Does surgical position affect infective complications in percutaneous nephrolithotomy?

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Received: 11 August 2022 / Accepted: 4 October 2022 / Published online: 10 October 2022
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Abstract

The downward orientation of the access sheath during supine percutaneous nephrolithotomy (PCNL) allows the faster evacuation of fluids and stone fragments. It theoretically can contribute to the reduction of the high intrarenal pressure-associated complications. We aimed to investigate whether there is a difference between prone and supine PCNL in terms of infective complications. This retrospective study includes 182 patients who underwent supine and prone PCNL due to kidney stones in our clinic between April 2020 and May 2022. Demographic (age, sex, body mass index, comorbidities), radiological (cumulative stone burden, stone density, number of stones, stone localization, stone laterality, presence of hydronephrosis), clinical (previous stone surgery, previous urinary tract) and perioperative (prone or supine position, surgery duration, hospitalization, success, non-infective and infective complications) data of all patients were evaluated. All patients were divided into two groups, the prone position group, and the supine position group. These two groups were compared in terms of pre and postoperative data above. Infective complications were observed in 16 (18%) patients in the prone position group and in 7 (7.5%) patients in the supine position group, and this difference was statistically significant ($p = 0.034$). Surgery duration (OR = 1.041; 95% CI 1.021–1.061; $p < 0.001$), number of stones (OR = 4.09; 95% CI 1.093–7.309; $p = 0.036$), previous urinary tract infection (OR = 6.272; 95% CI 1.936–9.317; $p = 0.002$) and prone position (OR = 4.511; 95% CI 1.265–7.087; $p = 0.02$) were found as independent risk factors for infective complications. Prone position was proved as an independent predictor of postoperative infectious events. Supine PCNL will be further adopted as the standard PCNL approach by a continuously growing proportion of endourologists.

Keywords Injectable complication · Percutaneous nephrolithotomy · Prone · Supine

Introduction

Percutaneous nephrolithotomy (PCNL) was introduced in the late 1970s and remains an effective operative modality for the extraction of a relatively large stone burden from the pelvicalyceal system of the kidney. According to the latest version of European Association of Urology (EAU) guidelines, PCNL comprises the standard procedure for voluminous renal stones exceeding a maximum diameter of 2 cm, while it remains a valid option for smaller stones [1].

During the historical route of PCNL, the technological developments contributed to the evolvement of the surgical procedure, with new types of energy generators, high energy output systems, energy transfer through flexible probes and smaller access sheaths and instruments [2]. A parallel change, which remains a matter of debate, is the ideal patient position for the PCNL procedure. Historically, PCNL was introduced as a procedure performed in the prone position, which is the most frequently selected variant still in present. However, in 1987 was presented for the first time the supine position-based variant, and nowadays there are several variants of the prone, supine, and lateral positions for PCNL surgery, each one with its combination of advantages and disadvantages [2].

The prone position was initially selected for performing PCNL procedures, which was based on the notion that it is accompanied by a reduced risk for intraabdominal organ...
Injury. The wider surface area for puncture and gaining access to the pelvicalyceal system is recognized as the main advantage of the prone position [3]. Furthermore, the feasibility of performing PCNL in patients with kidney disorders, such as the horseshoe kidney, the shorter length of the access tract, and the limited kidney mobility represent additional advantages of the prone position, which remains the main positioning option for the 77% of the urologists performing PCNL and the optimal approach for the young urologists with limited expertise [3]. On the other hand, supine PCNL is considered beneficial in terms of cardiovascular and airway control, anesthesiological safety, and reduced risk of peripheral nerve injury and thromboembolism [4]. Moreover, supine positioning is characterized by improved ergonomics for operation room personnel and increased feasibility of performing combined intrarenal surgery by combining the percutaneous and retrograde access to the pelvicalyceal system. Additionally, the downward orientation of the access sheath during supine PCNL allows the faster evacuation of fluids and stone fragments, which theoretically can contribute to the reduction of the high intrarenal pressure—associated complications [4]. Supine positioning represents a major change in PCNL procedure, which is the main reason for the attachment of even experienced endourologists to the prone approach.

Regarding the results and the safety profile of PCNL, the majority of the studies showed the equivalence of the prone and supine positions. Two meta-analyses demonstrated a significantly shorter operative time for the supine approach and equal complication rates [5, 6]. The supine position was associated with a lower stone-free rate in one of these meta-analyses [6]. The data of the largest patient database for PCNL results (CROES PCNL Global Study) showed a longer operation time and lower stone-free rate for the supine approach, which can be attributed to different definitions of operative time and variability in the examination of residual stones [7]. Stone-free rates and complications of the two approaches were equal according to the results of a randomized comparative study, while the mean blood loss, the mean operative time, the mean hospital stay, and the parameters of anesthesiological risk showed an advantage of supine PCNL [8]. In a recent retrospective comparison of the prone position with three variations of the supine position, no difference was found in terms of stone-free rate, blood loss, hospital stay, and complications, while the complete supine position was associated with shorter operative time [9]. According to the most recent meta-analysis, supine position seems to achieve a lower stone-free rate, but with lower complication rates compared to the prone position [10].

Relating to postoperative complications of PCNL surgery, symptomatic urinary infection comprises the most common postoperative event, with 10.5–39.8% of the patients developing postoperative fever and 0.3–1% of the patients developing sepsis [2]. Most of the available reports agree on the factors that affect the risk of postoperative infectious complications. The data from the CROES PCNL Global Study revealed that the positivity of preoperative urine culture, the presence of staghorn calculus or preoperative nephrostomy, the lower patient age, and diabetes were independent predictors of developing postoperative fever [11]. A report on 227 patients undergone PCNL surgery after antibiotic pre-treatment showed the presence of staghorn calculus as the sole factor with an independent effect on risk for fever or sepsis [12]. A recent meta-analysis on the important factors for the manifestation of postoperative infection incorporated the results of prospective and retrospective studies into the quantitative synthesis. This report concluded that the status of preoperative urine culture, the status of stone culture, the number of access points, and the blood transfusion were representative of the preoperative presence of bacteria and the extent of kidney trauma during the PCNL procedure, which are the major predictors of postoperative infection [13]. According to the results of a recent report on the effect of preoperative factors on postoperative infectious complications, the occurrence of severe infection depends not only on the presence of bacteria in preoperative specimens but also on a subset of patient biochemical parameters, which reflect the interaction of uropathogens with patient homeostasis [14].

Focusing on the comparison of prone to supine position in terms of results, complications, and especially postoperative infectious events, we collected the preoperative and postoperative data of patients undergone PCNL surgery. Through the analysis of the above data, we sought the significant factors, which influence the possibility of infectious complications, and additionally, we examined the independent effect of these factors on postoperative infectious events.

Materials and methods

The prospectively collected data of 182 patients who underwent supine and prone PCNL in our clinic between April 2020 and May 2022 were evaluated retrospectively. All operations were performed by 2 urologists (Y.K. experienced in supine percutaneous nephrolithotomy, C.O. experienced in prone PCNL). This study was approved by the Institutional Review Board of Ankara City Hospital (E2-22-2181).

Demographic (age, sex, body mass index [BMI], comorbidities), radiological (cumulative stone burden, stone density, number of stones, stone localization, stone laterality, presence of hydronephrosis), clinical (previous stone surgery, previous urinary tract) and perioperative [surgical position (prone or supine), surgery duration, hospitalization, success, non-infective and infective complications] data of all patients were evaluated. All patients
were divided into two groups, the prone position group, and the supine position group according to surgical technique. These two groups were compared in terms of pre and postoperative data above.

Patients were diagnosed with kidney stones by preoperative non-contrast computed tomography. The stone burden was measured by the two-dimensional area determined by the multiplication of the longest and perpendicular diameters of the stone. Stone burdens were also added if there were multiple stones.

Patients with positive urine cultures were treated with appropriate antibiotics for at least 7 days. Preoperative urine cultures of all patients were sterile. Prophylaxis with intravenous 2 g of cefazolin was administered within 1 h before surgery.

Surgical technique

All procedures were performed under general anesthesia. The patients in the prone position group were placed in lithotomy position and retrograde ureteral catheterization was performed. Then, the position of the patient was changed to the prone position. An 18-G coaxial needle (Geotech Healthcare Products, Turkey) was inserted into the desired calyx under the guidance of fluoroscopy (Siemens, Germany). After progressive dilatations with facial dilators (Arilar Inc. Turkey), a 26 Fr nephroscope was inserted through a 30-Ch Amplatz sheath (Karl Storz, Tuttingen, Germany). Stones were fragmented with a pneumatic lithotripter (Elmed Medical Systems, Turkey) and collected with stone forceps. Patients in the supine position group were placed in the supine position, slightly rotated by a 3 L water bag placed under the flank. The ipsilateral side of the patient was raised approximately 30° according to the operating room table. All other procedures were similar to the prone position. A 22 Fr nephrostomy catheter was placed in all patients at the end of the operation. If the urine is clear and there is no evidence of extravasation in the antegrade pyelogram, it was removed on the 3rd postoperative day. The surgery duration was recorded as the time from the insertion of a rigid ureterorenoscope through the urethra to the insertion of the nephrostomy tube.

Infective complications after PCNL were defined as fever (body temperature > 38 °C continuing for 48 h during hospitalization), urinary infection (urinary and/or blood culture positivity), sepsis (urinary infection and presence of ≥ 2 Sequential Sepsis-related Organ Failure Assessment [SOFA] score and septic shock (sepsis accompanied by serum lactate level > 2 mmol/L and vasopressor need for mean arterial pressure > 65 mmHg) [15]. Success was defined as the absence of residual stones on non-contrast computed tomography at 1st postoperative month.

Statistical analysis

Data coding and statistical analyzes were done on the computer using the SPSS 22 software package program (IBM SPSS Statistics, IBM Corporation, Chicago, IL). The conformity of the variables to the normal distribution was examined by the Shapiro–Wilk tests. Mann–Whitney U test was used to compare non-categorical parameters between groups. Chi-square test were used for categorical variables. Risk factors for infective complications in PCNL were determined by univariate logistic regression analysis. These parameters identified as risk factors in this analysis were evaluated by multivariate analysis with the Backward LR method. Independent risk factors were determined as a result of multivariate analysis. Cases with a p value below 0.05 were considered statistically significant.

Results

Of the 182 patients included in the study, 89 (48.9%) patients were operated in the prone position and 93 (51.1%) patients in the supine position. The success rate was 78.6%. The mean age of all patients was 49.6 ± 13.4 years. 122 (67%) of the patients were male. The mean stone burden was 599 ± 289.4 mm² and the mean stone density was 1103.8 ± 354.1 HU. The two groups were similar in terms of age, sex, BMI, comorbidities, cumulative stone burden, stone density, number of stones, stone localization, stone laterality, presence of hydroureter, previous stone surgery, and previous urinary tract infection (p > 0.05). Demographic, clinical, and radiological data of all patients were shown in Table 1.

Surgery duration was longer in the prone position group than in the supine position group and this difference was statistically significant (117.1 ± 34.1 vs 102.5 ± 36.9 min, p = 0.005). Non-infective complications were observed in 31 (17%) patients. Non-infective complication rates of the two groups were similar (17.2% in the supine position group vs 16.9% in the prone position group, p = 0.95). Infective complications were detected in 23 (12.6%) of all patients. 12 patients had a fever. Urinary tract infection in 9 patients, and sepsis in 2 patients. Septic shock did not occur in any patient. Infective complications were observed in 16 (18%) patients in the prone position group and in 7 (7.5%) patients in the supine position group, and this difference was statistically significant (p = 0.034). There was no difference between the groups in terms of success rate. The details and comparative analysis of the perioperative data of the patients who underwent supine and prone PCNL were shown in Table 2.

Univariate and multivariate logistic regression analysis was used to identify risk factors for infective
complications. According to univariate logistic regression analysis, cumulative stone burden, surgery duration, number of stones, previous urinary tract infection, and prone position were risk factors associated with infective complications. Parameters found as risk factors in this analysis were evaluated with multivariate logistic regression analysis. Accordingly, surgery duration (OR = 1.041; 95% CI 1.021–1.061; \( p < 0.001 \)), number of stones (OR = 4.09; 95% CI 1.093–7.309; \( p = 0.036 \)), previous urinary tract infection (OR = 6.272; 95% CI 1.936–9.317; \( p = 0.002 \)) and prone position (OR = 4.511; 95% CI 1.265–7.087; \( p = 0.02 \)) were found as independent risk factors for infective complications (Table 3).

### Discussion

Supine positioning during the PCNL procedure represents an important evolvement of percutaneous renal surgery, characterized by at least equal results compared to prone positioning. In the current study, the analysis revealed that the stone extraction during supine PCNL was equally effective to the prone variant. Moreover, supine procedures had a shorter operation time, which can be attributed mostly to the fact of performing the retrograde ureteral catheterization and the main operative procedure at the same patient position. In terms of non-infectious complications and hospital stay, both methods presented equally low event rates.

### Table 1: Demographic, radiologic and clinical characteristics of patients who underwent supine and prone percutaneous nephrolithotomy

|                          | Total (n = 182) | Supine (n = 93, 51.1%) | Prone (n = 89, 48.9%) | \( p \)  |
|--------------------------|-----------------|------------------------|----------------------|--------|
| Age (years) (Mean ± SD)  | 49.6 ± 13.4     | 50.7 ± 14.3            | 48.4 ± 12.4          | 0.176b |
| Sex                      |                 |                        |                      |        |
| Male, n (%)              | 122 (67)        | 63 (67.7)              | 59 (66.3)            | 0.835a |
| Female, n (%)            | 60 (33)         | 30 (32.3)              | 30 (33.7)            |        |
| BMI (kg/m²) (Mean ± SD)  | 27.2 ± 4.2      | 26.8 ± 4               | 27.7 ± 4.4           | 0.107b |
| Comorbidities            |                 |                        |                      |        |
| DM, n (%)                | 40 (22)         | 20 (21.5)              | 20 (22.5)            | 0.875a |
| HT, n (%)                | 79 (43.4)       | 44 (47.3)              | 35 (39.3)            | 0.277a |
| Cumulative stone burden (mm²) (Mean ± SD) | 599 ± 289.4 | 589.6 ± 317.4 | 608.9 ± 258.4 | 0.297a |
| Stone density (HU) (Mean ± SD) | 1103.8 ± 354.1 | 1080.9 ± 352.2 | 1127.8 ± 356.4 | 0.418b |
| Number of stones         |                 |                        |                      |        |
| One, n (%)               | 75 (41.2)       | 40 (43)                | 35 (39.3)            | 0.614a |
| Multiple, n (%)          | 107 (58.8)      | 53 (57)                | 54 (60.7)            |        |
| Stone localization       |                 |                        |                      |        |
| Pelvis, n (%)            | 66 (36.3)       | 35 (37.6)              | 31 (34.8)            | 0.193a |
| Lower calyx and pelvis, n (%) | 73 (40.1) | 36 (38.7)              | 37 (41.6)            |        |
| Lower calyx, n (%)       | 16 (8.8)        | 5 (5.4)                | 11 (12.4)            |        |
| Lower and middle calyx, n (%) | 10 (5.5) | 8 (8.6)                | 2 (2.2)              |        |
| > 2 calyces, n (%)       | 17 (9.3)        | 9 (9.7)                | 8 (9)                |        |
| Stone laterality         |                 |                        |                      |        |
| Right, n (%)             | 86 (47.3)       | 49 (52.7)              | 37 (41.6)            | 0.133a |
| Left, n (%)              | 96 (52.7)       | 44 (47.3)              | 52 (58.4)            |        |
| Previous stone surgery   |                 |                        |                      |        |
| Yes, n (%)               | 77 (42.3)       | 36 (38.7)              | 41 (46.1)            | 0.315a |
| No, n (%)                | 105 (57.7)      | 57 (61.3)              | 48 (53.9)            |        |
| Previous urinary tract infection |        |                        |                      |        |
| Yes, n (%)               | 45 (24.7)       | 28 (30.1)              | 17 (19.1)            | 0.085a |
| No, n (%)                | 137 (75.3)      | 65 (69.9)              | 72 (80.9)            |        |
| Presence of hydronephrosis |                |                        |                      |        |
| Yes, n (%)               | 145 (79.7)      | 72 (77.4)              | 16 (18)              | 0.441a |
| No, n (%)                | 37 (20.3)       | 21 (22.6)              | 73 (82)              |        |

SD Standard deviation, BMI Body mass index, DM Diabetes mellitus, HT Hypertension, HU Hounsfield unit

\( ^{a} \)Chi-square test

\( ^{b} \)Mann Whitney U test
and equal duration of hospitalization. Most importantly, supine PCNL seemed to be beneficial in terms of postoperative infectious complications, since the analysis showed a statistically significant difference. Other factors that were associated significantly with the manifestation of infectious complications were the cumulative stone burden, the number of stones, the previous occurrence of urinary tract infection, and the surgery duration. Multivariate logistic regression model revealed that the number of stones, the previous occurrence of UTI, the surgery duration, and the patient

Table 2  Perioperative data of patients who underwent supine and prone percutaneous nephrolithotomy

|                        | Total (n = 182) | Supine (n = 93, 51.1%) | Prone (n = 89, 48.9%) | p   |
|------------------------|----------------|------------------------|-----------------------|-----|
| Surgery duration (min) (Mean±SD) | 109.6±36.2     | 102.5±36.9             | 117.1±34.1            | 0.005a |
| Hospitalization (day) (Median)(min–max) | 4 (2–13)      | 4 (3–9)                | 4 (2–13)              | 0.496a |
| Non-infective complications, n (%) | 31 (17)       | 16 (17.2)              | 15 (16.9)             | 0.95b  |
| Nephrostomy tube displacement, n | 1             | 0                      | 1                     |       |
| Atelectasis, n | 4             | 2                      | 2                     |       |
| Bleeding requiring transfusion, n | 10            | 6                      | 4                     |       |
| Pulmonary thromboembolism requiring antithrombotic therapy, n | 5             | 2                      | 3                     |       |
| Cardiac dysrhythmia, n | 1             | 1                      | 0                     |       |
| Ileus requiring nasogastric tube, n | 1             | 1                      | 0                     |       |
| Perinephric abscess requiring drainage, n | 1             | 0                      | 1                     |       |
| Colon perforation, n | 1             | 1                      | 0                     |       |
| Urinary extravasation requiring a DJ catheter, n | 7             | 3                      | 4                     |       |
| Infective complications, n (%) | 23 (12.6)     | 7 (7.5)                | 16 (18)               | 0.034b |
| Fewer, n | 12            | 4                      | 8                     |       |
| Urinary tract infection, n | 9             | 2                      | 7                     |       |
| Sepsis, n | 2             | 1                      | 1                     |       |
| Success rate, n (%) | 143 (78.6)    | 75 (80.6)              | 68 (76.4)             | 0.486b |

Bold characters indicate statistically significant values
SD Standard deviation, DJ Double-J
*aMann Whitney U test
bChi-square test

Table 3  Determination of risk factors associated with infective complications in percutaneous nephrolithotomy by logistic regression analysis

|                          | Univariate                | Multivariate               |
|--------------------------|---------------------------|----------------------------|
|                          | OR (95% CI)               | p                          | OR (95% CI)               | p                          |
| Age (per year)           | 0.986 (0.954–1.018)       | 0.391                      | 1.001 (0.998–1.003)       | 0.622                      |
| Sex (male)               | 0.686 (0.256–1.841)       | 0.455                      | 4.09 (1.093–7.309)        | 0.036                      |
| BMI (per 1 kg/m²)        | 1.008 (0.911–1.116)       | 0.872                      | 1.292 (0.537–3.104)       | 0.567                      |
| Presence of DM           | 1.007 (0.816–1.221)       | 0.863                      | 1.292 (0.537–3.104)       | 0.567                      |
| Presence of HT           | 0.661 (0.265–1.648)       | 0.374                      | 1.292 (0.537–3.104)       | 0.567                      |
| Cumulative stone burden (per 1 mm²) | 1.002 (1.001–1.004) | <0.001 Cumulative stone burden (per 1 mm²) | 1.001 (0.998–1.003)       | 0.622                      |
| Stone density (per 1 HU) | 1 (0.999–1.001)           | 0.935                      | 4.09 (1.093–7.309)        | 0.036                      |
| Number of stones (multiple) | 2.831 (1.003–8.005)   | 0.049 Number of stones (multiple) | 4.09 (1.093–7.309)        | 0.036                      |
| Stone laterality (left)  | 0.974 (0.406–2.337)       | 0.953                      | 4.09 (1.093–7.309)        | 0.036                      |
| Previous stone surgery   | 1.292 (0.537–3.104)       | 0.567                      | 4.09 (1.093–7.309)        | 0.036                      |
| Previous urinary tract infection | 5.159 (2.075–12.83) | <0.001 Previous urinary tract infection | 6.272 (1.936–9.317)       | 0.002                      |
| Presence of hydronephrosis | 1.244 (0.396–3.907)     | 0.708                      | 1.244 (0.396–3.907)       | 0.708                      |
| Surgery duration (per 1 min) | 1.043 (1.024–1.062) | <0.001 Surgery duration (per 1 min) | 1.041 (1.021–1.061)       | <0.001                     |
| Prone position           | 2.693 (1.05–6.903)        | 0.039 Prone position       | 4.511 (1.265–7.087)       | 0.02                       |

Bold characters indicate statistically significant values
CI Confidence interval, BMI Body mass index, DM Diabetes mellitus, HT Hypertension, HU Houndsfield unit
position were independent predictors of the postoperative infectious events. For the prone position, the multivariate analysis showed that it increases independently the risk of postoperative infection by approximately 4.5 times, which was statistically significant.

Regarding the available data on the association of patient position during PCNL with postoperative infectious events, there is a limited number of reports. According to the quantitative synthesis of a meta-analysis, patients undergone supine PCNL had lower fever rates [16]. Of the included studies, only two showed a significant difference in postoperative infection in favor of supine PCNL [17, 18].

The results of the current study are in accordance with the above publications. In our opinion, the effect of the supine position on reducing infectious events can be attributed to the low intrarenal pressure and the optimal stone fragment extraction during the procedure. Lower intrarenal pressure implies a reduced translocation of bacteria from the pelvic-calycal system to the systematic circulation through the blood and lymph vessel route. Moreover, this translocation is further diminished based on the shorter procedure duration, a characteristic of the supine approach in the current study and other reports. Infectious complications can contribute to serious morbidity, or in rare cases can be fatal, so the reduction of the respective rates comprises an important advantage in favor of supine PCNL.

There are some limitations to our study. Firstly, our study was conducted retrospectively. Secondly, procedure were done by two different surgeons adding a bias related to surgical skill and attitude to care for maintaining low intrarenal pressures by personal tricks. Also, when calculating the surgery duration, the time of position change in the prone position was also included. It would be more appropriate to measure operative time from puncture of the renal cavities.

Regarding the advantages of the current study, for the comparisons relating to PCNL results and complications, we included patients with approximately similar characteristics to reduce the effect of possible confounders relating to these characteristics. Furthermore, we applied multivariate analysis to isolate the effect of each factor from the confounding of the other significant factors. The results of the study suggest that supine PCNL can be considered an equally effective and safer PCNL variant, which can be applied to a wide set of renal stone disease cases.

**Conclusion**

In the current study, supine PCNL showed equal effectiveness in achievement of a stone-free state and equal rates of non-infectious complications compared to the prone approach. Infectious complications were significantly fewer in the supine group, and the prone position was proved as an independent predictor of postoperative infectious events. Based on the above results, we hypothesize that supine PCNL will be further adopted as the standard PCNL approach by a continuously growing proportion of endourologists.

**Author contributions** Conception and design: YK, SS; Data acquisition: EU; Data analysis and interpretation: SS, MEP; Drafting the manuscript: AK, EU; Critical revision of the manuscript for scientific and factual content: SS, AK; Statistical analysis: SS; Supervision: YK.

**Funding** The author(s) received no financial support for the research, authorship.

**Data availability** The datasets generated and/or analyzed during the current study are available in Figshare Repository at https://figshare.com/s/3af84b7e1ah2b8b890b3.

**Code availability** Not applicable.

**Declarations**

**Conflict of interest** The authors report no conflicts of interest.

**Ethical approval** The present study protocol was reviewed and approved by the Institutional Review Board of ### Hospital (approval number: E2-22-2181).

**Consent to participate** Not applicable.

**Consent for publication** Not applicable.

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