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Factors associated with complications after percutaneous nephrolithotomy: an analysis of 1,066 cases

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SUMMARY

OBJECTIVE: The aim of this study was to identify predictive factors for complications after percutaneous nephrolithotomy.

METHODS: We prospectively analyzed patients who underwent percutaneous nephrolithotomy from June 2011 to October 2018. The association of preoperative and intraoperative factors with the presence of complications was assessed using univariate and multivariate analyses. The significance level was set at p<0.05.

RESULTS: A total of 1,066 surgeries were evaluated, and the overall complication rate was 14.9%. In all, 105 (9.8%) surgeries were performed in the prone position, and 961 (90.2%) were performed in the supine position. Univariate analysis demonstrated that surgical position, upper pole puncture, surgical time, number of tracts, and Guys Stone Score were associated with complications. In multivariate analyses, prone position (odds ratio [OR] 2.10; p=0.003), surgical time ≥90 min (OR 1.76; p=0.014), upper pole puncture (OR 2.48; p<0.001), and Guys Stone Score 3 or 4 (OR 1.90; p=0.033) were independent predictive factors for complications after percutaneous nephrolithotomy.

CONCLUSION: Performing percutaneous nephrolithotomy in the supine position, in under 90 min, and avoiding upper pole punctures may reduce complications during the treatment of large kidney stones.

KEYWORDS: Percutaneous nephrolithotomy. Kidney stones. Risk factors. Complications.

INTRODUCTION

Since its first description in 1976 by Fernström and Johansson[1], percutaneous nephrolithotomy (PCNL) has become the standard procedure for the treatment of renal stones>20 mm or complex and multiple kidney stones[2,3]. Technological advances have increased the success rates of PCNL, and major complications are less common today than in the past[4,5]. Minor postoperative complications account for the majority of cases, with a rate between 7.1 and 40.2%. Otherwise, major postoperative complications have been reported with rates of up to 17.1%[6,7]. In a large review, the most common complications were fever and bleeding. Other complications such as urinary leakage, hydrothorax, hematuria, urinary tract infection, and urinary fistula were also present but less frequent[8].

The reported risk factors for bleeding include an upper pole puncture, a solitary kidney, a staghorn stone, multiple punctures, and inexperienced surgeons[9]. Wang et al.[10] also analyzed the risk factors for bleeding and septic shock and reported the prevalence of septic shock and severe bleeding to be 2.4 and 1%, respectively.

Recent studies have evaluated the risk factors for specific complications, but there are insufficient data regarding the predictors of general complications after PCNL. In the present study, we aimed to report the risk factors for all perioperative deviations, rather than specific complications, in a very large sample.

METHODS

We performed a retrospective analysis of prospectively collected data pertaining to all patients who underwent PCNL between June 2011 and October 2018 at a single center. Informed consent was obtained from patients preoperatively, and the study protocol was approved by the Institutional Review Board.

Indications for surgery were renal stones >2 cm in size and symptomatic stones <2 cm for which first-line techniques (shockwave lithotripsy or ureterorenoscopy) failed. Considering the cases of failure after initial treatment, cases of multiple stones, inferior polar stones (>15 mm), and unfavorable anatomical conditions were eligible for percutaneous nephrolithotripsy.

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The following clinical and operative variables were collected: age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) physical status classification, hemoglobin level, stone size, laterality, number of PCNL, surgical position, surgical time, number of tracts, upper pole puncture, and Guy's Stone Score (GSS)[11]. The GSS was determined by a urologist during the preoperative consultation by analyzing computerized tomography (CT) findings, and it was rechecked immediately before surgery. All urologists were trained in evaluating the GSS.

Operating technique

All PCNL procedures were performed under general anesthesia. The patient was positioned in the prone or supine position based solely on the surgeon's preference. The surgeons were trained in performing PCNL in both the prone and supine positions. For prone positioning, we followed the classic method described by Clayman et al.[12] For supine positioning, we used the modified complete supine position described by Vicentini et al.[13] The main surgeon performed the calyceal puncture under fluoroscopic guidance. Subcostal skin punctures were preferred, but supracostal punctures through the 11th and 10th intercostal spaces were also used when necessary. A semirigid plastic dilators set (Amplatz dilatorsâ) was used to sequentially dilate the tract up to 30 Fr. Nephroscopy was performed using a 26 Fr nephroscope (Karl Storz, Germany), and stone fragmentation was performed using an ultrasonic lithotripter (Swiss Lithoclast Masterâ, EMS, Switzerland).

Intraoperative stone-free status was verified using fluoroscopy and flexible nephroscopy. A 16 Fr nephrostomy tube was placed at the end of the procedure in cases of bleeding, residual stones, solitary kidney, pelvic injury, or multiple tracts. Routinely, a 6 Fr ureteral catheter and an 18 Fr bladder catheter were left in place until the first postoperative day (POD1); in cases of ureteropelvic junction edema or injury, a 4.8 Fr´26 cm ureteral stent was used for 3 weeks. Ropivacaine 1% (20 mL) was injected into the tracts at the end of the surgery.

Outcome evaluation

All patients underwent an abdominal non-contrast-enhanced CT on POD1 to evaluate the surgical complications and residual stones. Finally, during the postoperative period, we analyzed the postoperative hemoglobin level 12 h after the surgery, the need for red blood cell transfusion, and complications (using the Clavien-Dindo classification adapted to PCNL)[14].

Statistical analysis

SPSS for Windows (version 21.0; SPSS Inc., Chicago, IL, USA) was used for statistical analyses. Continuous variables are expressed as mean and standard deviation. Categorical variables are described using simple and relative frequencies. Clinical and operative variables and complication status were compared using Pearson's chi-squared test. Variables with an expected frequency of less than five were analyzed using Fisher's exact test. The Cox proportional hazards model was used to determine the variables that influenced the presence of complications. The confidence interval was set to 5%.

RESULTS

We performed 1,066 PCNLs on 891 patients. The mean age of the patients was 48.6 years (range, 14–87 years). A total 105 (9.8%) surgeries were performed in the prone position, and 961 (90.2%) were performed in the supine position. GSS 3 or 4 (complex cases) were found in 47.7% of cases.

The overall complication rate was 14.9%. The Clavien grade of the complications was grade 1 in 36 (3.4%) patients, grade 2 in 60 (5.6%) patients, grade 3 in 39 (3.7%) patients, grade 4 in 20 (1.9%) patients, and grade 5 in 4 (0.4%) patients. Table 1 shows intra- and postoperative complications according to the Clavien classification (minor and major complications).

Table 1. Intra- and post-operative complications.

Type of complication*	n=1,066 (% of total)
Severe bleeding (transfusion)	48 (4.5)
Urinary tract infection	30 (2.8)
Pain	19 (1.7)
Tract leakage (persistent fistula)	15 (1.4)
Stone migration to ureter	14 (1.3)
Pleural injury	11 (1.2)
Acute kidney injury	7 (0.6)
Colon injury	6 (0.5)
Pseudoaneurysm	3 (0.28)
Liver injury	2 (0.1)
Thromboembolism	2 (0.2)
Duodenal injury	1 (0.09)
Spleen injury	1 (0.09)
Deaths (severe sepsis, septic shock, severe bleeding)	4 (0.37)
Clavien classification	**n=159 (% of complications)**
Clavien I	36 (22.6)
Clavien II	60 (37.7)
Clavien III	39 (24.5)
Clavien IV	20 (12.6)
Clavien V	4 (2.5)

*Multiple events may have occurred in a single patient.

The largest kidney stone diameter was significantly larger in patients with complications than in those without (31.7 vs. 28.6 mm, p=0.007). The complication rate progressively increased according to the GSS (p<0.001).

We also performed a univariate analysis of clinical and operative variables according to the complications (Table 2). Of the 105 patients who underwent surgery in the prone position, 25.7% had complications, while the complication rate for the patients in the supine position was 13.7% (p<0.001). Other variables such as surgical time ≥90 min (p<0.001), number of tracts (p<0.001), and upper pole puncture (p<0.001) were associated with the presence of complications.

In the multivariate analysis, the variables that remained as independent predictors of complications after PCNL were complex kidney stones (GSS 3 or 4) (OR 1.90; p=0.033), surgical time ≥90 min (OR 1.76; p=0.014), prone position (OR 2.10; p=0.003), and upper pole puncture (OR 2.48; p<0.001) (Table 3).

Table 2. Clinical and operative variables according to overall complication.

Variables	Overall complications		p-value
	Yes	No	
Age (years), mean (SD)	48.3 (12.7)	48.7 (12.5)	0.700
Largest stone diameter (mm), mean (SD)	31.7 (14.6)	28.4 (11.9)	**0.007**
BMI, mean (SD)	27.4 (5.18)	27.3 (5.14)	0.451
Gender (female), n (%)	102 (16.4)	520 (83.6)	0.108
ASA, n (%)			
1–2	145 (14.9)	830 (85.1)	
3–4	14 (15.4)	77 (84.6)	0.896
Number of PCNL, n (%)			
1	110 (14.4)	650 (85.6)	
2	31 (15.3)	171(84.7)	
3 or more	18 (17.3)	86(82.7)	0.707
Guys stone score, n (%)			
1	16 (7.4)	199 (92.6)	
2	38 (13)	255 (87)	
3	65 (17.4)	308 (82.6)	
4	40 (21.6)	145 (78.4)	**<0.001**
Surgical position, n (%)			
Supine	132 (13.7)	829 (86.3)	
Prone	27 (25.7)	78 (74.3)	**0.001**
Surgical time, n (%)			
<90 min	30 (8.5)	325 (91.5)	
≥90 min	129 (18.1)	582 (81.9)	**<0.001**
Number of tracts, n (%)			
1	100 (12.3)	714 (87.7)	
2	46 (23)	154 (77)	
3 or more	13 (25)	39 (75)	**<0.001**
Upper pole puncture			
Yes	44 (29.1)	107 (70.9)	
No	115 (12.6)	800 (87.4)	**<0.001**

Bold indicates statistically significant p-values.

DISCUSSION

PCNL remains the procedure of choice for kidney stones >2 cm and is associated with a high stone-free rate[15]. Despite its high potential for overall complications, PCNL is considered a safe procedure, mainly due to technological advances[15,16]. However, most complications are minor and do not require any additional treatment[7,8].

Our study aimed to identify the predictive factors for complications after PCNL for the treatment of kidney stones in a large number of patients from a single reference center. A retrospective single-center review reported an overall complication rate of 18.3%[16]. These results are very similar to our own findings, in which 159 (14.9%) patients had any kind of complication. In total, 9% had minor complications (Clavien 1–2) and 5.6% had major complications (Clavien ≥3).

Concerning the major complications in our series, 14 (1.3%) had septic shock or severe sepsis requiring management

Table 3. Cox regression analysis for overall complications.

Variables	OR (95%CI)	p value
Position (prone vs. supine)	2.10 (1.28–3.44)	**0.003**
Surgical time (≥90 min vs.<90 min)	1.76 (1.12–2.78)	**0.014**
Upper pole puncture	2.48 (1.63–3.75)	**<0.001**
Guys stone score (GSS)		
GSS 1	1 (reference)	0.097
GSS 2	1.55 (0.82–2.90)	0.169
GSS 3 or 4	1.90 (1,05–3.44)	**0.033**
ASA (3–4 vs. 1–2)	1.13 (0.604–2,14)	0.690
BMI (≥30 vs.<30)	1.18 (0.78–1.79)	0.424
Largest stone diameter	1.00 (0.994–1.02)	0.273
Number of tracts		
1	1 (reference)	0.303
2	1.37 (0.88–2.13)	0.152
3 or more	0.96 (0.44–2.11)	0.935

OR: odds ratio; CI: confidence interval. Bold indicates statistically significant p-values.

in the intensive care unit (ICU). Bleeding requiring transfusion occurred in 48 patients (4.5%). Of these patients, seven had severe bleeding and were also treated in the ICU. It is important to report that severe sepsis, septic shock, and bleeding were the causes of death in four patients in our series. Calculus migration to the ureter occurred in 14 (1.3%) patients and was treated using an endoscopic approach. A total of 15 patients (1.4%) had persistent urinary tract leakage, and eight of them also required double-J stent placement.

We identified several factors associated with the presence of complications, including surgical position, surgical time, number of tracts, GSS classification, and upper pole puncture. In multivariate analysis, the prone position, surgical time ≥90 min, upper pole puncture, and the presence of complex cases (GSS 3 or 4) were independent predictors of complications. It is important to note that surgical characteristics were more common predictors of complications than clinical characteristics.

Prospective and retrospective studies have revealed that patient demographics are not risk factors for complications after PCNL[15]. Thus, although age and BMI are generally considered to be risk factors in all surgeries, they were not statistically significant risk factors for complications after PCNL in this or previous studies.

Female sex has been reported to be an independent predictive factor for complications after PCNL in previous studies[17,18], which is contradictory to our own observations. The complication rates in men and women in our study were 12.8 and 16.4%, respectively (p=0.108).

The ASA classification is a widely accepted method to evaluate perioperative risk and a predictor of postoperative outcome[19]. However, this classification is not specific to urological procedures or to the risk of postoperative complications. In PCNL, the overall rate of complications was similar in patients who were identified as high-risk (ASA III or IV) or low-risk (ASA I or II)[20]. These findings are similar to our own; we found that the ASA score was not a predictive factor of complications after percutaneous surgery (p=0.690). In contrast, Labate et al.[7] showed that each increase in the ASA score increases the risk of complications as well as the chance of major complications in PCNL. It is important to note that all ASA 3 and 4 patients have a specific care protocol that includes invasive arterial blood pressure control, central intravenous access, and postoperative intensive care, developed by the anesthesiologists from our hospital. This protocol may aid in controlling complications in this group of patients.

It is well established that complex stones (GSS 3 and 4) are independent predictive factors for percutaneous complications[21], mainly due to the prolonged procedure time and the need for multiple punctures, including punctures in the upper renal pole. Falahatkar et al.[22] concluded that multiple punctures during PCNL were also predictive factors for complications. In our study, 151 patients (14.2%) underwent upper-pole puncture. The overall complication rate in the group with an upper pole puncture was 29.1%, compared to 12.6% in the group without this puncture (p<0.001). Among patients with an upper pole puncture, 73.5% had GSS 3 or 4. The treatment of complex cases (GSS 3–4) remains a challenge, and staged surgery may decrease complication rates.

Our study demonstrated that surgical time was a predictive factor for complications after PCNL. The overall complication rate for patients whose operating time was longer than 90 min was 18.1% compared to 8.5% among those with a surgical time of less than 90 min (p<0.001). Interestingly, the proportion of males with a score of 3 or 4 was also higher among those with surgical time ≥ 90 min (65.5 vs. 25.9%, p<0.001). Similarly, Labate et al.[7] reported that the risk of more severe postoperative complications increased in those with surgical times greater than 115 min (OR 2.06). It is important to mention that infections are common complications in the treatment of complex kidney stones. Thus, the stones are often colonized by bacteria, and the prolonged fragmentation associated with the irrigation fluid and hydrostatic pressure can translocate bacteria and endotoxins into the circulatory system. Treatment of complex stones is difficult, often requiring multiple punctures, puncture of the upper pole, and longer surgery times.

Regarding surgical position, the prone position has been the preferred position for PCNL in the last few decades. In 1998, Valdivia et al.[23] described the first series of patients who underwent surgery in the supine position. The association between surgical position and complication rates remains unclear. In two recent meta-analyses, surgical position was not associated with the overall complication rate; however, blood loss and fever rates were proportionally lower in the supine position[22,24]. A recent non-randomized prospective study demonstrated a higher rate of overall complications in the prone position compared to the supine position (18 vs. 8%)[25]. In our series, the complication rate in patients that underwent prone PCNL was twice as high as that noted in patients that underwent supine PCNL (OR, 2.10; 95% confidence interval 1.28–3.44, p=0.003). The proportion of complex cases (GSS 3 or 4) in the two groups was similar (p=0.401), but the surgical time ≥90 min was proportionally higher in those that underwent surgery in the prone position (82.9 vs. 64.9%) (p<0.001). Of note, only 105 patients underwent surgery in the prone position at the beginning of our series, which may represent a potential bias. Currently, this approach is reserved for specific cases and randomized studies.

Finally, this study has some limitations worth noting. It is a historical series from a single reference center with the limitations of a retrospective study. In addition, the analyses were not performed after adjustment for stone features and clinical parameters. Nevertheless, the results from this single-center study are valuable as the analysis was performed using data from the largest database in Brazil to date.

CONCLUSION

Performing PCNL in the supine position, reducing surgical time to less than 90 min, and avoiding upper pole punctures may reduce complications during the treatment of large kidney stones.

ETHICAL APPROVAL

All procedures performed in the study were in accordance with the ethical standards of the local Research Committee and with the 1964 Helsinki Declaration and its later amendments.

INFORMED CONSENT

Informed consent was obtained from patients.

AUTHORS' CONTRIBUTIONS

DFS: Conceptualization, Data curation, Formal Analysis, Methodology, Writing – original draft, Writing – review & editing. **DBF:** Conceptualization, Data curation, Formal Analysis, Software, Writing – original draft, Writing – review & editing. **KKREH:** Data curation, Formal Analysis, Investigation. **RP:** Data curation, Formal Analysis, Methodology. **PKVM:** Data curation. **DJC:** Data curation. **CAB:** Data curation. **CBM:** Data curation, Project administration, Visualization. **JFAC:** Supervision. **FCV:** Conceptualization, Data curation, Formal Analysis, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

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