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Original article

Is multiple tracts percutaneous nephrolithotomy (PCNL) safe modality in management of complex renal stones? A prospective study: Single center experience☆

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Abstract
Objectives : To evaluate and analyze the efficacy and the safety of multiple tracts PCNL in management of complex renal calculi.
Patients and Methods : The study was conducted during the period between March 2016 till January 2017 on 265 patients with complex renal stones, all patients underwent multiple tracts PCNL, either with double or triple punctures, preoperative and postoperative laboratory and radiological results were compared together in correlation to the stone size, shape and site.
Results : The results of our study have shown that increased size and complexity of stones is associated with increased number of punctures needed to achieve stone clearance, and the aggressive approach to complex renal calculi using multiple tracts PCNL is a safe and effective modality in management of complex renal calculi with acceptable complications.

☆ We participate in this research as we aim to evaluate the safety and the efficacy of multiple tracts PCNL in management of complex renal calculi.
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Conclusion: Number of percutaneous tracts needed for stone clearance was increased with the increase in stone size and complexity. Surgeon experience, accurate choosing puncture site and carefully performed multiple tracts will decrease the intra-operative and postoperative complications or transfusion requirements.

Introduction

Renal stones are one of the most common urinary tract disorders [1]. Management of such stones depends on many factors like stone size, site, complexity and patient's factors [2].

In complex renal stones, PCNL is a safe and efficient tool in the armamentarium of renal stone management with a relatively low incidence of significant complications. Compared to open surgery, PCNL has the advantages of having a high rate of stone clearance and being cost-effective. Additionally, it leads to early convalescence. PCNL is also superior to ESWL, which requires a prolonged period of time to achieve and reach a stone-free state, in addition to ureteric stenting in sizable stones [3].

Percutaneous nephrolithotomy (PCNL) is the treatment of choice for large complex renal stone and staghorn calculi [4].

In complex and staghorn stones with multiple calyceal involvement, access to all the calices is difficult through one percutaneous tract, in which case multiple-access PCNL is the mainstay of treatment to achieve better stone clearance and reduce the need for secondary ESWL. However, multiple-tract procedures have been associated with increased bleeding and transfusion rates [5]. Others have reported that monotherapy with PCNL, utilizing multiple percutaneous tracts, is highly effective in the treatment of staghorn and other large-volume renal calculi with comparable complication rates to single percutaneous tract for more straightforward calculi [6].

In this study, the primary end point was to evaluate the effectiveness of multiple puncture PCNL in complex renal stone. The secondary end point was to investigate the safety and complication rate of this approach.

Patients and methods

Between March 2015 and January 2017, 320 patients were presented to the urology department at Ain Shams University Hospital with renal stone. Of those, 271 patients were included in the study based on the following inclusion and exclusion criteria:

Inclusion criteria were:
- Adult patient above 18 years old
- Partial or complete stag horn stone
- Multiple renal stone more than one calyx

The exclusion criteria were:
- Children under the age of 18
- Radiolucent stone
- Co-existing renal anomalies
- Uncorrectable bleeding disorders
- Patients with febrile urinary tract infection
- Patients with a single functioning kidney
- Musculoskeletal deformities
- Patients with ureteral stones or ureteral obstructions

Approval of our university's ethical committee was granted before commencing our study and a written informed consent was obtained from all patients. Preoperative assessment included clinical evaluation, laboratory investigations in the form of complete blood count, urine analysis and culture, renal function tests and coagulation profile, and radiological studies such as plain x-ray PUT, abdominal ultrasonography and non-enhanced spiral CT scan.

Operative details

All procedures were conducted under general anesthesia. Cystoscopy was performed and a ureteric catheter was placed, through which retrograde pyelography was performed to plan the entry route for the percutaneous access. Considering stone location and burden was crucial in choosing the optimal sites for punctures. The patient was afterwards repositioned in prone position.

An 18-gauge puncture needle was advanced into the selected calyx guided with the C-arm in the vertical position. The puncture sites were made through the posterior axillary line, with an angle of 45–50° with the horizontal plane directed to the targeted calyx.

Once the puncture was established, a J-tipped guide wire was then introduced through the collecting system and secured. Subsequent punctures were made in the same way. The main tract was the one through which maximal stone burden could be removed. Initially, an Alkan rod was inserted over the guide wire under fluoroscopic guidance then dilatation of prospective main tract was completed. Usually two types of dilators were used, the facial and the Amplatz dilators. Subsequently larger dilators were inserted serially over the Alkan rod and guide wire, then the working sheath was introduced over the largest Amplatz dilator. Before inserting the nephroscope, therenal pelvis was flushed with irrigation through the ureteric catheter to wash out any blood clots.

Nephroscopy was completed using the rigid nephroscope through the 30 Fr Amplatz sheath. The Pneumatic Swiss lithoclast® was used for stone fragmentation. After removing the main bulk of stones, the working sheath was removed and the additional tract was dilated in the same manner through its guide wire. After finishing the procedure, a single nephrostomy tube (usually a Nelaton 20 Fr) was fixed through the tract in line with the renal pelvis. Double J stent was placed in patients with residual stones. All procedures were performed under guidance of a portable C-arm fluoroscopy.

Post-operative care and follow up

The nephrostomy tube was clamped for the first 24 h for tamponade, and was removed on third postoperative day. Ureteric catheter was removed on the second day if there were no clinically significant residual stones. Vital data and urine output were observed. Hemoglobin (HB) and serum creatinine were checked within 24 h of the procedure. Plain urinary tract X-ray (PUT) was taken on the second postoperative day to check the position of tubes and residual stones. Also on the second postoperative day, visual analogue scale for pain (VAS) was used to evaluate pain severity.

Asymptomatic residual fragments smaller than 5 mm were designated as clinically insignificant residual fragments (CIRF)

Two weeks after surgery, hemoglobin level, urine analysis and urine culture, serum creatinine, abdominal ultrasound and KUB were performed. Urosepsis is a urinary tract infection combined with systemic inflammatory response syndrome (SIRS). SIRS is considered when patients have more than one of the following findings: heart rate higher than 90 beats/min, body temperature above 38 °C or less than 36 °C, respiratory rate more than 20 breaths/min or $PaCO_2$ less than 32 mmHg, and a white blood cell count more than 12,000 cells/mm or less than 4000 cells/mm [8]. Residual stone size of more than 4 mm was considered significant.

Patient's data, stone size (measured by the sum of diameters on NCSCT) intra-operative and postoperative details, including complications and outcomes were recorded. Accordingly, data was analyzed using Statistical Program for Social Science (SPSS) version 18.0. Quantitative data were expressed as mean ± standard deviation (SD). Qualitative data were expressed as frequency and percentage. Paired sample *t*-test was used when comparing related samples, and Chi-square (χ^2) test of significance was used in order to compare proportions between two qualitative parameters. P-Value <0.05 was considered significant, P-value <0.001 was considered highly significant, and P-value >0.05 was considered insignificant.

Results

Two hundred and seventy-one patients were enrolled in this study of which 6 were lost to follow up. Hence, the of the study was composed of 265 patients, 189 of them (71.3%) men and 76 (28.7%) women. Mean age was 39.77 ± 13.54 (range 18–67) (Table 1).

Table 1 Patients' gender, stone shape and number of punctures.

	N	%
Sex		
Male	189	71.3
Female	76	28.7
Shape		
Complete stag	17	6.4
Partial stag	73	27.5
Non stag	175	66.0
Number of punctures		
2	218	82.3
3	47	17.7

Total number of stones in all patients was 717. Ninety-three patients (35.1%) had single branched renal stone; 21 patients had 2 stones (7.9%); 54 patients had 3 stones (20.4%); and 97 patients had >3 stones (36.6%), and the mean stone size was (42.49 ± 12.56) ranging from 23 to 74 mm.

Two hundred and eighteen patients underwent PCNL with 2 punctures whereby the mean size of stones was 38.16 ± 8.15 mm, and 47 patients underwent PCNL with 3 punctures where the mean stone size of the stones was 63.67 ± 7.73 mm, with P-value <0.001 indicating highly significant statistical difference. We found that increase in stone size is associated with increased number of accesses needed for stone clearance; however, increased number of stones was not associated with increased number of punctures to achieve stone clearance (Table 2).

Table 2 The relation between stone size and number of stones to achieve stone clearance.

	Number of punctures			
	2	3	*t*-Test	
	Mean ± SD	Mean ± SD	t	P-Value
Total size (cm)	38.16 ± 8.08	63.67 ± 7.37	19.577	<0.001**
number of stones	2.52 ± 1.38	3.67 ± 1.85	4.771	<0.064

** Highly significant.

On the other hand, we found that there is a statistically significant difference in the number of access needed to clear stones according to its shape, whereby complete staghorn stones needed more accesses to complete clearance than partial stag and non-staghorn stones (Table 3).

Stone clearance was achieved in 254 patients (95.8%). Eleven patients (4.2%) had residual stones, of which 9 (3.4%) were clinically significant; 3 patients (1.1%) passed stones spontaneously within 2 weeks; and 6 (2.3%) needed a single session of ESWL.

Pain severity was assessed by a visual analogue scale for pain on the second postoperative day, since a number of patients were uneducated, with a score 1–3 for mild pain, 4–6 for moderate pain, and 7–10 for severe pain. We found that the higher the number of accesses the more the pain; yet only 2 patients reported having severe pain, (Table 4).

Preoperative mean Hemoglobin (Hb) was 13.59 ± 2.08, ranging between 10.5 and 16 gm/dl while preoperative Serum creatinine was between 0.6 and 3.2 mg/dl with mean 1.09 ± 0.48 mg/dl. Although 24 h post-operativly Hb was between 9 and 15 gm/dl with mean 12.58 ± 2.19 gm/dl, within the two postoperative weeks, Hb was between 10–15.5 gm/dl with mean 13.21 ± 1.99 gm/dl. As for Serum creatinine, it ranged between 0.8–3.3 mg/dl with mean 1.14 ± 0.45 mg/dl within the first 24 h and after two weeks, it had a range of 0.6–2.3 with mean of 0.95 ± 0.53.

There was high statistically significant difference in hemoglobin levels preoperatively and 24 h postoperatively, P value <0.001. Nev-

Table 3 The relation between stone shape and no. of accesses needed to achieve stone clearance.

	number of punctures							
	2		3		Total		Chi-square	
	N	%	N	%	N	%	X^2	P-Value
Shape								
Complete stag			17	36.2	17	6.4		
Partial stag	73	33.2			73	27.5	88.677	<0.001**
Non stag	145	65.9	30	63.8	175	66.0		

** Highly significant.

Table 4 post-operative pain severity assessment using VAS (visual analogue scale for pain).

	Number of punctures							
	2		3		Total		Chi-square	
	N	%	N	%	N	%	X^2	P-Value
Pain								
Mild	201	92.2	16	34.0	217	81.9		
Moderate	17	7.8	29	61.7	46	17.4	94.919	<0.001**
Severe	0	0	2	4.3	2	0.8		

** Highly significant.

Table 5 difference between preoperative and postoperative Hb and serum creatinine level (24 h and 2 weeks postoperatively).

Hemoglobin level (gm/dL)	Range	Mean ± SD	Paired *t*-test	
			t	P-Value
Pre	10.5–16	13.59 ± 2.08		
24 post	9–15	12.58 ± 2.19	37.936	<0.001**
2 w post	10–15.5	13.21 ± 1.99	14.580	<0.071
Serum creatinine (mg/dL)				
Pre	0.6–3.2	1.09 ± 0.48		
24 post	0.8–3.3	1.14 ± 0.45	0.469	0.639
2 w post	0.6–2.3	0.95 ± 0.53	7.568	<0.001**

** Highly significant difference.

ertheless, only 4 (1.5%) patients needed blood transfusion (Clavien grade II) where hemoglobin drop more than 2 gm/DL in first 24 h post operative, 3 of whom underwent triple-puncture procedures and only one a double-puncture procedure. There was an insignificant difference in hemoglobin levels preoperatively and 2 weeks postoperatively (P value <0.071), and the same with preoperative and 24 h postoperative Serum creatinine, although the difference between levels in preoperative and 2 weeks postoperatively was highly significant at P value <0.001; this can be attributed to an improvement in serum creatinine postoperatively in patients with preoperative elevated Serum creatinine (Table 5).

Seventeen patients developed perforation to the collecting system during manipulation of the stone and were treated by DJ application and by leaving the nephrostomy tube in for a longer time; nephrostogram was completed before remove the nephrostomy tube (Clavien grade IIIb).

In our study, 9 patients (3.39%) suffered from high-grade fever (Clavien grade II), and were treated with supportive therapy and broad-spectrum antibiotic. Only 2 cases were admitted to ICU for non-surgical causes such as asthma and ischemic heart disease (Clavien grade IV).

Discussion

Percutaneous nephrolithotomy is an integral component of the management of most complex renal stones [7].

PCNL is associated with significant morbidity such as sepsis, bleeding, and injury to surrounding viscera [8]. In an effort to reduce morbidity related to PNL a PNL performed with smaller caliber instruments was developed and named mini PNL (miniperc). This procedure is performed through a 13 Fr Amplatz sheath, which could reduce the renal trauma and associated bleeding. It requires the use of a small nephroscope or a rigid or flexible URS and holmium laser fibres [9]. the mini-PCNL technique bought advantages such reduced pain, hemorrhage and sepsis, and a shorter hospital stay and made it into an attractive option, although this is somewhat overshadowed by the longer operative time [10,11].

This less-invasive type of PNL seems to be a reasonable option for patients who prefer a percutaneous approach for small- to mediumsized stones. Also, it can replace standard PNL for the treatment of large kidney stones, as well as, complete staghorn stones [12].

Traditionally, PNL has been performed in the prone position. Prone PNL appears to have several advantages; it has less visceral injury, provides a large surface area for the puncture site, has feasible multiple accesses and a wide space for instrument manipulation [13]. However, this approach has some disadvantages: it compromises blood circulation and ventilation especially in obese patients, prolongs the duration of the procedure, and if the procedure is carried out under spinal or epidural anesthesia, conversion to general anesthesia is made difficult. Additionally, sometimes it is impossible for the patient to lie in a prone position because of body habitus in conditions such as ankylosing spondylitis, severe lordosis, or kyphosis. Lastly, prone position makes the patient more vulnerable to radiation exposure [14].

Furthermore, for patients who cannot tolerate the prone position, the supine position can be used. which offers a wide variety of advantages, including allowing more rapid access to the airway and simultaneous ureteroscopic access [15]. It is also less straining for the patient and takes less time, is more comfortable for both patient and surgeon, reduces x-ray exposure as well aslow pressure in the renal pelivs, reducing the risk of fluid absorption and facilitating spontaenous stone fragment evacuation [13]. Also, it minimizes the possibility of a stone fragment migrating into the ureter during calculus fragmentation [16]. On the other hand, supine PNL means that the pelvicalyceal system is constantly collapsing, the surgical field is relatively small, challenging upper-pole calyceal puncture, and can be only applied to a limit in staghorn calculi and requires specific training. Another drawback is that the kidneys are easy to move anteromedially during tract dilation [17].

De la Rosette et al. reported in 2005 that for obese patients and staghorn calculi, prone PNL appears to be associated with decreased operative times with similar bleeding rates and slightly better stone-free rates than supine PNL [13].

Various safe and effective modifications of patient positioning for PNL have been proposed; one of these position is Galdakao-modified supine Valdivia (GMSV). The main advantage of this position is that it allows for the use of simultaneous retrograde and percutaneous access to the urinary tract while preserving all surgical and anaesthesiological advantages of supine position [15].

Recently, Retrograde Intrarenal Surgery (RIRS) has been a practical treatment for such large and complex kidney stones because RIRS has a minimal blood transfusion risk, short hospitalization and few restrictions on daily routines. However, as the stone size becomes larger, the stone-free rate decreases, and the number of operations required increases [18]. Moreover, the small working channels of flexible ureteroscopes has limited the usefulness of adjunctive instrumentation that allows concurrent stone fragmentation and removal. Hence, the ureteroscopic management of a large stone burden often requires prolonged surgery, combined with ESWL or multiple sessions of treatment and often results in less than satisfactory stone-free rates [19].

Despite retrograde irrigation, stone fragments often fail to clear completely after intracorporeal lithotripsy with RIRS. Residual stones may grow, become symptomatic and require further intervention. Alternatively, PNL combined with retrograde RIRS offers a large bore access that can allow efficient removal of these remaining fragments [20]. Undre et al. advice using flexible ureteroscopy and nephroscopy as an adjuvant procedure to decrease the number of tracts. The authors state that this option effectively decreases the disadvantages of multiple tracts, complications, without compromising stone-free rates [21].

Because of the anatomical variation of calyces, full access to the entire intrarenal collecting system through one access tract can be technically challenging, even when a combination of rigid and flexible instruments is used through one tract. Thus, these complex renal calculi, which can extend into multiple calyces or have peripheral satellite calculi, often require several access tracts during PNL [20].

Percutaneous nephrolithotomy is an integral component of the management of the most complex renal stones; nowadays, use of percutaneous monotherapy using multiple tracts is the preferred treatment option for most complex calculi [7].

With regards to the first end point, the success of the treatment was indicated by the high stone free rate. The stone free rate was achieved in 254 patients (95.8%), with 6 (2.3%) patients only needing a single session of ESWL. This result is comparable to those of Hegarty and Desai, who studied the outcome of multiple tracts PCNL and reported that complete clearance was achieved in 95% of patients and that the mean drop in hemoglobin was similar to single tract PCNL. They concluded that PCNL utilizing multiple percutaneous tracts was very effective in treatment of complex renal calculi scrapping the need for ancillary procedures [6]. Singla et al. reported that multiple tract PCNL was associated with a stone clearance rate of 74%–83%, and an ancillary procedure rate of 18% and that the stone-free rate is still clearly superior to ESWL, combination therapy, and open surgery [22]. Also, Ibrahima et al. reported an overall success rates of 57.1%, which increased at the end of three-month follow-up period to 81.5% [23].

Several factors may have attributed to the lower perioperative complication rate, which in our study was 12% compared to the reported rates of 21.5% and 28.6% [13,23]. They are that we did not report urine leak as a complication except if it persisted for 14 days, that supracostal access was not utilized, the appropriate choice and positioning of the puncture into the desired calyx under fluoroscopic guidance, and the performance of the procedure by a well-trained surgeon.

Bleeding is the most common reported major complication of PCNL. In our study, there was a significant decrease in the postoperative hemoglobin, which is comparable to results of Ibrahima et al. and Falahatkar et al. [23,24].

The need for transfusion correlated with lower preoperative hemoglobin and higher preoperative serum creatinine [6]. With refinement of techniques and equipment, the overall transfusion rate for PNL fell significantly from 6.9% in early series, to less than 2% [25]. This is comparable to our study where 4 patients (1.5%) required blood transfusion which is low in comparison with Desai et al., where transfusion rate was 12.4% [6]. and Singla et al., where 46 patients of 149 (30.8%) required blood transfusion [22]. On the other hand, Osman et al. reported no need for blood transfusion [26].

In this study, only 9 patients (3.39%) suffered from high grade fever; this rate is comparable to the study reported by Singla et al., where the rate of urosepsis was 5.3% and to Lojanapiwat's study where the rate of urosepsis was between 0.3–9.3% [22,27]. On the other hand, Srivastava et al. reported a high rate of urosepsis and hematuria [28].

Colonic injury after PCNL is a rare complication; in our study, no colonic injury was reported, a rate comparable to Elghoneimy et al., who in 2016 reported colonic injury following PCNL in three patients (0.14%), all of whom were managed conservatively [29]. Also, Ibrahima A et al. reported a low rate of colonic injury, only in 5 patients—3 were managed conservely, one needed colostomy, and one died from sepsis [23].

The nephrostomy tube is a probable cause of postoperative pain. To reduce this tube- related complication, modifications have been described such as the use of a smaller nephrostomy tube as in mini-PNL or tubeless PNL [30,31]. One of advantages in tubeless PNL is reduced postoperative discomfort and pain from the tube and reduced requirement of analgesics [31]. Levels of pain recorded, analgesic requirements, duration of inpatient stay and convalescence time were all significantly reduced in the tubeless PCNL group [32]. Cho et al. reported that the postoperative pain in all patients who underwent multiple punctures procedure and this could be attributed to nephrostomy tubes [7]. These is reverse to our study, where postoperative pain increased proportionately with increased number of punctures table.

There was significant improvement in 2 weeks postoperative serum creatinine levels of our patients who were presented preoperatively with elevated serum creatinine levels, this could be explained by the obstructive nature of stones in our study, despite prior reports showing that there was a significant rise in serum creatinine and a drop in creatinine clearance in cases of multiple tracts PCNL for patients who are known cases of renal insufficiency [6].

The number of accesses needed to achieve a stone-free state in our study increased with an increase in stone burden. It furthermore increased in complete stag horn stones rather than partial stag and non-stag stones. On the other hand, increased number of stones was not associated with increased number of punctures. This can be explained by the fact that multiple stones are not all large in size in many instances and flushing of renal system from Amplatz sheath actually washes out many small stones during the procedure.

When planning to perform multiple tracts, the anatomy of the collecting system, namely the angle, length and width of infundibulum should be considered. In addition, stone burden, complexity and the number of stones are all crucial factors in determining and planning the number of punctures needed.

We encountered several limitations in our study, including the use of KUB and ultrasound to determine the SFR, a **lack of stone types**, short follow-ups and a lack of comparative group.

Conclusion

Multiple punctures to clear complex renal stones is a valid approach. This method decreases the need for auxiliary procedures, and at the same time is considered to be safe and efficient, with an acceptable rate of complications. Multiple tracts PCNL is safe and effective in achieving a great stone clearance rate with non-significant blood loss and a minimal need for blood transfusion.

Conflict of interests

The authors declare that they have no conflict of interest.

Authors' contributions

Hossam Elawady: Project development, Data management.

Diaa Eldin Mostafa: Project development, Data management.

Mahmoud Ahmed Mahmoud: Project development, Data management.

Mohamed Abuelnaga: Project development, Data management.

Ahmed Tawfick: Project development, Data management.

Ahmed Farouk: Project development, Data management.

Tarek Elzayat: Project development, Data management.

Abdallah Ahmed: Senior Author, the supervisor of the research team.

Consent from the patient

Informed consent was obtained from all individual participants included in the study.

Ethical consideration

All procedures were in accordance with the ethical standards of the our institution and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the local ethical committee of the hospital.

Ethical committee approval

The study was approved by the local ethical committee of Ain Shams University Hospital.

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