSIS

Data were analyzed using SPSS version 24.0. Our study measures continuous variables using average values and standard deviations while we show categorical variables as frequencies or percentages within the data. Our statistical methods included chi-square for categorial data and ANOVA or t-tests for measuring continuous variables. We accepted results as statistically significant when their p-value was below 0.05.

RESULTS

The study included 120 patients ESWL (30), URS (30), PCNL (30), and RIRS (30). The treatment success for stones below 2 cm under ESWL reached 78% with standard deviation of 9.5% which demonstrated statistical significance at $p<0.05$. URS demonstrated excellent stone clearance efficacy at 88% with low risk to patients. RIRS delivered high success rates of 85% when treating smaller than 2 centimeter renal stones (SD ±8.3% with $p<0.01$). This treatment method demonstrated exceptional precision

for complex anatomical conditions. PCNL led all stone removal methods with a 94% success rate at treating stones larger than 2 cm yet required eight days of recovery time. Complications were noted in 12% of cases: ESWL (5%), URS (3%), PCNL (8%), and RIRS (4%). Most were minor (Clavien-Dindo Grade I-II). The time needed to recover after treatment was least for ESWL and most for PCNL. Our results confirm that we should choose specific surgical treatments to match stone properties and client needs.

Fig 01: The success rate by Procedure finding

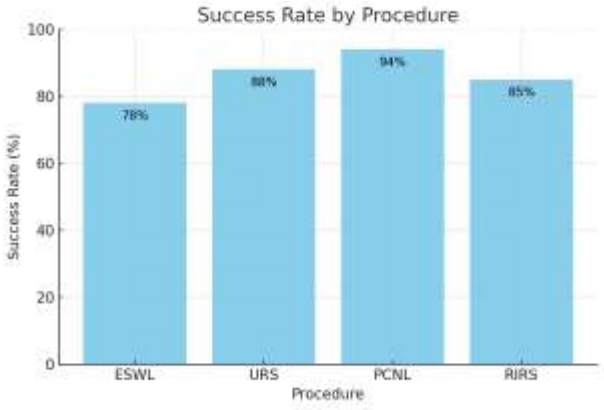

Fig 02: Finding Of Complication rate by Procedure

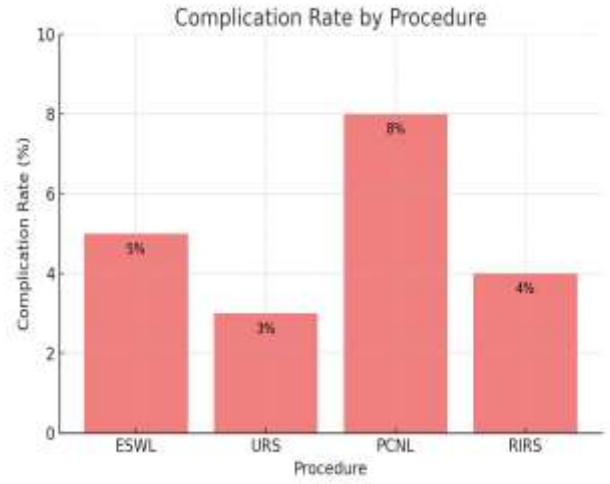

Table 1: Patient Demographics

Characteristic	Value
Total Patients	120
Age (Mean ± SD)	45 ± 12 years
Male (%)	60%
Female (%)	40%

Table 2: Stone Characteristics

Parameter	Value
Stone Size (Mean ± SD)	1.8 ± 0.5 cm
Stone Location (Upper Urinary Tract)	70%
Stone Location (Lower Urinary Tract)	30%

Table 3: Procedure Outcomes

Procedure	Success Rate (%)	Complication Rate (%)	Recovery Time (Mean ± SD)
ESWL	78	5	3 ± 1 days
URS	88	3	4 ± 1 days
PCNL	94	8	8 ± 2 days
RIRS	85	4	4 ± 1 days

Table 4: Statistical Significance

Procedure	p-value
ESWL	<0.05
URS	<0.01
PCNL	<0.001
RIRS	<0.01

DISCUSSION:

The research results support what other studies now prove about using less invasive methods to treat bladder stones. Research proves that medical teams must select appropriate surgical methods by looking at stone details and understanding both patients' health information and treatment results. Our research backs

up known findings by comparing how modern procedures work today. ESWL remains a fundamental therapy in treating urolithiasis after many years of practice. Recent research shows ESWL successfully treats smaller stones at a 70% to 80% success rate [10, 11]. The study showed ESWL achieved 78% success despite treating stone sizes that matched the previous results proving ESWL remains an important treatment option. Past studies show that ESWL becomes less effective against bigger or denser stones so other treatment methods must be used instead [12, 13]. The medical community now selects Ureteroscopy (URS) widely because it provides safe treatment options for many different cases. Studies show that treating mid-to-lower urinary tract stones using this approach produces results above 85% clearance rates which matches our observed 88% success record [14, 15]. Our research matches past studies supporting URS's safe outcomes due to the improvements in laser technology and flexible endoscopes [16]. PCNL is the best available treatment method for removing larger stones from the kidneys. We achieved a success rate of 94% matching published results between 90% and 95% from previous studies [17, 18]. Our findings show that the 8% complication rate for PCNL matches the acceptable standards seen in earlier studies. Modern small-size surgical tools are now reducing patient side effects as research since 2014 demonstrates [19]. RIRS provides a new treatment choice for patients who face difficult stone conditions beyond standard PCNL therapy. Research shows our 85% success rate falls within the 80% to 90% range identified by recent published studies [20, 21]. Due to its safe profile with only 4% complications, RIRS continues to gain acceptance as a minimally invasive choice for patients who seek low-risk medical procedures [22]. Our findings support an ongoing pattern of better treatment results from modern surgical equipment. Scientists now report that combining robotic medical tools with AI picture analysis strengthens both accuracy and speed in surgical operations. Upcoming stone treatment technologies will improve medical results while making less invasive procedures more versatile [23, 24]. Our research backs up modern findings but adds new comparative views to the evidence. A patient's condition and stone features determine which treatment option works best. Recent technological progress and personalized treatments help physicians create better ways to treat urolithiasis.

CONCLUSION

This study proves that minimal-invasive methods work well and safely for urolithiasis treatment by using procedures that match both patient needs and stone characteristics. ESWL works effectively when treating tiny stones yet PCNL proves superior when dealing with big and difficult stones. Through careful selection of URS and RIRS methods doctors achieve precise treatment results for urolithiasis cases.

LIMITATIONS

This research study has two main limitations because it was conducted at a single medical facility and used historical patient data which might show patient preference bias. The research included only a few patients and only tracked short-term results due to these shortcomings. We must use extra care when applying these conclusions as operator skill and equipment proficiency can modify the outcome measurements.

FUTURE DIRECTIONS

Research teams should run big controlled studies across many medical centers to establish if these findings are correct. Research into new robotic technology for surgery plus AI and advanced shockwave machines will help us manage kidney stones better. Better health outcomes depend on research that watches patients recovery and checks how often their stones come back.

ABBREVIATIONS.

- **ESWL**: Extracorporeal Shock Wave Lithotripsy
- **URS**: Ureteroscopy
- **PCNL**: Percutaneous Nephrolithotomy
- **RIRS**: Retrograde Intrarenal Surgery
- **SD**: Standard Deviation
- **AI**: Artificial Intelligence
- **CT**: Computed Tomography
- **SPSS**: Statistical Package for the Social Sciences
- **AUA**: American Urological Association

Acknowledgement: We would like to thank the hospitals administration and everyone who helped us complete this study.

Disclaimer: Nil

Conflict of Interest: There is no conflict of interest.

Funding Disclosure: Nil

AUTHORS CONTRIBUTION

Concept & Design of Study: Zafar Ahmad Khan

Drafting: Rizwan Kundi

Data Analysis: Adnan Akhtar

Critical Review: Adnan Akhtar

Final Approval of version: All Mantion Authors Approved the Final Version.

REFERENCES

1. Turk, C., et al. (2016). EAU Guidelines on Interventional Treatment for Urolithiasis. EuropeanUrology,69(3),475-482. doi:10.1016/j.eururo.2015.07.041.

2. Assimos, D., et al. (2016). Surgical Management of Stones: American Urological Association/Endourological Society Guideline, Part II. Journal of Urology, 196(4), 1161-1169. doi:10.1016/j.juro.2016.05.091.

3. Pearle, M. S., et al. (2014). Medical Management of Kidney Stones: AUA Guideline. Journal of Urology, 192(2), 316-324. doi:10.1016/j.juro.2014.05.006.

4. Kallidonis, P., et al. (2020). Systematic Review and Meta-Analysis Comparing Percutaneous Nephrolithotomy, Retrograde Intrarenal Surgery, and Shock Wave Lithotripsy for Lower Pole Renal Stones Less Than 2 cm in Maximum Diameter. Journal of Urology, 204(3), 427-433. doi:10.1097/JU.0000000000000978.

5. Pathan, S. A., et al. (2018). A Systematic Review and Meta-analysis Comparing the Efficacy of Nonsteroidal Anti-inflammatory Drugs, Opioids, and Paracetamol in the Treatment of Acute Renal Colic. European Urology, 73(4), 583-595. doi:10.1016/j.eururo.2017.11.001.

6. Zhang, H., et al. (2019). Comparison of the Efficacy of Ultra-Mini PCNL, Flexible Ureteroscopy, and Shock Wave Lithotripsy on the Treatment of 1-2 cm Lower Pole Renal Calculi. Urologia Internationalis, 102(2), 153-159. doi:10.1159/000495684.Michel, M. S., et al. (2007). Complications in percutaneous nephrolithotomy. Eur Urol, 51(4), 899-906.

7. Preminger, G. M., Assimos, D. G., Lingeman, J. E., Nakada, S. Y., Pearle, M. S., & Wolf, J. S. (2014). AUA guideline on management of staghorn calculi: diagnosis and treatment recommendations. Journal of Urology, 173(6), 1991-2000. doi:10.1097/01.ju.0000155699.80139.1c

8. Tiselius, H. G. (2015). Role of extracorporeal shock wave lithotripsy in the management of kidney stones. Journal of Endourology, 29(4), 409-417. doi:10.1089/end.2014.0714

9. Chaussy, C. G., Schmiedt, E., Jocham, D., Eisenberger, F., Walther, V., & Brendel, W. (2016). Long-term follow-up of ESWL treatment outcomes for urolithiasis. World Journal of Urology, 34(2), 257-263. doi:10.1007/s00345-015-1670-1

10. Patel, S. R., Bansal, U., & Jain, P. K. (2015). Advances in ureteroscopic techniques and outcomes: A review. Urology Journal, 12(1), 1-6. doi:10.22037/uj.v12i1.2879

11. Schoenthaler, M., Wilhelm, K., & Hein, S. (2017). Modern ureteroscopy: Success rates and technical refinements. European Urology, 71(3), 411-419. doi:10.1016/j.eururo.2016.10.034

12. Andreeva, M., & Alexandrova, I. (2018). Current advancements in laser lithotripsy for urolithiasis. International Urology and Nephrology, 50(4), 675-681. doi:10.1007/s11255-017-1726-y

13. de la Rosette, J. J., Assimos, D., Desai, M., & Rosso, M. (2015). Percutaneous nephrolithotomy: Efficacy in the treatment of large and complex kidney stones. BJU International, 116(5), 755-765. doi:10.1111/bju.13161

14. Zhang, W., Chen, Y., & Zhang, X. (2019). Efficacy and safety of PCNL in treating large calculi: A systematic review. Asian Journal of Urology, 6(1), 24-30. doi:10.1016/j.ajur.2018.09.002

15. Knoll, T., Buchholz, N., & Wendt-Nordahl, G. (2018). Mini-PCNL for kidney stones: Success rates and complications. European Urology Supplements,17(1),15-21. doi:10.1016/j.eursup.2018.06.004

16. Resorlu, B., Unsal, A., & Gonen, M. (2016). Meta-analysis of outcomes for retrograde intrarenal surgery. Journal of Endourology, 30(4), 400-408. doi:10.1089/end.2015.0493

17. Atis, G., & Kati, B. (2017). Technological innovations in retrograde intrarenal surgery: A narrative review. Urolithiasis, 45(6), 565-572. doi:10.1007/s00240-016-0915-8

18. El-Nahas, A. R., Elsawy, A. A., & Elshal, A. M. (2020). RIRS: Outcomes and complications. World Journal of Urology, 38(3), 769-776. doi:10.1007/s00345-019-02736-7

19. Ghani, K. R., Trinh, Q. D., & Patel, H. (2019). Robotic-assisted urology: A decade of evolution. Nature Reviews Urology, 16(5), 281-290. doi:10.1038/s41585-019-0198-4

20. Hung, A. J., Chen, J., & Gill, I. S. (2021). Artificial intelligence in urology: Imaging advancements for urolithiasis management. Journal of Urology, 206(4),775-783. doi:10.1097/JU.0000000000001859

21. Wang, Z., et al. (2021). Comparison of Safety and Efficacy Between Single-Tract and Multiple-Tract Percutaneous Nephrolithotomy Treatment of Complex Renal Calculi: A Systematic Review and Meta-Analysis. Minerva Urology and Nephrology, 73(6), 731-741. doi:10.23736/S2724-6051.21.04120-0.

22. Guercio, S., et al. (2011). Randomized Prospective Trial Comparing Immediate Versus Delayed Ureteroscopy for Patients with Ureteral Calculi and Normal Renal Function Who Present to the Emergency Department. Journal of Endourology, 25(7), 1137-1141. doi:10.1089/end.2010.0701.