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Mini-percutaneous nephrolithotomy versus Standard percutaneous nephrolithotomy: outcome and complications

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Abstract

Background Renal stones are a prevalent urological disorder with various treatment options, including minimally invasive techniques such as Standard-PCNL (S-PCNL) and Mini-percutaneous nephrolithotomy (M-PCNL). This study aims to compare the efficacy and safety outcomes of M-PCNL and S-PCNL for managing renal calculi.

Methods This randomized study enrolled 60 patients with renal stones, comparing the efficacy and safety of M-PCNL (Group A) and S-PCNL (Group B) procedures. Preoperative assessments, surgical procedures, and postoperative care were conducted, and outcomes such as operating time, stone clearance, analgesic requirement, and hospital stay were evaluated. Data analysis was performed using SPSS software, with comparisons between groups conducted using the Chi-square test and Student *t* test.

Results M-PCNL had a longer operation time (133.73 ± 29.18 min) than S-PCNL (48.6 ± 17.88 min, $p = 0.009$) but a lower mean drop in hemoglobin levels (0.14 ± 0.01 g/dL vs. 0.82 ± 0.05 g/dL, $p = 0.032$). The success rates (stone-free rate) were significantly different, with 100% in the M-PCNL group and 86.7% in the S-PCNL group ($p = 0.040$). Complications were generally fewer in the M-PCNL group, including postoperative fever in 2 cases (M-PCNL) vs. 8 cases (S-PCNL) and mild collection in 4 cases (M-PCNL) vs. 26 cases (S-PCNL).

Conclusions M-PCNL is an effective and safer method for managing renal calculi smaller than 3 cm, offering a higher stone-free rate, lower postoperative pain, and shorter hospital stays compared to S-PCNL. Despite longer operation times due to stone fragmentation, M-PCNL has fewer complications, including lower bleeding rates, hemoglobin drop, and leakage, and can be performed using an ureteroscope when a miniperc scope is unavailable.

Keywords Complications, Mini-percutaneous nephrolithotomy, Outcomes, Standard percutaneous stones

1 Background

Renal stones represent the most prevalent disorder in urology, with 10 percent of humans reporting complaints [1]. They exhibit a high recurrence rate of approximately 70%. As the stone moves, renal colic emerges, and kidney function may be compromised due to stone obstruction [2, 3]. The formation of renal stones occurs when the balance between salt precipitation solubility and solubility is disturbed [4].

Advancements in the management of renal stones have been significant, with the introduction of minimally invasive approaches such as laparoscopy, percutaneous nephrolithotomy (PCNL), and retrograde intrarenal surgery (RIRS), as well as noninvasive procedures like extracorporeal shock wave lithotripsy (ESWL) [5]. The European Association of Urology (EAU) recommends PCNL as the treatment of choice for renal stones larger than 20 mm and for stones between 10 and 20 mm in the lower pole

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of a kidney when ESWL has failed due to unsuitable conditions [6].

The standard option for treating renal stones larger than 2 cm is Standard-PCNL (S-PCNL) to achieve a high stone-free rate (SFR). However, S-PCNL is sometimes associated with complications, such as major bleeding requiring blood transfusion, prompting the need for less invasive techniques to reduce the likelihood of morbidity [7]. By implementing Mini-percutaneous nephrolithotomy (M-PCNL), which involves creating narrower tracts (≤ 18 Fr) to allow smaller scopes access to the kidney, parenchymal trauma and bleeding can be reduced [8]. This less invasive approach was established by Jackman et al. [9] and significantly improved the complexity profile of the PCNL procedure. Nonetheless, it was necessary to verify its efficiency compared to S-PCNL, as the smaller tract size might limit instrument manipulation for removing large stones [10].

Several studies have compared M-PCNL with S-PCNL [11, 12], but the sample size in most of these investigations was relatively small. Moreover, there remains controversy regarding their relative safety and efficacy. As a result, we conducted a randomized controlled study to prospectively compare the efficacy and safety outcomes of M-PCNL versus S-PCNL for managing renal calculi.

2 Methods

2.1 Study design and participants

Our study was a randomized comparison, enrolling 60 patients with renal stones between June 2019 and September 2020. Patients admitted to the outpatient clinic meeting the inclusion and exclusion criteria were systematically randomized into one of two groups: M-PCNL (Group A) and S-PCNL (Group B) in a 1:1 ratio. The allocation was performed blindly to minimize bias. The study was approved by the Scientific Research Ethics Committee of Helwan University, Egypt (no. **10-2019R**). Written informed consent was obtained from all patients, and the research aims were clarified. This randomized clinical study was reported following the Consolidated Standards of Reporting Trials (CONSORT) guidelines.

2.2 Inclusion and exclusion criteria

Eligible patients were those aged 18 years or older (both male and female) with a single unilateral renal stone less than 3 cm in size. Exclusion criteria included an abnormal coagulation profile, complicated urinary tract infection, congenital renal anatomy (horseshoe, pelvic, and mal-rotated kidneys), renal stones larger than 3 cm, staghorn stones, multiple renal stones, patients who had undergone transplant or urinary diversion, solitary kidney patients, obesity, and pregnancy.

2.3 Sample size calculation

The sample size was calculated using MedCalc v. 19 software, with a power of 80%, α of 0.05, and a confidence level of 95%. The result yielded an $n = 30$ for each group. A total of 60 patients met the inclusion criteria were randomly divided into two groups: Group A (M-PCNL) with 30 patients and Group B (S-PCNL) with 30 patients.

2.4 Preoperative assessment

Prior to the procedure, each patient underwent a detailed personal, medical, and surgical history, physical examination (general and local), and laboratory investigations (CBC, liver function, kidney function, coagulation profile, urinalysis, and urine culture). Imaging studies included kidney–urinary bladder X-ray (KUB), pelvic and abdominal ultrasonography, and either computed tomography urinary tract (CTUT) or intravenous pyelography (IVP). Patients with positive urine cultures received appropriate prophylactic antibiotics 48 h preoperatively and continued postoperatively.

2.5 Surgical procedure

The procedure was performed under general anesthesia. Retrograde ureteric catheterization with a 5–6-Fr open-ended ureteric catheter was done, and the patient was positioned prone under a C-arm image intensifier. An 18-gauge needle was placed under fluoroscopic guidance through the flank into the target calyx (lower calyx) of the kidney through the desired access. A guide wire of 0.035 or 0.038 sizes was passed through the needle, followed by a small incision in the skin and fascia. The tract was dilated using a Teflon or metal dilator over the guide wire. Single-tract dilation was performed for all cases under fluoroscopic control. An 11–13-Fr AmPlatz sheath for Group A and a 30-Fr AmPlatz sheath for Group B were passed over the dilator. A semi-rigid ureteroscope and nephroscope were passed through the sheath for Group A and Group B, respectively. In Group A, a ureteroscope sized 9.8–13 Fr and 38 cm long was used due to the unavailability of a miniperc scope at our hospital. A single-step dilatation was employed, and the calculus was fragmented using a pneumatic lithotripter with a 1.6-mm probe. Stone fragments were extracted with forceps. Stone clearance was assessed using nephroscope visualization and C-arm imaging during the operation. At the end of the procedure, a 10-Fr nephrostomy tube was placed in M-PCNL (Group A) patients, and a 22-Fr nephrostomy tube was placed in S-PCNL (Group B) patients, or a double J stent was inserted if necessary. Postoperatively, non-steroidal anti-inflammatory drugs (diclofenac) were administered for analgesia.

2.6 Postoperative care and follow-up

Patients were routinely discharged from the hospital the day after the procedure. If a double J (JJ) ureteral stent was inserted, it was removed two weeks after the procedure at the follow-up visit. In cases where postoperative leakage persisted for more than 72 h (three days), catheterization was prolonged. We evaluated operating time, stone clearance, postoperative analgesic requirement, and both postoperative hospital stay and leakage. Hemoglobin levels were measured, and a kidney, ureter, and bladder (KUB) X-ray and pelvic-abdominal ultrasound were performed on a postoperative day one before discharge from the hospital to determine stone clearance. Clinically insignificant residual stone fragments in the kidney were defined as ≦ 4 mm. Patients were followed one week after the operation.

2.7 Statistical analysis

Data analysis was conducted using SPSS® software, version 26 (Statistical Program for Social Science). Quantitative variables were described as mean and standard deviation, while qualitative data were reported as frequency. Comparison between groups regarding qualitative variables was performed using the Chi-square test. The Student t test was applied to compare the two

Table 1 Mini-PCNL vs. Standard-PCNL

	Group A (M-PCNL) n = 30	**Group B (S-PCNL) n = 30**	***P***
Mean (SD)			
Operation time (min)	133.73 (29.18) 95% CI 123.29–144.17	48.6 (17.88) 95% CI 42.2–55	0.009
Fluoroscopy exposure time (min)	2.93 (0.87) 95% CI 2.6–3.26	3.07 (0.87) 95% CI 2.74–3.4	0.361
Stone burden (cm)	1.6 (0.48) 95% CI 1.43–1.77	1.77 (0.53) 95% CI 1.58–1.96	0.018
Preoperative Hemoglobin, g/mL	13.09 (1.05) 95% CI 12.7–13.5	13.38 (1.49) 95% CI 12.6–13.7	0.796
Postoperative Hemoglobin, g/mL	12.95 (1.06) 95% CI 12.4–13.1	12.57 (1.54) 95% CI 12–13.1	0.601
Hemoglobin drop, g/dL	0.14 (0.01)	0.82 (0.05)	0.032
Hospital stay (Days)	1.4 (0.62) 95% CI 1.18–1.62	3.33 (1.21) 95% CI 2.9–3.76	0.003
No. of NSAID ampoules used to control postoperative pain	1.53 (0.50) 95% CI 1.35–1.71	4.2 (0.99) 95% CI 3.85–4.55	0.001
Catheter indwelling time (days)	1.4 (0.62)	3.23 (0.99)	0.022
DJ indwelling time (months)	0	1.5 (0.58)	0.013
Nephrostomy duration (days)	0	1 (0)	0.032
Postoperative VAS pain score	1.4 (0.48) 95% CI 1.22–1.58	3.5 (0.69) 95% CI 3.24–3.76	0.001
Clearance (SFR) *n* (%)	30 (100)	26 (86.7)	0.040
Auxiliary procedures *n* (%)			
(a) Catheterization for more than 72 h	0 (0)	14 (46.6)	0.040
(b) Double J insertion	0 (0)	4 (13.3)	0.040
(c) Nephrostomy tube	0 (0)	4 (13.3)	0.040
Complication (Clavien score) *n* (%)			
Grade I			
Leakage (follow-up)	4 (13.3)	26 (86.7)	0.001
Bleeding	0 (0)	2 (6.7)	0.153
Grade II			
Fever (SIRS)	2 (6.7)	8 (26.7)	0.039
Grade III			
Pelvic injury	0 (0)	2 (6.7)	0.153
ESWL postoperative	0 (0)	4 (13.3)	0.040

Data presented as mean (standard deviation), with range or percentage in some parameters

$P < 0.05$: statistically significant difference

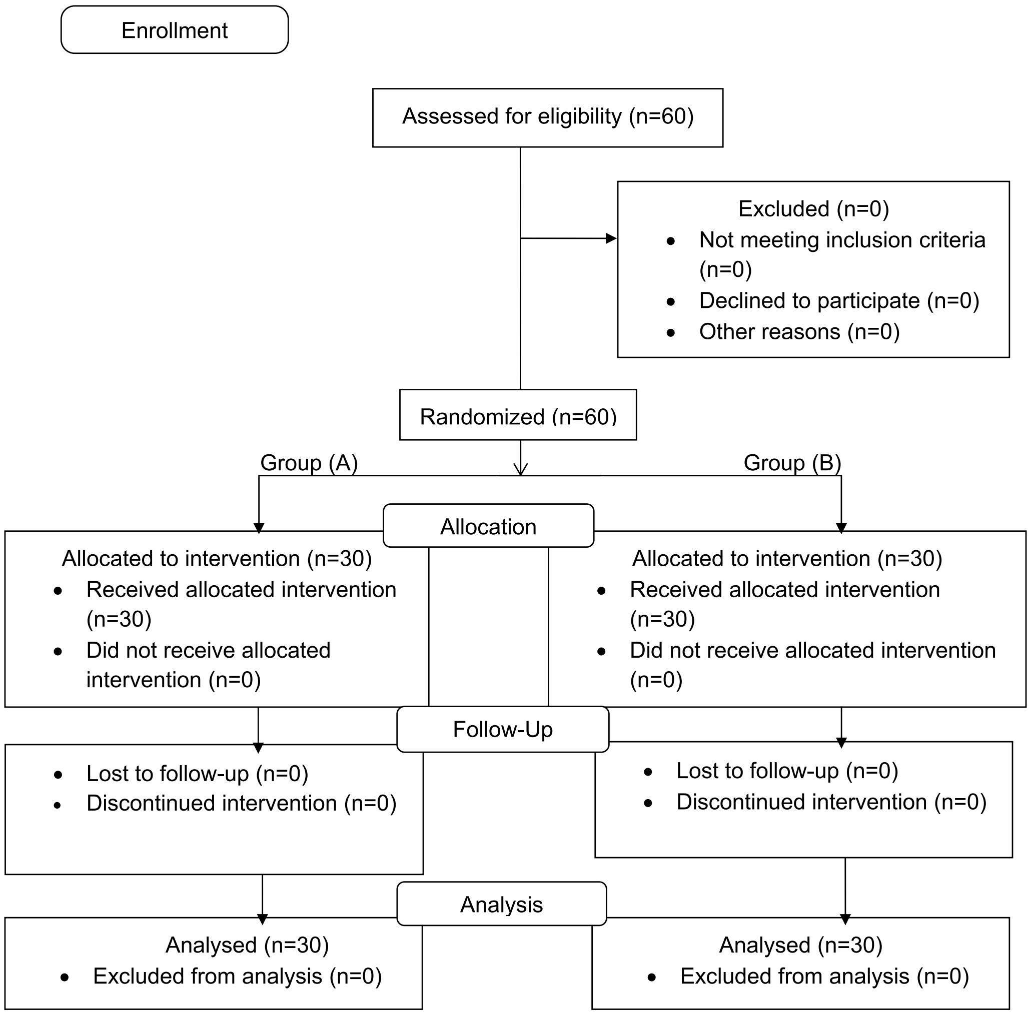

Fig. 1 CONSORT flow diagram showing the progress through the phases of a parallel randomized trial of the two groups, Group A: Mini-PCNL and Group B: Standard-PCNL

groups concerning quantitative variables in parametric data. Results were considered significant (S) with $P < 0.05$, highly significant (HS) with $P < 0.01$, and non-significant (NS) with $P \geq 0.05$.

3 Results

3.1 Demographic characteristics

In total, 60 patients were evenly divided into two groups of 30 patients each. The M-PCNL group comprised 16 females (53.3%) and 14 males (46.6%), with a mean age of 36.93 ± 8.58 years. The S-PCNL group included 10 females (33.3%) and 20 males (66.6%), with a mean age of 45.06 ± 10.65 years. A summary of the patients' characteristics is presented in Table 1.

3.2 Operation characteristics and outcomes

The operation time was longer for M-PCNL (133.73 ± 29.18 min) than for S-PCNL (48.6 ± 17.88 min), as stone fragmentation took longer ($p = 0.009$). In the M-PCNL group, stones had to be broken into smaller pieces for removal through the narrow nephrostomy tract. However, puncture and dilatation steps took the same time in both groups. The mean drop in hemoglobin levels was significantly ($p = 0.032$) lower in the M-PCNL group (0.14 ± 0.01 g/dL) compared to the S-PCNL group (0.82 ± 0.05 g/dL). Neither supracostal nor multiple accesses were performed in either group.

Auxiliary procedures were needed for 14 cases in Group B, including catheterization for more than three days and JJ insertion in 4 cases ($p = 0.040$). In Group A, postoperative leakage was observed in 4 patients who

Fig. 2 CT before M-PCNL shows right pelvic stone with size of 1 cm × 1.2 cm with HU = 1000

were conservatively managed with catheterization for two days (Grade I), whereas in Group B, leakage occurred in 26 cases, with 14 requiring ureteric catheterization for more than 72 h (4 days in 10 cases, five days in 2 cases, and six days in 2 cases), demonstrating a significant difference between the two groups ($p = 0.001$). For these 14 cases, catheterization was considered an auxiliary procedure. JJ insertion was performed in 4 cases from Group B (S-PCNL), but it was not needed in M-PCNL cases ($p = 0.040$).

Success rates (SFR %) differed significantly ($p = 0.040$) between the two groups, with 100% in the M-PCNL group and 86.7% in the S-PCNL group. In the S-PCNL group, 4 cases had residual stones and were later treated with ESWL (Grade III), with the DJ stent removed within two months after confirming no residual stones following ESWL.

3.3 Complications

Challenges were faced in M-PCNL due to the use of a ureteroscope instead of a miniperc scope. These included stone migration, limited movement of the ureteroscope due to its length, and sufficient but reduced irrigation compared to S-PCNL. A few complications occurred and were classified according to the Modified Clavien Score. These included intraoperative bleeding (Grade I) in 2 cases from Group B, which was controlled with a nephrostomy tube and JJ insertion; postoperative fever (Grade II) in 2 cases from Group A and 8 cases from Group B; intraoperative pelvic injury (Grade III) in 2 cases from Group B; and mild collection in 4 cases from Group A and 26 cases from Group B (Fig. 1).

3.4 Qualitative assessment

An example from Group A (M-PCNL) involved a patient with a history of double J insertion and three failed ESWL attempts. A CT scan revealed a right pelvic stone measuring 1 cm × 1.2 cm with an HU of 1000 (Fig. 2). The operation and instruments used are illustrated in Fig. 3. The operation lasted for 1 h and 40 min. The postoperative X-ray is shown in Fig. 4.

An example from Group B (S-PCNL) involved a patient whose CT scan showed a right pelvic stone measuring 1 cm × 1.5 cm with an HU of 1133 (Fig. 5). The S-PCNL operation is depicted in Fig. 6 and lasted for 40 min. The postoperative X-ray is shown in Fig. 7.

4 Discussion

The primary goal in treating renal calculi is to utilize a procedure that is highly safe, effective, and associated with fewer complications. Our study compared the outcomes and complications of Mini-PCNL (M-PCNL) and Standard-PCNL (S-PCNL) in managing patients with a single unilateral renal stone smaller than 3 cm and normal renal function tests.

Regarding operation time, we found a statistically significant increase in cases using M-PCNL compared to S-PCNL. These findings are consistent with some publications by [3, 13–15]. This significant difference in operation time resulted from the highly limited field of vision due to miniaturized endoscopes and the time required to fragmentize the stones into smaller pieces for easy removal through the small tract. On the other hand, some studies, such as [6, 11, 16, 17], reported no significant difference in operative time.

In our study, the clearance achieved in M-PCNL was 100%, while it was 86.7% in S-PCNL. These clearance results align with the trial conducted by Cheng et al. 2010, who reported that using a small-caliber ureteroscope facilitates access to different calyces, leading to increased clearance [13]. However, these results contradict Elsheemy et al.'s study, which concluded that clearance is higher in PCNL [7]. Some other authors, such as [10, 16–18], published that there was no difference between M-PCNL and S-PCNL regarding the stone-free rate. In contrast, Abdelhafez et al. 2016 revealed that the stone-free rate (SFR) significantly decreased for large-sized stones (≥ 2 cm) compared to smaller ones (76.3% vs. 90.8%) when M-PCNL was applied [15].

M-PCNL had a considerable advantage in terms of postoperative pain and hospital stay. Our study showed

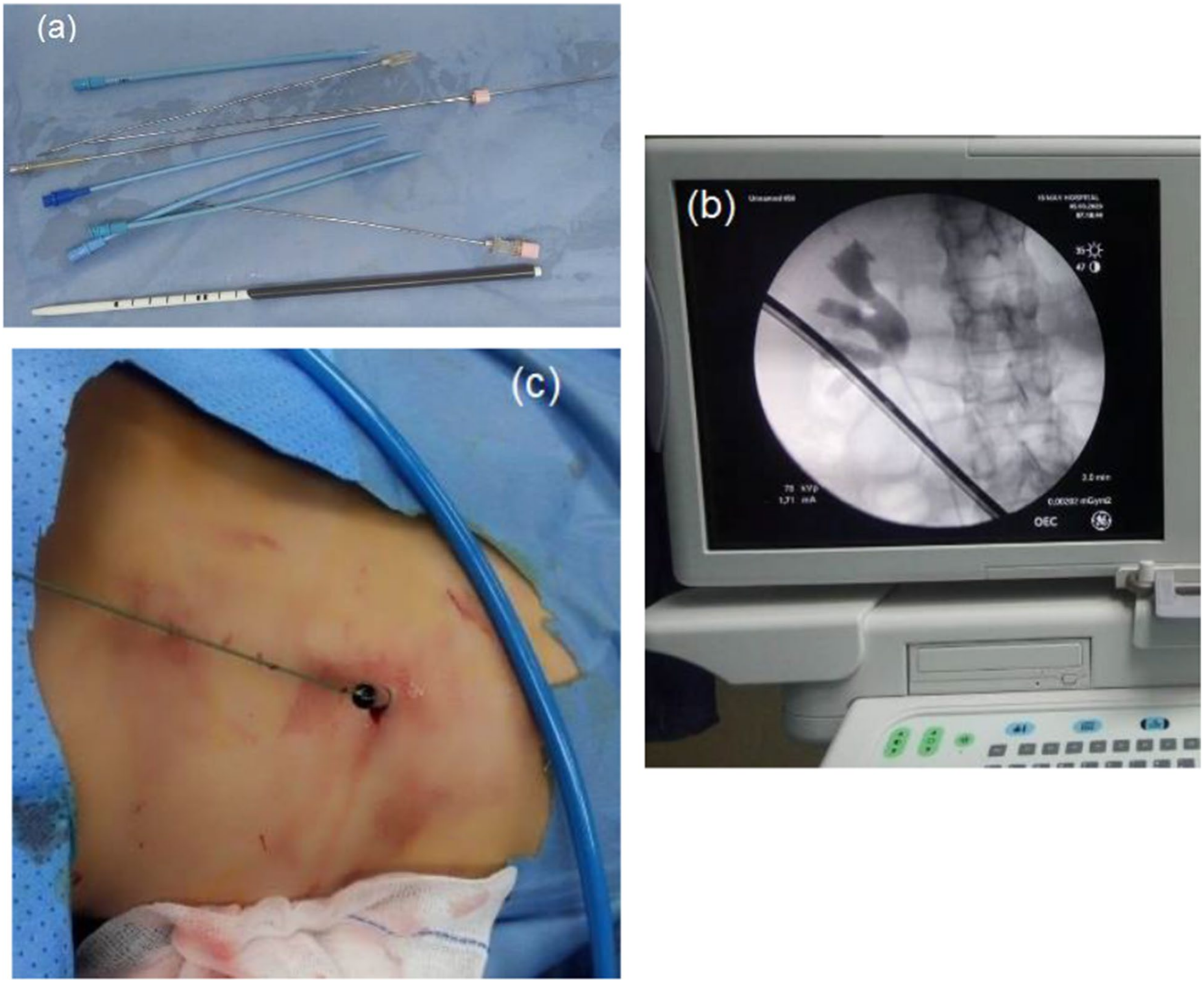

Fig. 3 M-PCNL operation and the instruments used: **a** Instruments (puncture needles, dilators and AmPlatz sheath). **b** Intraoperative retrograde pylography by ureteric catheter. **c** Insertion of AmPlatz sheath during M-PCNL operation

significantly shorter hospital stays and reduced postoperative pain in the M-PCNL group, similar to other studies by [7, 8, 16, 19]. Sakr et al. [6], Cheng et al. [13], and Li et al. [14] noted that hospital stay results showed no significant difference between M-PCNL and S-PCNL. Hospital stays were shortened in M-PCNL patients because it typically employs a tubeless approach, and patient comfort was improved post-M-PCNL [6].

There was a statistically significant difference in NSAID doses between our groups, as patients treated with M-PCNL used fewer NSAID vials than those in the S-PCNL group. This result aligns with Zeng et al. study, which found higher VAS scores and more patients needing analgesics in the S-PCNL group [8].

Hemorrhage is a significant risk of the S-PCNL procedure, resulting in the need for blood transfusion and increased susceptibility to renal damage. The development of M-PCNL emerged from the need to reduce morbidity (particularly bleeding) associated with the use of large nephroscope and their access tracts [13]. In our study, the hemoglobin drop was found to be lower after M-PCNL than after S-PCNL. This result is consistent with several studies, such as ElSheemy et al. 2019, Zeng et al. 2021, Cheng et al. 2010, and Zhu et al. 2015, which found bleeding and blood transfusion rates to be lower in the M-PCNL group [7, 8, 13, 18].

Our present study agreed with ElSheemy et al. 2019 in that there was a statistically significant difference in postoperative fever between cases using M-PCNL and S-PCNL, with 6.7% of cases using M-PCNL having postoperative fever, compared to 26.7% of S-PCNL cases [8]. This finding differs from [6, 20], who reported no significant difference regarding postoperative fever.

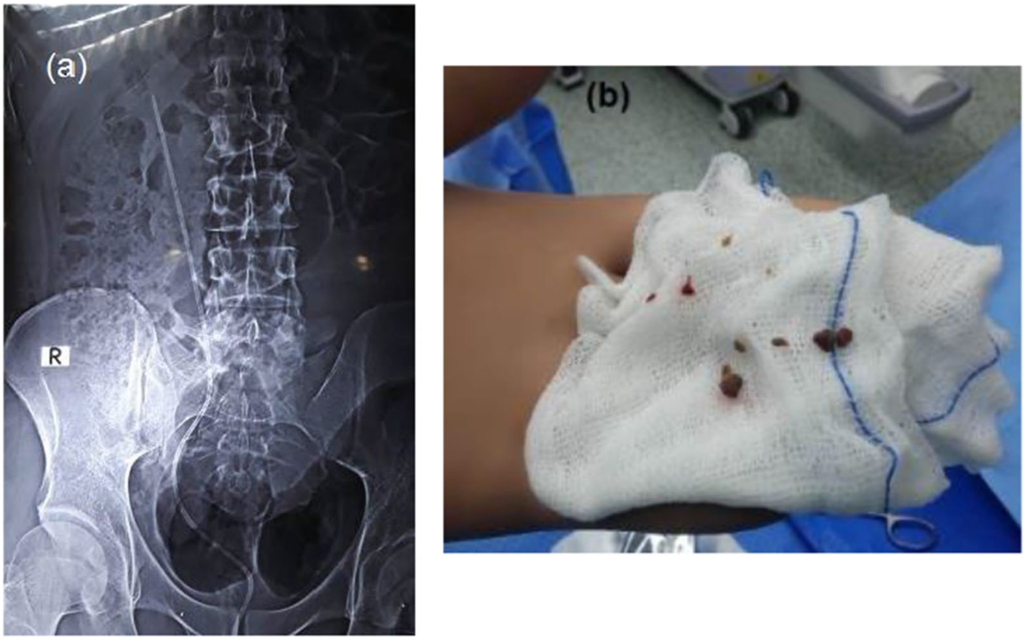

Fig. 4 Post-M-PCNL: **a** Postoperative X-ray showing no residual stones. **b** Extracted stone after its fragmentation to smaller size to fit the smaller sheath

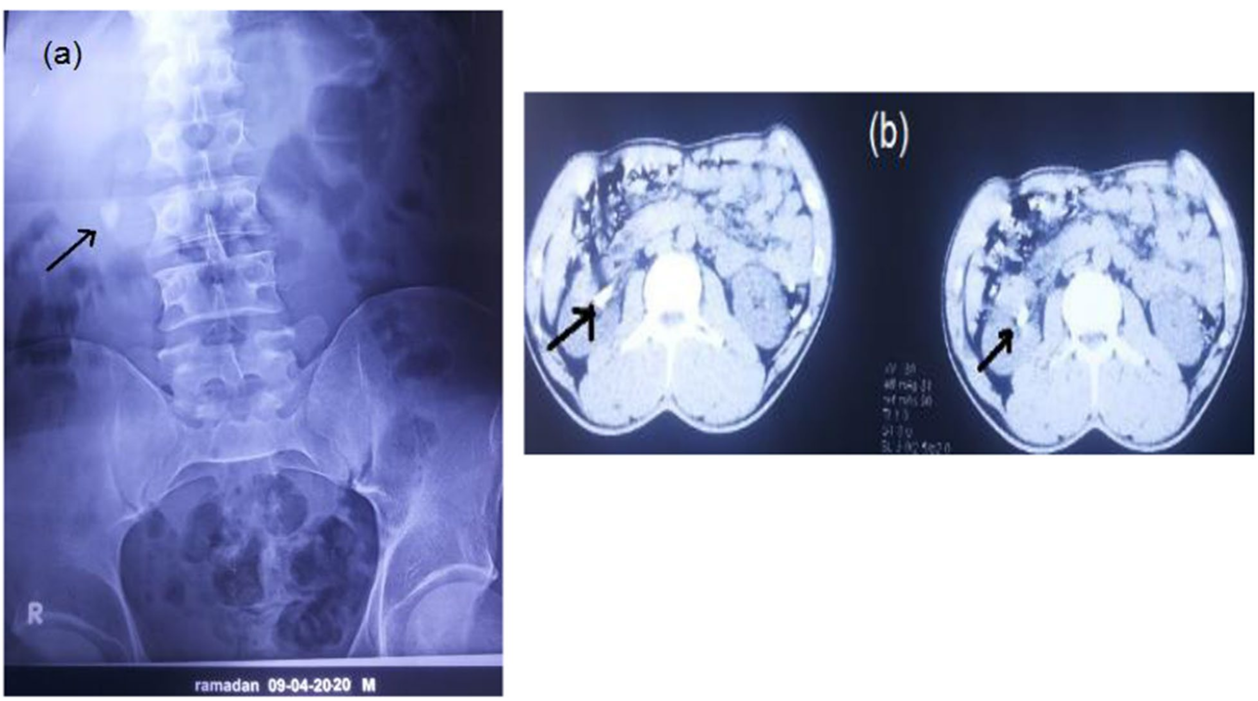

Fig. 5 Imaging before S-PCNL: **a** X-ray showing right pelvic stone **b** CT before S-PCNL shows right pelvic stone with size of 1 cm × 1.5 cm with HU = 1133

Fig. 6 Tract dilatation and the AmPlatz sheath is inserted during S-PCNL operation

Our study also demonstrated that S-PCNL was associated with higher leakage, in agreement with ElSheemy et al. 2019, Zhong et al. 2011, and Deng et al. 2020 studies [7, 21].

In conclusion, M-PCNL is effective for managing renal calculi, offering a longer operative time and a higher stone-free rate compared to S-PCNL. M-PCNL provides the advantage of greater safety and fewer complications, particularly for single renal pelvic stones smaller than 3 cm. This advantage is reflected in lower postoperative pain and shorter hospital stays. Another significant benefit of M-PCNL over S-PCNL is the ability to use a ureteroscope when a miniperc scope is unavailable. S-PCNL is associated with higher leakage and postoperative fever. Bleeding and hemoglobin drop rates are higher in S-PCNL than in M-PCNL. M-PCNL is partially limited by the need to break down stones into smaller fragments to fit through the small sheath, resulting in increased operation duration.

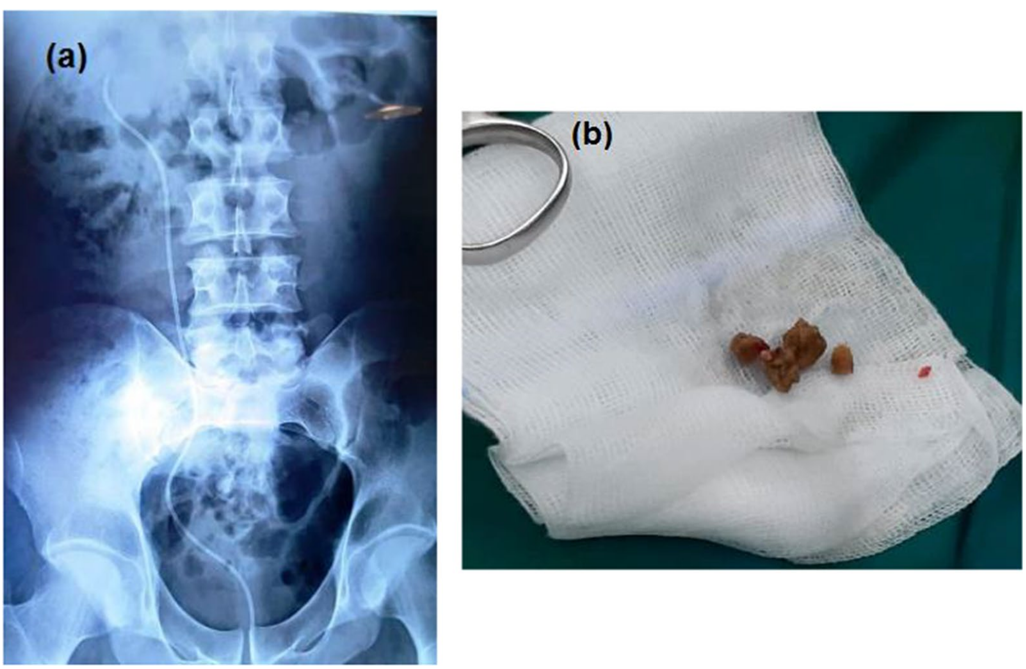

Fig. 7 Post S-PCNL: **a** KUB showing stone-free status after S-PCNL. **b** Extracted stone after its fragmentation; size of fragments is bigger than fragments extracted in M-PCNL so operation time is shorter in S-PCNL

Abbreviations

ESWL	Extracorporeal shockwave lithotripsy
KUB	Kidney–urinary bladder X-ray
(M)(S) PCNL	(Mini) (Standard) percutaneous nephrolithotomy

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Author contributions
HR and MZ and MH were involved in concept, design, supervision, processing, writing a manuscript, and critical analysis. TS was involved in supervision, processing, reviewing the manuscript, and worked on critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
License to do this study was given by the research ethics committee (REC) for Human Subject Research at the Faculty of Medicine, Helwan University, Cairo, Egypt, with approval No. 10/2019 (R). All patients who participated in this investigation signed the consent letter after they had read it.

Consent for publication
This study was a prospective randomized comparative study, so the consent is not applicable.

Competing interests
The authors declare that they have no competing interests in this section.

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References

1. Li M, Zheng H, Zang Z et al (2018) Minimally invasive percutaneous nephrolithotomy compared with retrograde intrarenal surgery: a meta-analysis. Biomed Res 29(8):1558–1566
2. Ganpule AP, Bhattu AS, Desai M (2015) PCNL in the twenty-first century: role of Microperc, Miniperc, and Ultraminiperc. World J Urol 33(2):235–240
3. Jiang H, Yu Z, Chen L et al (2017) Minimally invasive percutaneous nephrolithotomy versus retrograde intrarenal surgery for upper urinary stones: a systematic review and meta-analysis. Biomed Res Int. https://doi.org/10.1155/2017/203585
4. Han H, Segal AM, Seifter JL, Dwyer JT (2015) Nutritional Management of Kidney Stones (Nephrolithiasis). Clinical Nutrition Research 4(3):137–152
5. Ferakis N, Stavropoulos M (2015) Mini percutaneous nephrolithotomy in the treatment of renal and upper ureteral stones: Lessons learned from a review of the literature. Urology Annals 7(2):141–148
6. Sakr A, Salem E, Kamel M et al (2017) Minimally invasive percutaneous nephrolithotomy vs standard PCNL for management of renal stones in the flank-free modified supine position: a single-center experience. Urolithiasis 45(6):585–589
7. Elsheemy MS, Elmarakbi A, Hytham M et al (2019) Mini vs. standard percutaneous nephrolithotomy for renal stones: a comparative study. Urolithiasis 47(2):207–214
8. Zeng G, Cai C, Duan X et al (2021) Mini percutaneous nephrolithotomy is a noninferior modality to standard percutaneous nephrolithotomy for the management of 20–40 mm renal calculi: a multicenter randomized controlled trial. Eur Urol 79(1):114–121
9. Jackman SV, Hedican SP, Peters CA et al (1998) Percutaneous nephrolithotomy in infants and pre-school age children: experience with a new technique. Urology 52(4):697–701
10. Güler A, Erbin A, Ucpinar B et al (2019) Comparison of miniaturized percutaneous nephrolithotomy and standard percutaneous nephrolithotomy for the treatment of large kidney stones: a randomized prospective study. Urolithiasis 47(3):289–295
11. Xu S, Shi H, Zhu J, Wang Y, Cao Y et al (2014) A prospective comparative study of hemodynamic, electrolyte, and metabolic changes during percutaneous nephrolithotomy and minimally invasive percutaneous nephrolithotomy. World J Urol 32(5):1275–1280
12. Kokurewicz T, Ogórek R, Pusz W et al (2016) Bats increase the number of cultivable airborne fungi in the "Nietoperek" bat reserve in western Poland. Microb Ecol 72(1):36–48
13. Cheng F, Yu W, Zhang X, Yang S, Xia Y, Ruan Y (2010) Minimally invasive tract in percutaneous nephrolithotomy for renal stones. J Endourol 24(10):1579–1582
14. Li LY, Gao X, Yang M, Li JF, Zhang HB et al (2010) Does a smaller tract in percutaneous nephrolithotomy contribute to less invasiveness? A prospective comparative study. Urology 75(1):56–61
15. Abdelhafez MF, Wendt-Nordahl G, Kruck S et al (2016) Minimally invasive versus conventional large-bore percutaneous nephrolithotomy in the treatment of large-sized renal calculi: Surgeon's preference? Scand J Urol 50(3):212–215
16. Knoll T, Wezel F, Michel MS, Honeck P, Wendt-Nordahl G (2010) Do patients benefit from miniaturized tubeless percutaneous nephrolithotomy? A comparative prospective study. J Endourol 24(7):1075–1079
17. Song L, Chen Z, Liu T et al (2011) The application of a patented system to minimally invasive percutaneous nephrolithotomy. J Endourol 25(8):1281–1286
18. Zhu W, Liu Y, Liu L et al (2015) Minimally invasive versus standard percutaneous nephrolithotomy: a meta-analysis. Urolithiasis 43(6):563–570
19. Mishra S, Sharma R, Garg C, Kurien A, Sabnis R et al (2011) Prospective comparative study of M-PCNL and S-PCNL for treatment of 1 to 2 cm size renal stone. BJU Int 108(6):896–900
20. Zhong W, Zeng G, Wu W, Chen W, Wu K (2011) Minimally invasive percutaneous nephrolithotomy with multiple mini tracts in a single session in treating staghorn calculi. Urol Res 39(2):117–122
21. Deng J, Li J, Wang L, et al (2020) Standard versus mini-percutaneous nephrolithotomy for renal stones: a meta-analysis. Scand J Surg

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