Original Article

Prone versus prone-flexed position in percutaneous nephrolithotomy: A randomized controlled trial

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Abstract

Background: The aim of this study intends to assess prone and flexed prone positions for percutaneous nephrolithotomy (PNL) for safety and efficacy.

Methods: From May 2017 to August 2022, a stratified randomized approach was carried out to randomly assign 346 PNL candidates into prone or flexed prone groups. Perioperative data, such as stone-free rate, stay length, operative time, and complication rates, were studied.

Results: In the prone and flexed prone groups, the mean ages of 51.7 ± 12.2 and 49.4 ± 11.9 min, respectively ($P = 0.1$). The mean body mass indexes of 24.2 ± 13.4 and 29.9 ± 11.9, respectively ($P = 0.03$). The pyelocaliceal perforation occurred in 15 (8%) and 11 (6.4%) participants, respectively. In the prone and flexed prone postures, postoperative bleeding occurred in 15 (7.9%) and 9 (5.4%) patients, respectively ($P = 1.0$). The average percentage decrease in hemoglobin concentration was 1.29 ± 0.42 and 1.21 ± 0.32, respectively ($P < 0.000$). The success rates were 92 and 93.6%, respectively ($P = 0.6$). The average access length was 3.9 ± 1.2 and 4.8 ± 1.8 min ($P = 0.08$), whereas the average operation duration was 68.7 ± 37.4 and 50.4 ± 21.9 min ($P = 0.04$).

Conclusion: Both the prone and prone-flexed positions are equally safe for PNL. The flexed prone position is more likely to be beneficial for obese patients. The prone-flexed position enabled a somewhat shorter average operation time. The pelvicalyceal system could be more readily reached when the prone position was flexed.

Keywords: Percutaneous nephrolithotomy, prone-flexed position, prone position

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INTRODUCTION

The most effective strategy of action for severe and complicated urolithiasis is percutaneous nephrolithotomy (PNL).[1] Fernström and Johansson disclosed the prone PNL[2] since 1976. Supine PNL was defined for the first time by Valdivia Uría *et al*.[3]

In PNL Global Study,[4] Along with having higher rates of fever (11.1% vs. 7.6%), receiving blood transfusions (6.1% vs. 4.3% supine), and shorter surgical times (82.7 vs. 90.1 min), the prone group accomplished superior than the supine group overall (77%). PNL in the supine position has been attributed to a lower success rate and an increased risk of bleeding in patients with anterior calyceal stones given that the tract does not cross the Brodel's avascular line, and the side of the bed hinders the nephroscope from being deflected laterally in the direction of the anterior calyx.[5]

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Compression of the abdominal wall while the patient is in the prone position is common during prolonged surgeries, especially in morbidly obese patients. This can lead to engorgement of the vertebral and epidural veins, a significant reduction in vena cava flow, and ultimately, pose a risk to spinal cord perfusion.[6] Likewise in circumstances requiring immediate relocation – like a cardiac arrest – a patient cannot be safely relocated while supine.[7] Furthermore, tracheal tube displacement, higher intraocular pressure, and a greater likelihood of cervical spine damage are all linked with the prone posture.[8,9]

A straightforward adjustment that improves mobility and access to the upper pole during lower pole PNL is flexed prone positioning. Supine orientation was deemed more dangerous than prone or flexed prone position due to the liver and spleens more medially positioned anatomy during upper pole punctures. The colon was more medially positioned for lower pole punctures in the prone and prone-flexed positions than in the supine position. The left kidney was always lower than the right kidney in 92.3% of cases when the patient was flexed prone. Relative to the 12th and 11th ribs, the posterior iliac crest moved 2.9 and 3.0 cm in the prone-flexed modification, respectively. Upper pole access above the 11th rib would have been changed to one above the 12th in 5 of the 11 (45.5%) patients if the most superior calyx had been used.[10]

The inquiry pertains to the potential replacement of the prone position in specific circumstances by the flexed prone posture. As far as we are aware, no randomized controlled trial has examined the differences in the effects of PNL in the prone and flexible prone positions. Our study aims to determine which position – prone or prone flexed – will vary based on the parameters of the surgery, the proportion of patients free of stones, and the frequency of complications during and after the procedure.

METHODS

Each patient provided their informed consent, and the institutional board approved 351 PNL candidates between May 2017 and August 2022. The investigation was registered as NCT04345835, a clinical trial.

Randomization

Patients were randomly assigned to two groups using simple randomization (1:1): Group 1 underwent PNL in the prone position (control group), while Group 2 underwent in the prone-flexed position instead. The randomization procedure was concealed from the patient and the surgeon. In compliance with the Consolidated Standards of Reporting Trials [Figure 1], the investigation will be completed and reported.

Sample size

G*Power (version 3.1.9.2) (the statistical power analysis software, Faul, F.,et al.2007, universitat, Dusseldorf). was used for power analysis to establish the sample size *a priori*.[11,12] A power analysis was performed based on two variables: the stone-free rate and surgical complications associated with the prone PNL position. Type I statistical error is defined as <5%, whereas type II statistical error is defined as <20%. The sample size was calculated using the previously indicated assumptions, resulting in an estimated 150 patients per group. This sample size has 80% statistical power when the 20% dropout rate was taken into account.

Among the exclusion criteria were renal abnormalities, immunosuppression, pregnancy, uncontrolled coagulopathy, major cardiovascular problems, and being younger than 18.

In compliance with the sensitivity antibiogram, antibiotics were administered for 7–10 days after urine cultures were acquired before PNL. Before having PNL, the patients underwent an abdominopelvic computed tomography (CT) scan without intravenous contrast to evaluate the size and location of the stone as well as the morphology of surrounding organs, including the retrorenal colon. The scalene ellipsoid formula, which is $\pi \times$ length $\times$ breadth $\times$ depth $\times$ 0.167, can be used to calculate stone volume on CT images, according to the European Association of Urology.[13] The subgroups based on volume (<1.5 cm^3, 1.5–6 cm^3, and >6 cm^3).[14]

Before being positioned for lithotomy, each patient in our study underwent general anesthesia. The ipsilateral ureteral orifice was retrogradely filled with a 4F or 5F ureteral catheter under the guidance of a cystoscopy. Thereafter, the patients in Groups 1 and 2 were placed prone flexed in Figure 2 and prone-oriented prone, respectively. Using fluoroscopy guidance, PNL was applied to both patient groups. After contrast was given through the ureteral catheter, an 18-gauge needle was inserted under the guidance of fluoroscopic pictures. Repeatedly, a hole in the calyceal system was made, and a 0.038" guidewire was sent through the needle into the renal pelvis. To dilate the tract, Alken coaxial metal dilators were employed. A 30F Amplatz sheath was positioned at the site of progressive telescopic dilatation to insert a 26F nephroscope (Karl Storz, Tuttlingen, Germany). Swiss LithoClast EMC, Nyon, Switzerland)

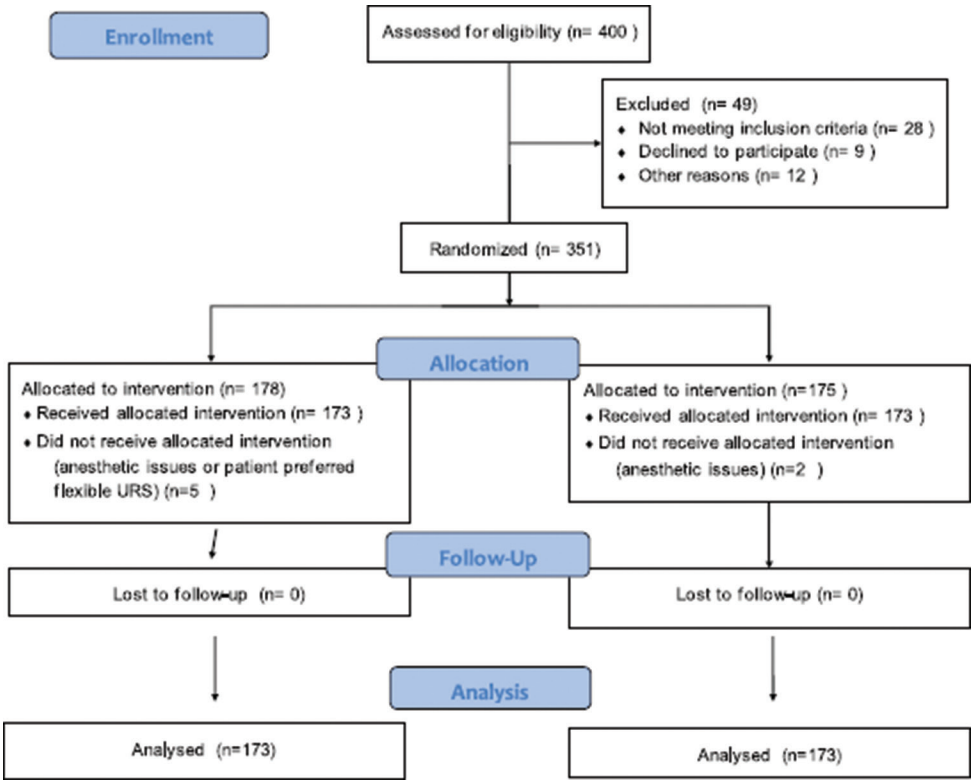

Figure 1: Flowchart

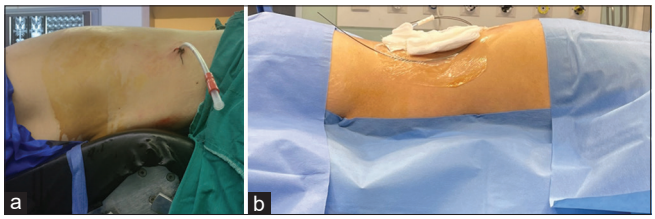

Figure 2: Percutaneous nephrolithotomy in a prone-flexed position (a) in comparison to standard prone position (b)

pneumatic lithotripter and ultrasonic (Storz) disintegration were employed. Using control fluoroscopy, any leftover stone was located.

Every patient's access time, from the point of puncture to the insertion of the Amplatz sheath, as well as the operating time, from the point of access to the nephrostomy tube implantation or skin suturing, were documented. Following surgery, the whole blood cell count and serum electrolyte levels were assessed. The patients were closely monitored for fever and other problems while they were there. At the 1-month follow-up visit, patients underwent abdominopelvic CT scans to assess the success rate (any residual stones with a diameter of ≤3 mm were considered clinically insignificant). Records were kept on hospital stays and postoperative complications. The procedure was performed by three really talented surgeons.

Assessment

The percentage of stone-free rate and the operation's specifics are the main results. The frequency of postoperative and surgical complications is a secondary outcome.

Statistical analysis

For data entry and analysis, SPSS Inc., Chicago, IL, USA, provided the Statistical Package for the Social Sciences (Statistical Package for the Social Sciences, version 21). Numerical values and percentages were utilized to describe the qualitative data. To characterize quantitative data, the terms mean, standard deviation (SD), median, and range were utilized. We used the Student's *t*-test to compare the groups with data that were consistently distributed. Variables that were not regularly distributed were compared using the Mann–Whitney test. We compared category data from both groups using Fisher's exact test and Chi-square test. Significant statistically, $P = 0.05$ was considered.

RESULTS

The average age of the prone and prone-flexed groups was 51.7 ± 12.2 and 49.4 ± 11.9 min, respectively ($P = 0.1$). The prone and prone-flexed groups had mean body mass indexes (BMIs) of 29.2 ± 13.4 and 24.9 ± 11.9, respectively ($P = 0.03$). Table 1 contains demographic information for other patients.

Table 1: Demographic and clinical characteristics of patients

	Prone (*n*=173), *n* (%)	Prone flexed (*n*=173), *n* (%)	*P*
Mean age (years), mean±SD	51.07±12.24	49.04±11.94	0.23
Sex			
Male	100 (57.1)	94 (54.3)	0.33
Female	73 (42.9)	79 (45.7)	
BMI (kg/m^2), mean±SD	24.2±13.4	29.9±11.9	0.03
BMI			
20–25	58 (35.4)	54 (36.9)	0.000
26–29	66 (40.2(	57 (32.9)	
30–34	28 (17.1)	33 (19.07)	
More 35	21 (7.3)	29 (11.2)	
DM	42 (22.0)	17 (9.9)	0.001
HTN	47 (24.6)	33 (19.2)	0.132
CKD	7 (3.7)	6 (3.5)	0.582
ASA			
I	111 (62.8)	126 (73.7)	0.018
II	62 (37.2)	45 (26.3)	
Previous ESWL	24 (12.6)	13 (7.6)	0.080
Previous PNL	22 (11.5)	8 (4.7)	0.013
Previous open surgery	25 (13.1)	52 (30.2)	0.000
Solitary kidney	8 (4.2)	4 (2.3)	0.24
Stone number			
Single	106 (60.7)	75 (43.4)	0.01
Multiple	67 (39.3)	98 (56.6)	
Radiopacity			
Radiopaque	165 (91.1)	157 (90.8)	0.57
Radiolucent	8 (8.9)	15 (8.7)	
Stone location			
Renal pelvis	58 (31.4)	52 (30.4)	0.311
One calyx	23 (12.1)	20 (11.7)	
Renal pelvis and one calyx	55 (29.8)	81 (41.5)	
Staghorn stone	37 (20.4)	20 (11.7)	
Stone score/Guy score			
I	64 (36.5)	45 (26.5)	0.000
II	46 (26.5)	49 (34.7)	
III	25 (14.8)	22 (18.8)	
IV	38 (22.2)	38 (10.6)	
More than 2 cm	105 (53.9)	115 (66.5)	
Hydronephrosis			
Mild	152 (69.6)	146 (74.6)	0.058
Moderate	20 (10.5)	25 (14.5)	
Sever	1 (0.5)	2 (1.2)	
Stone side			
Right	80 (46.6)	84 (47.6)	0.46
Left	93 (53.4)	89 (52.4)	
Anomalies kidney			
Horseshoe kidney	1 (0.5)	2 (1.2)	0.35
Duplex kidney	3 (1.6)	1 (0.6)	
Acute kidney injury and recovery	9 (4.7)	5 (2.9)	0.26
Surgeon satisfaction (%)	94	98	0.00
Preoperative urine culture (positive)	69 (37.1)	72 (45.3)	0.076

SD: Standard deviation, BMI: Body mass index, DM: Diabetes mellitus, HTN: Hypertension, CKD: Chronic kidney disease, ASA: American Society of Anesthesiologists, PNL: Percutaneous nephrolithotomy, ESWL: Extracorporeal shock wave lithotripsy

The success rate (residual stone <3 mm) in the prone and prone-flexed positions was 92% and 93.6%, respectively ($P = 0.6$).

In the prone and prone-flexed groups, the mean access length was 3.9 ± 1.2 and 4.8 ± 1.8 min ($P = 0.08$), while the mean operation time was 68.7 ± 37.4 and 50.4 ± 21.9 min ($P = 0.04$), respectively.

Pyelocaliceal perforation occurred in 15 (8%) and 11 (6.4%) patients in prone and prone-flexed positions, respectively ($P = 1.0$), and was treated with drainage nephrostomy and a DJ stent.

Intraoperative bleeding occurred in 15 (7.9%) and 9 (5.4%) patients in the prone and prone-flexed positions, respectively ($P = 1.0$).

The average percentage decrease in hemoglobin concentration was 1.29 ± 0.42 and 1.21 ± 0.32, respectively ($P < 0.000$).

The average percentage of blood transfusions (%) was 12 (6.9%) and 8 (4.8%), respectively ($P = 0.4$).

Pleural injury occurred following superior calyx access in a prone-flexed position, and the chest tube was fixed. There was no damage to any surrounding organs, including the liver, duodenum, spleen, colon, or major vessels.

Twenty-eight (14.7%) patients in the prone group and 16 (9.6%) patients in the prone-flexed had fever following surgery, which was handled conservatively.

The average postoperative hospital stays were 2.6 ± 0.6, 2.9 ± 0.6, and 2.6 ± 0.6 days, respectively. Table 2 presents a summary of patients' intraoperative and postoperative data in both groups.

DISCUSSION

Although PNL is still frequently performed this way, urologists find it less pleasant to shift patients into the prone position.[1] Urologists are experienced with PNL because the prone position offers a larger working area, unfettered instrument excursion, and greater access to the pyelocaliceal system for nephroscope manipulation.[15]

The flexed prone position increases the amount of space available to surgeons for working, extending the area between the iliac crest and the costal boundary. The location specifics are shown in further detail in Figure 2.

Comparing supine PNL to prone PNL, it is claimed that the former shortens operating times by 30–40 min.[16] Additional advantages include enhanced patient and surgeon comfort, irrigation-induced spontaneous stone fragment evacuation,[17] easier simultaneous ureteroscopic access,[18] and lower radiation exposure to surgeon's hands.[19] In the

Table 2: Intraoperative and postoperative data

	Prone, *n* (%)	Prone flexed, *n* (%)	*P*
Access			
Superior calyx	8 (6.3)	9 (4.8)	0.245
Middle calyx	6 (5.2)	19 (10.1)	
Inferior	155 (85.9)	140 (82.1)	
Combined	4 (2.6)	5 (3.0)	
Access no			
Single	186 (97.4)	160 (94.7)	0.228
Multiple	5 (2.6)	13 (5.3)	
Operation time (min)	68.7±37.4	50.4±21.9	0.08
Access time (min)	3.9±1.2	4.8±1.8	0.04
Mean preoperative HB, mean±SD	13.25±1.69	13.01±1.87	
Mean postoperative HB, mean±SD	11.97±1.61	11.74±1.81	
Mean HB deficit, mean±SD	1.29±0.42	1.21±0.32	0.000
Intraoperative bleeding	15 (7.9)	9 (5.4)	0.23
Postoperative hematuria	10 (5.2)	11 (6.6)	0.37
Postoperative angioembolization	0	2 (1.2)	0.21
Blood transfusion	12 (6.9)	8 (4.8)	0.4
Mean hospital stay, mean±SD	2.23±0.96	2.31±0.915	0.4
Fever	28 (14.7)	16 (9.6)	0.09
Pyelocaliceal perforation	12 (6.3)	3 (1.8)	0.02
Success rate	92	93.6	0.6
Residual stone			
Significant	10 (5.2)	5 (2.9)	0.13
Insignificant	3 (1.6)	8 (4.6)	
Clavien-Dindo classification			
I	26 (13.6)	8 (6.5)	0.03
II	1 (0.5)	0	0.54
III	2 (1.0)	1 (0.6)	0.53
IV	1 (0.5)	1 (0.6)	0.72

SD: Standard deviation, HB: Hemoglobin

current analysis, the average operation time for the prone and prone-flexed groups was 50.4 ± 21.9 min ($P = 0.04$) and 68.7 ± 37.4 min, respectively. To find out how satisfied he was, questions about the patient's position were asked of the surgeon after the treatment. It was requested by someone who is blind.

In a randomized study by De Sio *et al*.,[20] regarding hospital stay, stone-free rate, and complication rate, there was no discernible difference between the supine and prone positions. Neither the group's members required a blood transfusion or suffered pleural or intestinal damage. Similarly, our study did not find any statistically significant difference between the prone and prone flexible postures with respect to the rate of stone-free extractions, intraoperative problems, or postoperative complications.

Our findings indicate a significant difference ($P = 0.04$) in the operative time between the flexed prone and prone positions.

Patients with staghorn calculi should consider the prone position, and those who may need upper pole access based on preoperative imaging should also be investigated.[17] The prone-flexed group in our study had a higher stone-scoring system, and both the groups' stone-free percentage were similar ($P = 1.0$).

Manikandan[21] showed that although lateral position improved oxygenation without affecting carbon dioxide elimination, prone position was associated with an improvement in both carbon dioxide elimination and oxygenation. During our study, we found that the mean (±SD) BMI in the prone position was significantly higher than in the prone-flexed position ($P = 0.03$). A mean (±SD) BMI of 29.2 ± 13.4 and 24.9 ± 11.9 was recorded in the prone and prone-flexed positions, respectively.

Without the use of ultrasonography, every patient in both the groups in our study arrived at the collection system through X-ray. In the prone and prone-flexed postures, the success rate was 92.6%, and the residual stone rates (stone < 3 mm) were 93.6% ($P = 0.6$). In an additional study, Karami *et al*.[22] contrasted the PNL results in the flank and prone positions (30 patients in each group), finding that the flank position had a complete stone clearance rate of 85% without any visceral damage.

With just two (1.0%) and one (0.6%) Grade 3 Clavien-Dindo classifications in the prone and prone-flexed positions, respectively, our study's results regarding complications and side effects were favorable. Up to 83% of all complications following PNL were extravasation (7.2%), transfusion (11.2%–17.5%), and fever (21.0%–32.1%); nevertheless, serious issues such as septicemia (0.3%–4.7%), colonic (0.2%–0.8%), or pleural injury (0.0%–3.1%) are uncommon.[23]

Our study is unique in that it includes all consecutive patients who require PNL, regardless of BMI, size of stones, or other features. This is one of its main strengths.

Anesthetic settings are not taken into consideration, which is the main disadvantage of the prone-flexed posture. In these circumstances, obese patients still experience difficulties. This position allowed the surgeon to have a good amount of workspace, which speed up operations and reduced anesthetic complications.

CONCLUSION

We believe that PNL is equally safe in the prone and prone-flexed positions. Patients who are obese are more likely to benefit from the flexed prone position. The average operation time was somewhat shortened in the prone-flexed position. Flexing the prone position made it

easier to access the pelvicalyceal system. For each position, the surgeon's preference and the appropriate case selection are vital and critical.

Ethical approval and consent to participate

Done.

Consent for publication

Done.

Availability of data and material

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Authors contribution

DT, Protocol/project development, Data analysis, Manuscript writing/editing AI, Data collection or management AZ, Data collection or management ES, Data collection or management TA, Protocol/project development HN, Protocol/project development, management Data analysis "all authors have read and approved the manuscript."

Ethics approval and consent to participate

The study was approved from IRB Kafrelsheikh University. Moreover, IRB was taken from clinical trials. Gov.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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