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Predictive factors for success after supine percutaneous nephrolithotomy: an analysis of 961 patients

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SUMMARY

OBJECTIVE: The aim of this study was to evaluate the predictive factors for success following percutaneous nephrolithotomy in the supine position.

METHODS: Patients who underwent percutaneous nephrolithotomy in the supine position from June 2011 to October 2018 were evaluated. Age, sex, body mass index, the American Society of Anesthesiologists physical status classification, hemoglobin level, number of previous surgeries, stone size, and the Guy's Stone Score were analyzed. Success was considered if no fragments were observed on the computed tomography scan on the first postoperative day. Univariate and multivariate analyses were performed to determine significant parameters.

RESULTS: We evaluated 961 patients; of them, 483 (50.2%) underwent previous stone-related surgery, and 499 (51.9%) had Guy's Stone Score 3 or 4. The overall success rate in a single procedure was 40.7%, and complication rate was 13.7%. The univariate analysis showed that the maximum diameter of the stone (25.10±10 mm; p<0.001), previous percutaneous nephrolithotomy (OR 0.52; p<0.001), number of previous percutaneous nephrolithotomy (OR 0.15; p<0.001), the Guy's Stone Score (OR 0.28; p<0.001), and the number of tracts (OR 0.32; p<0.001) were significant. In the multivariate analysis, the number of previous percutaneous nephrolithotomy (OR 0.54; p<0.001) and the Guy's Stone Score (OR 0.25; p<0.001) were statically significant.

CONCLUSIONS: Guy's Stone Score and the number of previous percutaneous nephrolithotomy are predictors of success with the supine position. Complex cases and with previous percutaneous interventions may require technical improvements to achieve higher stone-free rates.

KEYWORDS: Computed tomography. Kidney stone. Nephrolithiasis. Percutaneous nephrolithotomy. Supine position.

INTRODUCTION

The complete removal of kidney stones is the main objective in treating urinary stones. Failure can lead to complications, increased readmission rates, reoperation, and economic implications for the patients and the health system[1]. To date, stone size is the major parameter for choosing the treatment method, and percutaneous nephrolithotomy (PCNL) is currently recommended for kidney stones of up to 20 mm by the European Association of Urology and American Urological Association guidelines[2].

First described in 1976 by Fernström and Johansson[3], the PCNL in prone position was followed by the first supine position technique description in 1987[4]. The technique evolved, new equipments and endoscopes allowed better outcomes, and decreased complication rates. Comparing positioning, both have similar success rates, although recently, the supine approach has become more widely accepted. The possibility of performing all procedures in the supine position, its easy anesthetic management, and a safe profile are positive characteristics[5-7].

Several parameters may affect the stone-free rate such as the stone size, density and complexity, the anatomical variations, and the patient profile (e.g., body mass index [BMI] and comorbidities). Recent reports suggest that greater sensitivity and specificity make computed tomography (CT) the best tool to evaluate success[8-11].

To address this knowledge, we conducted a study to define predictors of stone-free rate after PCNL in the supine position in a large series of patients, evaluated by CT scan.

METHODS

A retrospective analysis of prospectively collected data was performed including all consecutive adult patients who underwent supine PCNL between June 2011 and October 2019 in a single center. Informed consent was obtained from patients preoperatively, and the study protocol was approved by the local ethics committee (institutional review board number: 8258117.8.0000.0091).

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Indications for surgery were single or multiple renal stones >2 cm in size and symptomatic stones <2 cm wherein first-line techniques (shockwave lithotripsy or ureteroscopy) failed. Prior to surgery, the variables analyzed were age, sex, BMI, American Society of Anesthesiologists (ASA) physical status classification, hemoglobin level, previous surgeries, stone diameter (maximum diameter defined as the cumulative size of the stones), history of spina bifida or spinal injury, and the Guy's Stone Score (GSS). The GSS, routinely evaluated in all cases, was determined by a urologist during the preoperative consultation by CT scan analysis and was confirmed just before the surgery. All urologists were previously trained in GSS.

Operative technique

All the supine PCNL procedures were performed under general anesthesia. Beginning with cystoscopy and placement of a 6-Fr ureteral catheter, a retrograde pyelogram and subsequent calyceal puncture were performed by the main surgeon under fluoroscopic and ultrasonic guidance. Subcostal skin punctures were preferred, although supracostal punctures through the 11th and 10th intercostal spaces were also used when necessary. Semirigid plastic dilators set (Amplatz dilators®) were used to sequentially dilate the tract up to 30 Fr. Nephroscopy was performed with a 26-Fr nephroscope (Karl Storz®, Germany), and stone fragmentation was performed with an ultrasonic lithotripter (Swiss Lithoclast Master®, EMS, Switzerland).

Intraoperative stone-free status was verified with 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 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. Of note, 20 mL of 1% ropivacaine was injected on the tracts at the end of the surgery.

Outcome evaluation

A low-dose non-contrast CT scan was routinely performed on POD1 in all cases. The success rate was defined as the absence of any residual fragments (RFs) (i.e., stone-free rate).

Statistical analysis

Software R Core 3.5.1 (Microsoft®, USA) was used for statistical analysis. Continuous variables were described by mean and standard deviations. Categorical variables were described by simple and relative frequencies. Odds ratio (OR) were presented using logistic regression. For the variables with a lower number of observations, the Fisher's test was used. Statistical significance was set at 0.05.

RESULTS

We enrolled 961 patients in the study. The mean age and BMI were 48.8±12.6 years and 27.4±5.1 kg/m², respectively (Table 1); 483 (50.2%) patients had previous stone-related surgery, and 499 (51.9%) had GSS 3 or 4 (complex cases). The overall success rate in a single procedure was 40.7% (Table 2), and the complication rate was 13.7%.

A univariate analysis of the continuous variables targeting the success outcome observed a statistical significance in maximum diameter (OR 0.95 [0.94 – 0.96]; p<0.001). The median size for RFs was 15.2±9.3 mm. There was no statistical significance in BMI (Table 2).

In the univariate analysis, previous PCNL (OR 0.52 [0.36; 0.75]; p<0.001), the number of previous PCNL (OR 0.15 [0.13; 0.33]; p<0.001), the GSS (OR 0.28 [0.18; 0.42]; p<0.001), and the number of tracts (OR 0.32 [0.21; 0.46]; p<0.001) were significant (Table 2).

After choosing the variables with statistical significance and performing a multivariate analysis, ORs and p-values were obtained, and the number of previous PCNL (OR 0.54 [0.42; 0.69]; p<0.001) and the GSS (OR 0.25 [0.13; 0.47]; p<0.001) were found to be significant (Table 3).

Table 1. Patient demographic and clinical characteristics.

	Total (n=961)
Sex; n (%), Female	551 (57.3)
Age; Mean (SD)	48.8 ± 12.6
BMI (kg/m²); Mean (SD)	27.4 5.1
Mean stone size; Mean (SD)	28.8±11.9
ASA; n (%)	
1	319 (33.2)
2	553 (57.5)
3 or more	89 (9.3)
Interventional stone treatments; n (%)	
None	468 (48.7)
Open surgery	44 (4.6)
ESWL	154 (16.1)
PCNL	184 (19.1)
Others	111 (11.5)
Guy's Stone Score; n (%)	
1	192 (19.9)
2	270 (28.1)
3	335 (34.9)
4	164 (17.1)

BMI: body mass index; ASA: American Society of Anesthesiologists; ESWL: external shock wave lithotripsy; PCNL: percutaneous nephrolithotomy.

DISCUSSION

Several factors influenced the previous underuse of supine PCNL, among them, the lack of experience in most urology centers[12] and the fear of colonic injuries. However, this scenario has been changing worldwide, and approximately 20% of centers use this technique currently[13], reaching up to 45% in certain locations[14] and 38.9% in Latin America[15]. Any of the supine position variations do not have an impact on success or complications compared to the prone position[16], and the supine position can be easily learned when training is done in a proper center.

This study involves 961 patients, operated in a single center, by 6 surgeons. All the surgeons have experience in both prone and supine positions and in using the standard technique in all cases. In the univariate analysis, the stone diameter, the time of fluoroscopy, the operative time, and the drop of hemoglobin were associated with residual stones. However, some of these factors (i.e., fluoroscopy and operative time) cannot be determined as a cause as they are essentially a consequence of more complex cases, which are reportedly associated with lower success rates[17].

The stone diameter was proven to be a predictor of success as shown in a study by Pérez-Fentes et al.[18] when stone burden was described as a predictor of being stone free. BMI has been demonstrated to not influence success in supine PCNL[19].

Previous kidney surgery, previous PCNL, and the number of previous PCNL had a negative impact on success rates, probably due to anatomic variations in the urinary tract such

Table 3. Multivariate analysis for predictive factors for success.

	Odds ratio [95%CI]	p-value
Number of previous PCNL	0.545 [0.423–0.689]	<0.001
Guy's Stone Score 2	0.337 [0.220–0.512]	<0.001
Guy's Stone Score 3	0.211 [0.134–0.328]	<0.001
Guy's Stone Score 4	0.250 [0.129–0.475]	<0.001
Number of tracts	0.975 [0.729–1.285]	0.861
Mean stone size	0.986 [0.972–1.001]	0.069

AUC 0.766 [0.736; 0.796]; PCNL: Percutaneous nephrolithotripsy.

Table 2. Univariate analysis according to outcoming stone free.

Variables	Stone-free status		Odds ratio [95%CI]	p-value
	Any residual stone (n=570)	Stone free (n=391)		
Age (years)	48.2±12.5	49.8±12.7	1.01 [1.00–1.02]	0.046
BMI (kg/m²)	27.3±5.3	27.4±4.9	1.01 [0.98–1.03]	0.85
Drop in hemoglobin level (g/dl)	2.2±1.4	1.9±1.2	0.82 [0.74–0.91]	<0.001
Mean stone size (mm)	31.4±13.7	25.2±9.3	0.95 [0.94–0.96]	<0.001
Hospital stay (h)	63.1±41.7	52.4±50.8	0.99 [0.99–1.00]	0.03
Operative time (min)	117.7±47.5	91.1±45	0.98 [0.98–0.99]	<0.001
Fluoroscopy time (min)	11.7±4.8	10.5±3.8	0.94 [0.92–0.95]	<0.001
Previous interventional stone treatments				
Open surgery		44	0.455 [0.215–1.894]	0.051
ESWL		154	1.474 [1.023–2.127]	0.063
PCNL		184	0.523 [0.358–0.754]	0.001
Guy's Stone Score				
1		192	1 (reference)	<0.001
2		270	0.279 [0.185–0.416]	<0.001
3		335	0.126 [0.083–0.188]	<0.001
4		164	0.081 [0.048; 0.132]	
Number of tracts				
1		729	1 (reference)	
2		182	0.314 [0.212–0.456]	<0.001
3 or more		50	0.404 [0.204–0.754]	0.006

BMI: body mass index; ESWL: external shock wave lithotripsy; PCNL: percutaneous nephrolithotomy.

as infundibular and calyx stenosis. Furthermore, the number of tracts and the GSS had a negative impact. Souza Melo et al.[17] validated and demonstrated that the GSS directly impacts surgery outcome of supine and prone PCNL and that the number of tracts may be related to the complexity of the case.

Multivariate analysis has shown importance of the GSS on success analysis. This nomogram can be easily used in preoperative evaluations, and it is quicker than S.T.O.N.E. score and CROES nomogram[20]. We also can use it to brief patients on postoperative results before the surgery. As GSS and the number of previous PCNL were predictive factors of success, we should be prepared for lower success rates in complex cases, and we must consider the use of other resources such as endoscopic combined intrarenal surgery (ECIRS)[21]. ECIRS is an important technique to increase success rates[22]. Regarding the antegrade flexible nephroscope use at the end of surgery, Gokce et al.[23] recently demonstrated that the retrograde approach may improve outcomes as more calyces can be reached and more fragments can be removed in this manner.

Comparing our success rates with previous results, we have obtained relatively poor results with our overall success rate at only 40.7% against the 75.7% of CROES PCNL global study[5]. This may be due to our high proportion of complex cases with only 31.69% of GSS 1. We have adopted the staged procedure for complex cases (GIII and GIV) to reduce complications. In these complex cases, we removed all pelvic stones for up to 90 min, lowered the middle pole, and left only the upper pole for the second procedure. If the patient is doing well within the 90-min duration, we continued the procedure. Many cases underwent a similar approach; therefore, it may be reflective of the relatively low success rate of a single procedure. Recently, Krambeck et al.[24] proved in a multi-institutional study, success rates on POD1 similar to ours (44.4%) with this approach. Furthermore, the use of CT on POD1 is a very rigorous criterion. We have decided to use CT, despite its radiation exposure, because of its precision in showing the immediate success rate and eventual complications. Moreover, in cases of residual stones, planning the next procedure will be necessary.

Ultrasound and kidney-urinary-bladder (KUB) imaging cannot demonstrate real success[5]. Antonelli et al.[9] compared CT with KUB and concluded that CT is the optimal post-PCNL imaging modality to detect RFs. It is also important to note that the CT scan can prematurely evaluate organ lesions. Some groups consider clinically insignificant fragments smaller than 2 mm; however, those smaller than 4 mm as RF, in accordance with Raman et al.'s study[1] that demonstrated that second-look flexible nephroscopy is not cost-efficient for RF ≤4 mm. The definition of stone-free status remains a point of debate. The evaluation of the patients on POD1 could provide lower numbers of stone-free patients even with the current definition since the RFs need some time to be expelled.

This retrospective study has limitations such as the problem of radiation exposure on performing CT on POD1 and the lower success rates. Nevertheless, we also want to highlight that this was a single-center study with a large number of patients wherein the standardized technique was employed, the consolidation of the use of GSS, and the importance of patient history in predicting the success with PCNL.

Therefore, it is important to note the use of GSS on preoperative evaluation, to advise patients on the success probability, and to expect lower success rates when the patient has previous PCNL. These observations may lead to technical improvement, as the use of retrograde nephroscopy at the end of the surgery has been a good option for checking patient status when being stone free is expected according to final fluoroscopy.

CONCLUSION

GSS and the number of previous PCNL are predictors of success with the supine position. Complex cases and with previous percutaneous interventions may require technical improvements to achieve higher stone-free rates.

AUTHORS' CONTRIBUTIONS

KKRH: Data curation, Formal analysis, Investigation, Writing – original draft. **RP:** Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Writing – original draft. **DBF:** Data curation, Formal analysis, Software. **CAB:** Data curation, Methodology. **PKVM:** Data curation. **DJC:** Data curation. **CBM:** Data curation, Project administration, Visualization. **JFAC:** Supervision. **FCV:** Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Supervision, Writing – original draft.

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