Original Article

East Coast Malaysia mini percutaneous nephrolithotomy series: an effective and safe approach to treat renal stones

Nirmal Raj Selvakumaran[1], Islah Munjih Ab. Rashid[2], Syahril Anuar Salauddin[1], Hamid Ghazali[1]

[1]Department of Urology, Hospital Tengku Ampuan Afzan, Kuantan, Pahang, Ministry of Health Malaysia, [2]Department of Surgery, Kulliyyah of Medicine, International Islamic University Malaysia, Kuantan, Pahang, Malaysia

Keywords:
Percutaneous nephrolithotomy, PCNL, mini PCNL, kidney stones, retrospective, Malaysia

Abstract

Objective: This paper aims to determine the safety and efficacy of mini percutaneous nephrolithotomy (PCNL) by evaluating the postoperative pain score, postoperative length of hospital stay, stone free-rate, perioperative blood loss, and changes in renal function in patients with nephrolithiasis.

Materials and Methods: This retrospective cohort study involved patients who underwent mini PCNL at the Hospital Tengku Ampuan Afzan (HTAA), Pahang, Malaysia, from January 1st, 2019, until December 31st, 2023. Data are presented descriptively. Changes in haemoglobin and serum creatinine pre- and post-operative were compared using univariate analysis.

Results: The cohort included a total of 50 patients who underwent mini PCNL at our centre. Ninety two percent of the cases had radiopaque stones with a median size of 1.57cm^3. The total operative time was 143.7±32.16 minutes, access being established in 90% of cases via the intracostal route. Four patients (8%) had complications (two (4%) were sepsis-related). Postoperative pain was reported as mild and tolerable, with a median length of hospital stay of 2 days. The stone-free rate was 96%, and the haemoglobin drop was less than 1 g/dl (MD=-0.57 (95% CI: -0.77, -0.37), $p < 0.001$) following mini PCNL. There was no significant change in serum creatinine observed

Conclusion: Our study determined that mini PCNL is a safe and efficacious treatment modality in the management of nephrolithiasis in this Malaysian cohort. The growing trend of mini PCNL in Malaysian urology reflects the advancements in surgical techniques and the commitment of healthcare professionals to provide the best possible care for the patients.

Insight Urol 2024;45(2):64-72. doi: 10.52786/isu.a.87

Corresponding author: Nirmal Raj Selvakumaran

Address: Department of Urology, Hospital Tengku Ampuan Afzan, Jalan Tanah Putih, 25100 Kuantan, Pahang, Malaysia

E-mail: snirmal004@gmail.com

Manuscript received: April 28, 2024
Revision received: September 23, 2024
Accepted after revision: October 23, 2024

Introduction

Percutaneous nephrolithotomy (PCNL) has evolved significantly since its introduction in the late twentieth century as a procedural technique for the removal of renal stones. The first successful PCNL procedure was performed in 1976 by Fernström and Johansson,[1] marking a pivotal moment in urological history. Upon its conception, the procedure was primarily used for the treatment of large renal calculi that were challenging to manage with other therapeutic modalities.[2]

Conventional PCNL involves a larger access tract and is performed under general anaesthesia.[3] The procedure typically begins with the patient placed in a prone position. Under fluoroscopic guidance, a large calibre nephrostomy tract (usually 24-30 Fr) is created to gain access to the renal collecting system.[4] Following the tract creation, rigid nephroscopy is used to visualise and fragment the renal calculi using either pneumatic or ultrasonic lithotripsy. Once stone fragmentation is achieved, the fragments are removed using a stone retrieval mechanism (e.g., baskets or forceps). The procedure concludes with the placement of a nephrostomy tube to drain the renal collecting system, which is usually left in place for a few days post-operatively. Although it is effective, significant morbidity is associated with PCNL due to its invasive nature. The procedure is also coupled with longer hospital stays, greater postoperative pain, and blood loss.[2,5,6]

Miniaturization PCNL (mini PCNL), also known as minimally invasive PCNL or its modifications (including micro PCNL, super mini PCNL, and ultra-mini PCNL)[7], utilizes a smaller access tract in comparison to the conventional PCNL.[2] The concept originally evolved from the use of smaller working sheaths to reduce the trauma observed during paediatric PCNL[8,9] and can be performed under regional or general anaesthesia. It frequently results in shorter hospital stays and quicker recovery times.[10] The procedure usually begins with the patient positioned either prone or supine. A smaller calibre nephrostomy tract (typically 11-20 Fr) is created under fluoroscopic or ultrasound guidance.[11] Flexible nephoscopy is then used to visualise and fragment the renal calculi using holmium laser lithotripsy or miniaturized pneumatic lithotripsy devices. Stone fragments are removed using various retrieval devices, and a smaller calibre nephrostomy tube or a ureteral stent may be placed for drainage.[11] Mini PCNL has helped in the management of renal stones with smaller sized sheaths without compromising the stone-free rate. It also provides an excellent surgical outcome and reduced incidence of surgical complications.[12]

Although mini PCNL has significant appeal for endoscopic urologists due to the clinical benefits of a smaller tract[11], there were only a handful of urology centres in Malaysia performing this technique due to limited resources (e.g., lack of availability of specific sized scopes). This paper aims to determine the safety and efficacy of mini PCNL performed in our centre by evaluating the postoperative pain score and length of hospital stay, stone free-rate, perioperative blood loss, and changes in renal function in nephrolithiasis patients. The findings of the study will inform future developments in this area to improve patient experience and outcomes.

Materials and Methods

Ethical approval

The study was registered with the National Medical Research Register (NMRR) of the Ministry of Health Malaysia (NMRR ID-23-01741-FWZ (IIR)) and received ethical clearance from the Medical Research and Ethics Committee (MREC) of the Ministry of Health Malaysia (Ref.: 23-01741-FWZ (2)).

Setting and study design

This was a retrospective cohort study involving all patients who underwent mini PCNL at Hospital Tengku Ampuan Afzan (HTAA), the main tertiary referral centre for the state of Pahang, Malaysia, from January 1st, 2019, until December 31st, 2023.

Patients selection

All patients who underwent mini PCNL within the specified time period at our centre were included. This included patients with a history of failed extracorporeal short wave lithotripsy (ESWL), patients with residual renal stones following PCNL, patients with lower pole stones with unfavourable anatomy for ESWL, and patients with a nephrostomy tract. Pregnant patients, patients with uncorrected coagulopathy, congenital kidney abnormalities, and active urinary tract infections were excluded.

Data collection

All peri-operative data of interest were collected in a designated data collection form. Pre- and post-operative blood workout, urine analysis, and imaging findings were recorded. Length of hospital stay, post-operative analgesia requirement and pain score (using visual analogue score), stone free-rate (stone clearance), perioperative blood loss and changes in renal function (assessment of changes in serum creatinine) were all collected.

Mini PCNL procedure

General preparation

Preoperative evaluation included complete blood workup, urine analysis, urine culture and image studies, including kidneys, ureter and bladder (KUB) X-ray, ultrasound, and CT urography (CTU). CTU was done to evaluate the stone characteristics, renal anatomy and other visceral conditions. Stone dimensions were recorded in millimetre (mm) along the maximum length. Patients with clinical evidence of urinary tract infection were treated with antibiotics for 2 to 7 days prior to surgery. All patients were admitted 1-2 days before surgery to ensure nil by mouth (NBM) status. After adequate general anaesthesia has been achieved, the patient was placed in the lithotomy position. Prophylactic antibiotics were prescribed 30 minutes pre-surgery. Equipment used included: rigid cystoscope, 0.035 inch guidewire, 5 Fr ureteral access sheath, 10 Fr fascia dilator, 16 Fr mini PCNL dilator, 16 Fr mini PCNL sheath, 12 Fr nephroscope, and a laser.

Cystoscopy and retrograde pyelogram

First, rigid cystoscopy was performed. The ipsilateral ureteral orifice was identified, and access obtained with a 0.035 inch guidewire and a 5 Fr retrograde-pyelography (RP) ureteral catheter was placed at the renal pelvis and a Foley's catheter was inserted. Plain image and retrograde pyelogram images were taken under fluoroscopy.

The patient was then turned prone with bolsters and padding to cover the pressure joint areas. All renal access was obtained under fluoroscopic guidance using the "eye of the needle" technique. The puncture site was chosen to maximize stone clearance, usually the calyx that gives a straight direct tract. An 18-gauge needle was passed under fluoroscopic guidance into the appropriate calyx, and its position confirmed by biplanar fluoroscopy and return of urine. A standard working guidewire was passed into the collecting system and manipulated down the ureter.

Tract access

A single step dilatation was done using a 16 Fr mini PCNL dilator over the guidewire and an outer sheath was placed into the targeted calyx (Fig. 1).

Figure 1. Single step 16 Fr dilation using a metal dilator and insertion of 16 Fr metal outer sheath followed.

Figure 2. Mini PCNL and lithotripsy performed with Holmium-YAG laser.

Insertion of endoscope

A 16 Fr nephroscope was used to examine the renal collecting system and allow passage of irrigation fluid, preventing pressure build-up in the urinary tract. An appropriate size offset cystoureteroscope is ideal and can function as a nephron.

Lithotripsy

With a combination of lithotripsy, for example laser (Fig. 2), and manual extraction using baskets and graspers, the stone can then be removed and sent for analysis. Smaller fragmented stones will pass around the endoscope and wash out through the sheath. An initial stone-free status was defined as no visible stone under direct vision, and was checked via intra-operative fluoroscopy. After the stone had been evacuated, a guidewire was placed into the collecting system and the access sheath slowly retracted. The access tract was carefully checked for severe bleeding, and fluoroscopy was employed to check along the retrograde pyelogram angio-catheter for any stone impaction.

Post-operative care and outcomes

Operative findings, surgical duration (from insertion of puncture needle to the end of the procedure) and outcomes were recorded. The urine catheter was removed on post-operative day 1. The overall type, frequency, and dosage of analgesia requirement was also documented. Post-operative pain was assessed using the Visual Analogue Score (VAS).

Complete blood work and biochemistry tests were performed on the day immediately post-operative. KUB X-ray was performed as a routine procedure prior to discharge to confirm the stone-free status for radiopaque stones, and renal ultrasound in the case of radiolucent stones. The length of post-operative hospital stay was calculated as the number of days from the first day post-operative to the day of hospital discharge. The initial stone-free status was checked at the end of the operation, and a final stone-free status (%) was defined as a residual stone ≤ 2 mm under renal ultrasonography 3 months after mini PCNL. In cases of residual stone fragments, ancillary procedures were done. The Clavien-Dindo grading system[13] was used to assess any surgical-related morbidity. Patients were discharged home only if they progressed well.

Statistical analysis

Data were cleaned and analysed using Statistical Package for Social Sciences (SPSS) version 26.0. The distribution of continuous variables was checked using skewness, kurtosis, and histogram. Continuous variables with normally distributed data are presented using mean ± standard deviation, otherwise median (25^{th} percentile, 75^{th} percentile) are used. Categorical variables are

presented as frequency and percentage. The mean changes in haemoglobin and serum creatinine pre- and post-operative were compared using a paired sample t-test. All the tests were two-sided and statistical significance was denoted by $p < 0.05$.

Results

A total of 50 patients were included in the study with an overall mean age of 54.0±12.35 years old. The majority were Malay (84.0%) and were male (54.0%). The reported median body mass index (BMI) was 26.08 (IQR: 24.09, 30.10) kg/m^2 (Table 1).

The X-ray findings found that almost all stones were radiopaque in nature (92.0%). The median stone size on CTU was 1.57 cm^3 (IQR: 1.10, 3.30). The reported total operation and prone PCNL times were 143.68±32.16 minutes and 104.90±34.55 minutes, respectively. The sizes of laser fibre used were 365 nm (70%) and 600 nm (28%), and in the majority of the patients access was intracostal (86%) followed by supracostal 12th (10%) and lower pole (4%).

Four patients were punctured twice. The calyces puncture sites included lower pole (70%), midpole (14%), midpole and lower pole (2%), and upper pole (14%). Eighty percent of the stones were simple in nature, followed by complex (14%), complex and impacted (4%), and lastly nephrocalcinosis (2%). The majority of the stones were distributed at the lower pole (38%) and in the renal pelvis (28%). There were three (4%) cases of incomplete stone clearance reported; one with nephrocalcinosis at the lower pole, one with a residual midpole stone due to acute angle, and one with an inaccessible upper pole due to narrow infundibulum.

Stents were placed in 27 (54%) patients post-operatively. Complications were observed in four patients, the complications reported including sepsis (2%), septic shock (2%), stent irritation (2%) and vomiting (2%). The median post-operative pain score was 2 (IQR: 2.0, 2.0). Medications used post-operatively were mostly a combination of paracetamol and tramadol (56.0%) (Table 2).

The haemoglobin decreased significantly post-operatively with a mean decrease of 0.57 µmol/L post-operatively compared to pre-operative ($p < 0.001$). There was no significant change observed in serum creatinine between pre- and post-operative readings ($p = 0.205$) (Table 3).

Table 1. Demographic characteristics of the patients.

Characteristics	Output
Age in years, mean ± SD	53.74±12.35
Gender, n (%)	
Female	23 (46.0)
Male	27 (54.0)
BMI in kg/m^2, median (IQR)	26.08 (24.09, 30.10)
Race, n (%)	
Malay	42 (84.0)
Chinese	2 (4.0)
Indian	3 (6.0)
Others	3 (6.0)

BMI = Body mass index, IQR = Interquartile range, SD = Standard deviation

Discussion

Our study determined that mini PCNL is indeed a safe and efficacious treatment in the management of nephrolithiasis in this Malaysian cohort. The median post-operative pain score in our study cohort was 2, denoting a mild and tolerable pain. We observed that the majority of our patients required a combination of paracetamol and tramadol for adequate pain relief. Our findings are in alignment with a randomised trial by Lee et al.[14] which found that patients who underwent mini PCNL reported lower pain score and less analgesia requirements in comparison to retrograde intrarenal surgery among 70 patients with renal stones bigger than 10 mm. This is potentially due to the minimally invasive nature of mini PCNL, and the smaller tract resulting from the procedure has garnered popularity as a safe and effective alternative to the conventional PCNL.[15] Hence, with the ongoing advancements and a growing body of evidence supporting its efficacy[16], mini PCNL is poised to become an integral part of the standard of care for kidney stone management in Malaysia.

The median post-operative length of hospital stay following mini PCNL was only two days. Our findings were echoed in a recent review paper evaluating the clinical outcomes of mini PCNL in comparison to conventional PCNL. In one review, five papers (three prospective cohort studies, one randomised controlled trial and one retrospective study) it was collectively found that mini PCNL was associated with reduced length of hospital stay.[17] Flexible nephroscopy with

Table 2. Perioperative characteristics of the patients.

Characteristics	Output
Pre-operative	
Stone opacity, n (%)	
Radiolucent	4 (8.0)
Radiopaque	46 (92.0)
Size on CTU in cm^3, median (IQR)	1.57 (1.10, 3.30)
Intra-operative	
Total operation time in minutes, mean±SD	143.68±32.16
Total prone PCNL time in minutes, mean±SD	104.90±34.55
Laterality, n (%)	
Left	29 (58.0)
Right	21 (42.0)
Size of laser fibre in nm, n (%)	
365	35 (70.0)
600	15 (30.0)
Access site, n (%)	
Intracostal	45 (90.0)
Supracostal 12^{th}	5 (10.0)
Number of punctures, n (%)	
1	46 (92.0)
2	4 (8.0)
Calyces punctures, n (%)	
Lower pole	35 (70.0)
Midpole	8 (16.0)
Upper pole	7 (14.0)
Nature of the stone, n (%)	
Simple	40 (80.0)
Complex	7 (14.0)
Complex, impacted	2 (4.0)
Nephrocalcinosis	1 (2.0)
Intraoperative stone distribution, n (%)	
Proximal ureter	2 (4.0)
Renal pelvis	15 (30.0)
Lower pole	19 (38.0)
Lower pole renal parenchymal stone	1 (2.0)
Lower pole + renal pelvis	4 (8.0)
Lower + midpole	2 (4.0)
Midpole	4 (8.0)
Upper pole	3 (6.0)
Stone clearance, n (%)	
Complete	47 (96.0)
Incomplete	3 (4.0)
Post-operative	
Tubeless post-op, n (%)	
Tubeless	24 (48.0)
Totally tubeless	26 (52.0)
Complication, n (%)	
Nil	46 (92.0)
Sepsis	1 (2.0)
Septic shock	1 (2.0)
Stent irritation	1 (2.0)
Vomiting	1 (2.0)

Table 2. Perioperative characteristics of the patients. (continued)

Characteristics	Output
Pain score, median (IQR)	2 (2, 2)
Medication used, n (%)	
Nil	1 (2.0)
PCM	17 (34.0)
Tramadol	2 (4.0)
PCM + tramadol	28 (56.0)
PCM + tramadol + celebrex	2 (4.0)
Total length of post-operative stay in days, median (IQR)	2 (2, 2)

CTU = computed tomography urography, IQR = interquartile range, PCM = paracetamol, PCNL = percutaneous nephrolithotomy, SD = standard deviation.

Table 3. Changes in haemoglobin and serum creatinine pre- and post-operatively.

Parameters	Timepoint	Mean ± SD	Mean difference (95% CI)	P-value
Hb (g/dl)	Pre-op	12.83±1.60	-0.57 (-0.77, -0.37)	<0.001*
	Post-op	12.25±1.64		
Serum creatinine (μmol/l)	Pre-op	100.77±40.40	-2.23 (-5.72, 1.26)	0.205
	Post-op	103.00±42.15		

Paired sample t-test, *Statistical significance

holmium laser lithotripsy or the use of miniaturized pneumatic devices is typically utilized for stone fragmentation in mini-PCNL. Hence, this smaller calibre approach often results in shorter hospital stays, quicker recovery times, and potentially reduced morbidity in comparison to conventional PCNL.[2,3,15,16]

We also found that up to 96% of our patients had complete stone clearance and remained stone-free for at least three months post-mini PCNL. However, a recent meta-analysis of 20 trials with a total of 4,953 people found no difference in the stone-free rates between mini PCNL and conventional PCNL.[6] This could be due to the heterogeneity of the patient characteristics (e.g., substantial stone burden) and the level of experience and surgical skills (e.g., lack of experience with flexible nephroscopy) in the studies included in the meta-analysis. It is a generally accepted premise that mini PCNL has a significantly lower stone-free rate (but clinically comparable) when compared to the conventional PCNL, but with markedly reduced complications.[2,3,15,18] This is evident in our study as 92% of our patients did not report any complication following mini PCNL.

Despite the observed statistical significance, the haemoglobin drop of less than 1 g/dL following mini PCNL in our study was not clinically significant. Studies mostly found that mini PCNL were associated with less perioperative blood loss in comparison to conventional PCNL[6,10,16,19,20], however, Lee et al. did not find any statistical difference in perioperative blood loss between mini PCNL and retrograde intrarenal surgery.[14]

Additionally, we did not find any significant difference in the change of serum creatinine following mini PCNL. This contradicts a recent prospective cohort study among 46 patients with chronic kidney disease in Kashmir, which reported a statistically significant improvement in renal function.[21] However, it is important to note that the estimated glomerular filtration rate (eGFR) was used as a parameter to assess renal function in that study, while we evaluated changes in the baseline serum creatinine in our patient pool (which was still preserved even at the preoperative stage). It is worth noting that both eGFR and serum creatinine are indexes of glomerular function, and the inclusion of specific indexes of tubular function and injury (e.g., urinary albumin-to-creatinine ratio, urinary β2-microglobulin) would render the assessment of safety and efficacy of endourological procedures more comprehensive.[22]

To the best of our knowledge, this is the first paper of its kind reporting on the clinical outcomes of mini PCNL in Malaysia. Over the past few years, the urology community in Malaysia has

witnessed a significant shift towards the adoption of mini PCNL as a standard procedure in patients with nephrolithiasis. This shift has not only improved patient outcomes but has also set a new milestone in Malaysian urology.

Despite the small sample size and it being a single centre study, our findings provide evidence, corroborated by the relevant literature, on the safety and efficacy of mini PCNL over conventional PCNL. Moving forward, we would suggest that future studies explore the use of cyclical clinical audits to monitor and sustain the safety and efficacy of mini-PCNL, ensuring optimal healthcare delivery for patients with nephrolithiasis.

Conclusions

This analytical retrospective report which assesses the clinical outcomes, safety and effectiveness of mini PCNL in Malaysian patients has shown promising results. The growing trend of the use of mini PCNL in Malaysian urology does not only signify advancements in surgical techniques, but also reflects the commitment of healthcare professionals to provide the best possible care for the patients. As more healthcare professionals and facilities embrace this technique, it is expected that the overall standard of urological care will continue to improve, leading to better outcomes for patients, nationwide and globally.

Acknowledgement

The authors would like to thank the Director General of Health Malaysia for his permission to publish the paper.

Conflict of Interest

The authors declare no conflict of interest.

References

1. Fernstrom I, Johansson B. Percutaneous pyelolithotomy. Scand J Urol Nephrol 1976;10:257-9.
2. ElSheemy MS, Elmarakbi AA, Hytham M, Ibrahim H, Khadgi S, Al-Kandari AM. Mini vs standard percutaneous nephrolithotomy for renal stones: a comparative study. Urolithiasis 2019;47:207-14.
3. Güler A, Erbin A, Ucpinar B, Savun M, Sarilar O, Akbulut MF. Comparison of miniaturized percutaneous nephrolithotomy and standard percutaneous nephrolithotomy for the treatment of large kidney stones: a randomized prospective study. Urolithiasis 2019;47:289-95.
4. Migliozzi MT, Biebel MG, Kurtz MP. PCNL. Minim Invasive Robot Surg Pediatr Urol 2020:251-73.
5. Lotan P, Goldberg H, Nevo A, Darawsha AE, Gefen S, Criederman G, et al. Post-operative pain following percutaneous nephrolithotripsy- clinical correlates. Urol J 2023;90:503-9.
6. Wan C, Wang D, Xiang J, Yang B, Xu J, Zhou G, et al. Comparison of postoperative outcomes of mini percutaneous nephrolithotomy and standard percutaneous nephrolithotomy: a meta-analysis. Urolithiasis 2022;50:523-33.
7. Lahme S. Minimal-Invasive PCNL (Mini-PCNL). In: Zeng G, Sarica K, editor (s). Percutaneous Nephrolithotomy. Singapore: Springer Nature Singapore Pte; 2020: p. 137-49.
8. Monga M, Oglevie S. Minipercutaneous nephrolithotomy. J Endourol 2000;14:419-21.
9. Chan DY, Jarrett TW. Mini-percutaneous nephrolithotomy. J Endourol 2000;14:269-73.
10. Wishahi M, El Feel A, Elkhouly A, Fahmy A, Roshdy M, Elbaz AG, et al. Concerns about stone free rate and procedure events of percutaneous nephrolithotripsy (PCNL) for 2–4 cm kidney stones by standard-PCNL vs mini-PCNL- comparative randomised study. BMC Urol 2023;23:1-7.
11. Chen Y, Zhou Z, Sun W, Zhao T, Wang H. Minimally invasive percutaneous nephrolithotomy under peritubal local infiltration anesthesia. World J Urol 2011;29:773-7.
12. Lin CH, Lin YC, Chiang HC, Yan MY, Fang WY, Chen PH. Totally tubeless single access tract mini-percutaneous nephrolithotripsy in treatment of large burden > 2-cm and/or complex renal stones: a case series of 62 patients. BMC Urol 2022;22:1-6.
13. Mitropoulos D, Artibani W, Biyani CS, Bjerggaard Jensen J, Rouprêt M, Truss M. Validation of the Clavien–Dindo Grading System in Urology by the European Association of Urology Guidelines Ad Hoc Panel. Eur Urol Focus 2018;4:608-13.
14. Lee JW, Park J, Lee SB, Son H, Cho SY, Jeong H. Mini-percutaneous Nephrolithotomy vs Retrograde Intrarenal Surgery for Renal Stones Larger Than 10 mm: A Prospective Randomized Controlled Trial. Urology 2015;86:873-7.
15. Jiao B, Luo Z, Huang T, Zhang G, Yu J. A systematic review and meta-analysis of minimally invasive vs. standard percutaneous nephrolithotomy in the surgical management of renal stones. Exp Ther Med 2021;21:1-1.
16. Qin P, Zhang D, Huang T, Fang L, Cheng Y. Comparison of mini percutaneous nephrolithotomy and standard percutaneous nephrolithotomy for renal stones? >2cm: a systematic review and meta-anal-

ysis. Int Braz J Urol 2022;48:637-48.
17. Thapa BB, Niranjan V. Mini PCNL Over Standard PCNL: What Makes it Better? Surg J 2020;06:e19-23.
18. Awedew AF, Alemu CT, Yalew DZ. Efficacy and safety of various endosurgical procedures for management of large renal stone: a systemic review and network meta-analysis of randomised control trials. Urolithiasis 2023;51:1-12.
19. Guddeti RS, Hegde P, Chawla A, de la Rosette JJMCH, Laguna Pes MP, Kapadia A. Super-mini percutaneous nephrolithotomy (PCNL) vs standard PCNL for the management of renal calculi of <2 cm: a randomised controlled study. BJU Int 2020;126:273-9.
20. Deng J, Li J, Wang L, Hong Y, Zheng L, Hu J, et al. Standard versus mini-percutaneous nephrolithotomy for renal stones: a meta-analysis. Scand J Surg 2021;110:301-11.
21. Ansari FM, Para SA, Wani MS, Bhat AH, Khawaja AR, Malik SA, et al. Mini-PCNL–a boon for CKD patients with nephrolithiasis. Arab J Urol 2024;22:115-20.
22. Mykoniatis I, Sarafidis P, Memmos D, Anastasiadis A, Dimitriadis G, Hatzichristou D. Are endourological procedures for nephrolithiasis treatment associated with renal injury? A review of potential mechanisms and novel diagnostic indexes. Clin Kidney J 2021;13:531-41.