ORIGINAL RESEARCH

Percutaneous Nephrolithotomy Versus Open Surgery in the Treatment of Urinary Calculi

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ABSTRACT

Objective • To evaluate the effectiveness of percutaneous nephrolithotomy (PCNL) compared with open surgery for urinary stone removal.

Methods • A total of 95 patients with urinary stones were screened for eligibility between October 2020 and December 2021. After excluding 5 patients who revoked their consent, 90 patients were randomized to receive either traditional open surgery (traditional group) or PCNL (PCNL group), with 45 patients in each group. In addition, the two groups received Shugan Qingre Tonglin decoction twice daily for 2 weeks. Outcome measures included intraoperative indexes, stone removal rate, postoperative healing, and quality of life.

Results • PCNL resulted in significantly better intraoperative indexes (95% CI, 0.49–1.11; $P < .001$), lower creatinine concentration (95% CI, 0.59–1.61; $P < .001$), and higher glomerular filtration rate (95% CI, 2.43–2.91; $P < .001$) compared with traditional open surgery. Patients in the PCNL group had a significantly higher stone removal rate (95% CI, 1.09–2.51; $P < .001$) and a lower incidence of adverse events (95% CI, 0.69–1.87; $P < .001$) compared with those receiving traditional open surgery. Patients in the PCNL group had significantly higher quality of life (95% CI, 1.39–2.81; $P < .001$) and significantly higher maximum urinary flow rate (95% CI, 1.36–2.61; $P < .001$) than those in the traditional group at 1 month and 3 months after treatment.

Conclusion • PCNL provides better postoperative renal function improvement, enhances the postoperative recovery of patients with urinary stones, and features manageable safety compared with traditional open surgery. The benefits of PCNL make it a promising technique for the clinical management of urinary stones. Its minimally invasive nature reduces patient discomfort, promotes faster recovery, and improves overall patient satisfaction. The superior outcomes of PCNL in terms of renal function improvement and postoperative recovery suggest that it is a viable alternative to traditional open surgery. Further research and clinical trials are warranted to validate these findings and establish PCNL as a widely adopted approach in the field of urology. (*Altern Ther Health Med.* 2024;30(12):291-295).

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INTRODUCTION

Urinary stones are a prevalent condition within the field of urology and are currently the most common urologic diseases. They encompass various types, including urethral stones, bladder stones, ureteral stones, and renal stones.[1] Common calculi are renal stones and ureteral stones, which cause clinical manifestations such as vomiting, severe back pain, and difficulty in urination, seriously compromising the health and quality of life (QOL) of patients. [2,3] The incidence of urinary stones has increased in both developed and developing countries over the last decades.[4] The development of urinary stones is a multifactorial process influenced by various factors, including anatomical abnormalities, genetic predisposition, infections, metabolic disorders, changes in urine composition, and dietary habits. In the fast-paced modern lifestyle, holding urine for extended periods of time can lead to an increased concentration of urine, promoting the precipitation of crystals and the formation of urinary stones. These calculi often become lodged or impacted in the narrow passages of the ureter, causing obstruction and the accumulation of fluid in the renal pelvis. Common symptoms associated with this condition include difficulty urinating, discomfort in the kidney region, lower abdominal pain, urinary pain, and back pain. Ureteral obstruction can result in impaired renal function, chronic renal insufficiency, or even renal failure, necessitating prompt and comprehensive medical attention.

Medication and surgical treatment are the primary approaches for managing urinary stones. However, the

effectiveness of pharmacological interventions is often limited, leading to mediocre outcomes and a higher risk of disease recurrence. On the other hand, surgical removal offers improved treatment outcomes. Nonetheless, traditional open surgery methods for stone removal, such as pelvic or parenchymal lithotomy, are highly invasive, associated with a higher risk of hemorrhage, and require a longer postoperative recovery period.[5]

Currently, the main surgical treatments for urinary stones include laparoscopic ureterotomy lithotripsy and procedures like flexible holmium laser lithotripsy and minimally invasive percutaneous nephrolithotripsy. Holmium laser lithotripsy combined with ureteral chondroscopy has shown promising results and promotes disease regression.

With the continuous advancements in endoscopic technology, percutaneous nephrolithotomy (PCNL) has emerged as a minimally invasive technique for stone removal. It offers advantages such as smaller incisions and shorter operative times compared to traditional approaches.[6-9]

In traditional Chinese medicine, the pathogenesis of ureteral stones lies in the kidney and bladder. Therefore, treatment is based on clearing heat and dampness and moving qi to drain stones. Nevertheless, surgeries are associated with postoperative complications such as intraoperative bleeding, residual stone, postoperative stone recurrence, and urinary tract infection. Furthermore, kidney stone surgery has implications for renal function, leading to renal atrophy and insufficiency. The aim was to compare the efficacy of PCNL versus open surgery for urinary stone removal in the context of TCM intervention.

METHODS

Participants

A total of 95 patients with urinary stones diagnosed in General Hospital, Panzhihua, Sichuan Province between October 2020 and December 2021 were assessed for eligibility, and 90 patients were recruited after excluding 5 patients who revoked their consent. The eligible patients were randomly assigned to receive either traditional open surgery (traditional group) or PCNL (PCNL group), with 45 patients in each group. The randomization was carried out using an online web-based randomization tool (http://www.randomizer.org/). For concealment of allocation, the randomization procedure and assignment was managed by an independent research assistant who was not involved in screening or evaluation of the participants.

All patients provided written informed consent before enrollment. The study protocol was approved by the ethics committee of Panzhihua Iron and Steel Group General Hospital (approval No. DF-UD20201019 and ChiCTR2300075867). All procedures complied with the Declaration of Helsinki's ethical guidelines for clinical research.

Inclusion and exclusion criteria

Inclusion criteria. Patients who were diagnosed by abdominal plain film, ultrasonography, or computed tomography; first urinary stone presentation and met the ureteroscopic lithotripsy (URL) criteria; aged 20 to 75 years; normal preoperative cardiopulmonary, hepatic, and renal functions and biochemical indexes; no medication related to renal function within 1 month prior to surgery; complete medical and surgical records; and no preoperative kidney stones or only microkidney stones.

Exclusion criteria. Patients with urinary tract infection or other serious urinary tract diseases; diabetic nephropathy, glomerulonephritis, nephrotic syndrome, renal tumor, or history of renal transplantation; contraindications to surgery; pregnant or lactating; severe coagulation disorders; distal stone ridge or stenosis obstruction; severe urinary tract infection; mental disorders; or severe heart, brain, liver, or kidney diseases.

Treatment methods

All procedures were performed by the same physician. Informed consent was obtained from all patients prior to treatment.

Preoperative preparation. All patients underwent routine preoperative examinations, including routine blood tests, coagulation function, and cardiac function tests, and cross-compatibility tests according to the patients' blood type. Three-dimensional reconstruction of the urinary system and color Doppler angiography of the urinary system were performed to determine the location and size of the stones. Anti-infection treatment with antibiotics was routinely administered, and the patients' blood pressure, heart rate, respiration, pulse rate, and blood glucose were monitored. All patients received epidural general anesthesia, and 0.9% saline was used as the irrigation solution.

Traditional open surgery. Patients in the traditional group underwent traditional open surgery after anesthesia induction. The location of the stone was determined by preoperative color Doppler ultrasonography, a longitudinal incision of 5 to 7 cm was made under the first and second rib margins of the affected side to fully expose the kidney and renal pelvis tissue, and the calculi were removed. After lithotripsy, the surgical site was thoroughly irrigated, a drainage tube was placed, the wound was sutured, and postoperative anti-infection treatment was administered. Strict bed rest was enforced for 24 hours during the recovery period.

PCNL. In the PCNL group, patients underwent percutaneous nephrolithotomy (PCNL) following anesthesia induction. The procedure was performed with the patient positioned in lithotomy position. The location of the urinary calculi was determined using preoperative color Doppler ultrasonography. Under the supervision of a nephrologist, an F5 ureteral catheter was retrogradely inserted on the affected side. A suitable puncture site was identified between the posterior axillary line and the subscapular angle line, just below the 12th rib. The calculi were then crushed using appropriate techniques. Following lithotripsy, the surgical site was meticulously irrigated. A drainage tube and double J-stents were inserted, and any fistulas were repaired. Postoperative anti-infection treatment was administered as per protocol. Strict bed rest was enforced for 24 hours during the recovery period.

Traditional Chinese medicine. In the study, both groups received the Shugan Qingre Tonglin decoction, a traditional Chinese medicine formulation, twice daily for a duration of 2 weeks. The ingredients of the decoction were as follows:

- 50 g of Astragali Radix (Astragalus membranaceus)
- 30 g each of Christina Loosestrife Herb (Pterocephalus hookeri) and Lygodii Spora (Lygodium japonicum)
- 10 g each of Endothelium Corneum Gigeriae Galli (gallus gallus domesticus), Semen Plantaginis (Plantago asiatica), Radix Rehmanniae (Rehmannia glutinosa), Curcumae Radix (Curcuma longa), and Radix Scrophulariae (Scrophularia ningpoensis)
- 15 g each of Radix Bupleuri (Bupleurum chinense), talcum, Rhizoma Alismatis (Alisma orientale), and Eucommiae Cortex (Eucommia ulmoides)
- 20 g each of Radix Bupleuri (Bupleurum chinense) and Semen Cuscutae (Cuscuta chinensis)
- 40 g of fried Bitter Orange (Citrus aurantium)
- Radix Achyranthis Bidentatae (Achyranthes bidentata) and Akebiae Caulis (Akebia quinata) were added for cases of serious stagnation in the lower jiao.
- Agrimoniae Herba (Agrimonia pilosa), Japanese Thistle Herb (Cirsium japonicum), and Herba Cirsii (Cirsium setosum) were added for cases of hematuria.
- Dandelion (Taraxacum mongolicum), Cortex Phellodendri (Phellodendron chinense), and Radix et Rhizoma Rhei (Rheum palmatum) were added for cases of lumbar and abdominal colic with fever.
- Common Anemarrhena Rhizome (Anemarrhena asphodeloides) and Carapax Trionycis (Trionyx sinensis) were added for patients with deficiency of qi and blood.
- Aconiti Lateralis Radix Praeparata (Zingiber officinale) and Cortex Cinnamomi (Cinnamomum cassia) were added for cases of deficiency of kidney yang.

The ingredients were decocted with water and administered half in the morning and half in the evening for a total duration of 4 weeks.

Outcome measures

Surgical indexes.

1. Operation time: The duration of the surgical procedure was measured and recorded.
2. Intraoperative bleeding: The amount of blood loss during the surgery was quantified and documented.
3. Time lapse before out-of-bed activity: The period of time between the surgery and when the patient was able to engage in activities outside of bed was noted.
4. Length of hospital stay: The duration of the patient's hospitalization following the surgery was recorded.
5. Stone removal: The success and effectiveness of stone removal were evaluated.
6. Adverse events: Any untoward incidents or complications that occurred during or after the surgery were documented.
7. Serum creatinine (Cr) and glomerular filtration rate (GFR): The levels of serum creatinine and the glomerular filtration rate of the affected kidney were measured both before and after the treatment.
8. Postoperative recovery time: The time required for patients to recover from the surgery and return to their normal daily activities was assessed and recorded.

Quality of life and maximum urinary flow rate. QOL and maximum urinary flow rate (Qmax) were evaluated 1 month and 3 months after treatment. QOL is scored from 0 to 6, with 0 points for happy, 1 point for satisfied, 2 to 3 points for moderately satisfied, 4 points for unsatisfied, 5 points for disappointed, and 6 points for poor satisfaction.

Statistical analysis

SPSS software, version 26.0 (IBM Corp) was used to organize and statistically analyze the data. Normally distributed measures were expressed as mean (SD). Comparisons of means between the 2 groups were first performed with the chi-square F test. The count data were expressed as No. (%) and analyzed using the chi-square test. $P < .05$ was used as the cut-off for statistical significance.

RESULTS

Patient characteristics

Table 1 shows the patient characteristics for the traditional and PCNL groups, in terms of sex, age, stone size, type of stone, and presence or absence of hydronephrosis. There were no statistically significant differences between the 2 groups in terms of patient characteristics (all $P > .05$).

Operative indexes

The PCNL group had better surgical outcomes compared with the traditional group, when comparing operative time,

Table 1. Patient Characteristics

Characteristics	Traditional (n = 45)	PCNL (n = 45)	*t*	*P* value
Sex, No. (%), y				
Male	26 (57.78)	29 (64.44)	NA	NA
Female	19 (42.22)	16 (35.56)	NA	NA
Age, mean (SD), y	39.4 (3.85)	39.9 (3.24)	0.0573	.57
Age, range, y	30-65	32-67	NA	NA
Stone size, mean (SD), cm	3.51 (1.03)	3.42 (1.12)	0.397	.69
Pathological type, No. (%)				
Kidney stones	24 (53.33)	23 (51.11)	NA	NA
Ureteral stones	13 (28.89)	14 (31.11)	NA	NA
Bladder stones	5 (11.11)	6 (13.33)	NA	NA
Renal pelvic stones	2 (4.44)	1 (2.22)	NA	NA
Kidney stones with ureteral stones	1 (2.22)	1 (2.22)	NA	NA
Hydronephrosis, No. (%)				
Yes	25 (55.56)	28 (62.22)	NA	NA
No	20 (44.44)	17 (37.78)	NA	NA

Abbreviations: NA, not applicable; PCNL, percutaneous nephrolithotomy.

Table 2. Operative Indexes

Group	n	Operative time, mean (SD), min	Intraoperative bleeding, mean (SD), mL	Time lapse before out-of-bed activity, mean (SD), d	Length of hospitalization, mean (SD), d
Traditional	45	143.51 (19.56)	190.15 (23.68)	8.14 (2.11)	15.58 (2.89)
PCNL	45	98.87 (11.23)	99.98 (15.15)	3.94 (1.83)	7.45 (2.01)
t	NA	13.277	21.517	10.087	15.439
P value	NA	<.001	<.001	<.001	<.001

Abbreviations: NA, not applicable; PCNL, percutaneous nephrolithotomy.

Table 3. Creatinine Concentration and Glomerular Filtration Rate

Group	n	Before treatment, mean (SD)		After treatment, mean (SD)	
		Cr, μmol/L	GFR	Cr, μmol/L	GFR
Traditional	45	108.54 (20.56)	28.45 (3.94)	101.77 (15.12)	29.54 (4.41)
PCNL	45	105.96 (21.48)	28.64 (3.89)	94.23 (10.15)	36.94 (4.92)
t	NA	0.582	0.230	2.777	7.513
P value	NA	.056	.82	.007	<.001

Abbreviations: Cr, creatinine; GFR, glomerular filtration rate; NA, not applicable; PCNL, percutaneous nephrolithotomy.

Table 4. Calculi Removal and Adverse Reactions

Group	n	Calculi removal rate, No. (%)	Incidence of adverse reactions, No. (%)
Traditional	45	38 (84.44)	12 (26.67)
PCNL	45	44 (97.78)	1 (2.22)
χ^2	NA	4.9	100.9
P value	NA	.03	.001

Abbreviations: NA, not applicable; PCNL, percutaneous nephrolithotomy.

Table 5. Postoperative Recovery

Group	n	1 month after treatment, mean (SD)		3 months after treatment, mean (SD)	
		QOL	Qmax	QOL	Qmax
Traditional	45	2.45 (0.51)	12.02 (1.55)	2.03 (0.48)	15.12 (2.12)
PCNL	45	1.65 (0.33)	15.69 (1.43)	1.52 (0.41)	18.89 (2.34)
t	NA	8.835	11.674	5.420	8.009
P value	NA	<.001	<.001	<.001	<.001

Abbreviations: NA, not applicable; PCNL, percutaneous nephrolithotomy; QOL, quality of life; Qmax, maximum urinary flow rate.

intraoperative bleeding, time lapse before out-of-bed activity, and length of hospitalization (all $P < .05$; Table 2).

Renal function indexes

The 2 groups had similar pretreatment Cr concentration and GFR (both $P > .05$). After treatment, the PCNL group had lower Cr concentration and higher GFR compared with the traditional group (both $P < .05$; Table 3).

Calculi removal and adverse reactions

The calculi removal rate in the PCNL group (97.78%) was significantly higher than that in the traditional group (84.44%), and the incidence of adverse reactions in the PCNL group (2.22%) was significantly lower than that in the traditional group (26.67%) (both $P < .05$; Table 4).

Postoperative recovery

Patients in the PCNL group had significantly improved QOL and Qmax at 1 month and 3 months after treatment than those in the traditional group (all $P < .05$; Table 5).

DISCUSSION

In traditional Chinese medicine, poor blood circulation and the occurrence of blood stasis are attributed to spleen and kidney deficiencies, dampness and heat accumulation, prolonged accumulation of dampness and heat, impaired bladder qi transformation, qi flow blockage, and qi stagnation. The therapeutic approach involves strengthening qi and promoting blood circulation, clearing dampness and heat, facilitating qi movement and resolving stasis, as well as promoting stone elimination.[10,11] In the Shugan Qingre Tonglin decoction, specific herbs are used for their respective actions: Christina Loosestrife Herb, Endothelium Corneum Gigeriae Galli, and Lygodii Spora are employed to clear heat, induce diuresis, and aid in stone elimination. Radix Bupleuri, Semen Plantaginis, talcum, and Curcumae Radix are used to promote liver dredging, unblock urine flow, while Semen Cuscutae and Eucommiae Cortex help protect the kidneys from stone-related damage. Astragali Radix and amber are included to enhance urinary excretory capacity, while a higher dose of Bitter Orange (Citrus aurantium) effectively dilates the ureter and facilitates stone expulsion. Radix Scrophulariae is utilized to activate blood circulation and cool the blood, and Lygodii Spora helps alleviate postoperative urinary tract pain.[12,13]

Open surgery provides a clear and unobstructed view during the procedure, with a relatively simple operation. However, it is associated with drawbacks such as prolonged operative time, significant intraoperative bleeding, slow postoperative recovery, and an extended hospital stay. [14,15] When compared to percutaneous nephrolithotomy (PCNL), traditional open surgery tends to have longer operative durations and hospital stays, a higher incidence of postoperative complications, greater impairment of renal function, and lower operation tolerance.[16]

PCNL uses ureteroscopes instead of nephroscopes to enter the renal pelvis and calyces through a fistula to perform the operation,[17] with a renal incision of approximately 1 cm and a microfistula incision of 0.4 to 0.6 cm, which minimizes damage to the kidney and contributes to the preservation of renal function.[18] PCNL allows for real-time and legible observation of the puncture route to avoid unexpected damage to the pleura and spleen. Desirable percutaneous renal access is a key factor for effective stone removal.[19] As a result, clinical treatment should be tailored to the location and size of the stone to establish puncture access via a pathway with a thin renal cortex and few vessels to the target kidney's junction of the calyx, pelvis, and ureter, allowing for maximum operating angles and convenient placement of double J-stents. Furthermore, PCNL uses an ultrasonic lithotripsy probe to swiftly aspirate stone pieces, irrigate, accelerate perfusion outflow, and decrease puncture diameter and renal cortical loss, reducing pressure in the renal pelvis and significantly increasing stone removal.[20]

Herein, patients receiving traditional open surgery had longer operation times and lengths of hospitalization and more intraoperative bleeding volume than those who received PCNL, indicating that open surgery was associated with accidental injury to the large perirenal vessels and delayed postoperative recovery. The PCNL group also had lower Cr concentration and higher GFR compared with the traditional group, suggesting that PCNL provides more benefits in the preservation of renal function.[21]

Moreover, patients who underwent percutaneous nephrolithotomy (PCNL) demonstrated significantly improved quality of life (QOL) and maximum urinary flow rate (Qmax), as well as a lower incidence of postoperative adverse events compared to those who underwent traditional open surgery. These findings suggest that PCNL enables more thorough removal of calculi and reduces the occurrence of adverse events, ultimately enhancing patient prognosis and QOL. This

may be attributed to the smaller surgical wounds associated with PCNL, which lower the risk of postoperative infections.

Performing PCNL requires careful considerations, including accurate positioning of the puncture site under ultrasound guidance to avoid excessive puncture, prevention of bleeding caused by medically induced renal tears resulting from surgical overdistension, monitoring of coagulation factors, and judicious use of preoperative antimicrobial drugs to prevent infection.[19]

This study provides valuable information on the short-term efficacy of PCNL compared with traditional open surgery for urinary stone removal. However, it is essential to acknowledge certain limitations in the study design and methodology:

Single-center study. The research was conducted at a single institution (Panzhihua Iron and Steel Group General Hospital), which may limit the generalizability of the findings to a broader population. Results from a single center may not fully represent the diverse patient profiles and treatment practices across different health care settings.

Limited sample size. The study included a relatively small sample size of 90 patients (45 in each group). A larger sample size would enhance the statistical power and reliability of the findings. The small sample size might also affect the ability to detect subtle differences and generalize the results to a larger population.

Short duration of follow-up. The follow-up period for evaluating outcomes such as QOL and Qmax was limited to 1 month and 3 months post-treatment. Longer-term follow-up would provide a more comprehensive understanding of the sustained effectiveness and potential complications associated with each treatment approach.

Treatment uniformity. While the study compared PCNL with traditional open surgery, it introduced the use of Shugan Qingre Tonglin decoction in both groups. The inclusion of this traditional Chinese medicine may confound the results, as its impact on outcomes was not isolated and evaluated independently.

Non-blinded assessment. The outcomes were assessed by the same physician who performed the procedures, which introduces the potential for bias. Blinding the assessors to the treatment groups could enhance the objectivity of the outcome evaluations.

Ethnic homogeneity. The study's focus on a specific geographic region (China) might limit the generalizability of the results to populations with different ethnic backgrounds and health care systems.

Incomplete reporting of adverse events. The study mentions adverse events but does not provide a comprehensive analysis of the types and severity of these events. A more detailed examination of adverse events would contribute to a better understanding of the safety profile of each treatment modality.

Limited comparison parameters. The study primarily focused on surgical outcomes, renal function, calculi removal, and postoperative recovery. Including additional parameters, such as patient-reported outcomes and cost-effectiveness, would offer a more holistic evaluation of the treatments.

CONCLUSION

PCNL provided better postoperative renal function improvement, enhanced the postoperative recovery, and had manageable safety compared with traditional open surgery in patients with urinary stones.

CONFLICT OF INTEREST

All authors declare that they have no financial conflict of interest.

FUNDING

The authors received no financial support for the research authorship or publication of this article.

AUTHOR CONTRIBUTIONS

Ruipeng Tang and Zhengjin Yi contributed equally to this work.

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are included in this published article.

CONSENT FOR PUBLICATION

All authors have read and approved this manuscript to be considered for publication.

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