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ORIGINAL ARTICLE

Comparison of safety and efficacy of one shot dilation vs. gradual dilation technique in supine percutaneous nephrolithotomy

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Abstract

Purpose To compare the efficacy and safety of gradual dilation (GD) and one-shot dilation (OSD) techniques in patients who underwent supine percutaneous nephrolithotomy (PCNL).

Methods The data of 176 patients who underwent supine PCNL were reviewed. Eighty-seven patients who underwent OSD were defined as group 1, and 89 patients who underwent GD were defined as group 2. Both surgical techniques were compared with each other in terms of various parameters. Then, regression analysis of factors predicting stone-free status and complications in patients who underwent supine PNL were performed. Then, regression analysis of factors predicting success rate and complications in patients who underwent supine PNL were performed.

Results No statistical difference was found in terms of stone-free rate, Clavien–Dindo complication grade and operation time. No statistical difference was found in terms of success rate, Clavien–Dindo complication grade and operation time. However, the fluoroscopy time was found to be significantly shorter in group 1 ($p<0.001$). In the analysis of factors predicting stone-free status, the presence of calyceal stones, increased stone size and number were associated with a decrease in stone-free rate. In the analysis of factors predicting success, the presence of calyceal stones, increased stone size and number were associated with a decrease in success rate. Increased fluoroscopy and operation time, increased complication rates were found to be significantly associated with residual stone. Analysis of factors predicting complications found a higher complication rate in patients with low BMI and severe hydronephrosis. Increased complication was associated with increased time to nephrostomy removal and hospital stay, decrease in stone-free rate, decrease in Hb and increase in Cre value at the postoperative 24th hour.

Conclusion When comparing OSD and GD in patients undergoing supine PCNL, both techniques have similar stone-free and complication rates. When comparing OSD and GD in patients undergoing supine PCNL, both techniques have similar success and complication rates. Compared to GD, the OSD technique can be preferred primarily due to its shorter fluoroscopy time.

Keywords Percutaneous nephrolithotomy · Supine percutaneous nephrolithotomy · Gradual dilation · One-shot dilation

Introduction

Percutaneous nephrolithotomy (PCNL) is the first-line treatment option for large sized kidney stones [1]. Initially, the percutaneous approach to the kidney was described with patients in the prone position [2]. The first explanation regarding the feasibility of the supine position in PCNL was made by Valdivia et al. [3]. Supine PCNL has many advantages over the traditional prone position. Thanks to this position, there is no need to change the position of the patient during surgery [4]. At the same time, the supine position is safer than the prone position, as it reduces the risk of complications and fever [5].

The most important steps of PCNL are percutaneous access using a needle into the renal collecting system and widening of the percutaneous access tract. These stages are directly related to the success and complications of PCNL [6]. Today, dilation methods in PCNL can be basically classified as one-shot dilation (OSD), gradual dilation (GD) and balloon dilation.

The GD is mainly used in Asia and South America, and balloon dilatation is used in North America. This is likely

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to occur due to the high costs and lack of training associated with balloon dilation [7]. OSD is accepted as a simpler, safe and effective technique associated with reduced fluoroscopy time [8]. There are studies in the literature investigating the effects of different dilation techniques on the complications and success of prone PCNL. However, there is no study comparing GD with Amplatz and OSD techniques in supine PCNL.

In this study, it was aimed to compare the efficacy and safety of GD and OSD techniques in patients who underwent supine PCNL in Galdakao-modified Valdivia position (GMVP).

Materials and methods

This study was carried out with the approval of the ethics committee of the University of Health Sciences Izmir Tepecik Health Practice and Research Center (Decision No: 2021/11-20). The data of patients who underwent supine PCNL in GMVP between November 2019 and June 2022 in our clinic were reviewed. Patients younger than 18 years of age, with solitary kidney, with kidney anomaly, with active infection or bleeding disorder, and who underwent simultaneous retrograde intrarenal surgery were excluded from the study. A total of 176 patients who had kidney stones with a long axis of 20–40 mm and underwent conventional PCNL (dilated up to 30 Fr Amplatz dilator) were reviewed. As a result, 87 patients who underwent OSD were defined as group 1, and 89 patients who underwent GD were defined as group 2.

All patients were evaluated with kidney–ureter–bladder (KUB) radiography and non-contrast computed tomography (NCCT) of the abdomen preoperatively. Presence of complications was defined according to the Clavien–Dindo classification [9]. Severe hydronephrosis was defined as grade 3 or higher hydronephrosis. Success rate was evaluated with NCCT at the postoperative 1st month. After PCNL, residual fragments of 4 mm or less were considered as success.

Operation

All surgeries were performed by three surgeons experienced in prone PCNL, supine PCNL and endourology. One of the three experienced endourologists preferred OSD in the supine position and two preferred GD due to hypermobility of the kidney. However, over time, all three surgeons performed OSD. General anesthesia was applied to all patients on a table compatible with C-arm. For supine PCNL, the patients were placed in GMVP. Under fluoroscopic control, the appropriate calyx was accessed with an 18 Gauge (Boston Scientific Corporation, Natick MA) needle. A guide wire (SensorTM Guide Wire, Boston Scientific) was placed in the collecting system. The fascia was dilated with a 12 Fr fascial dilator over the wire. A 30 Fr Amplatz renal dilator (Boston Scientific Corporation, Natick MA) was placed directly in the patients in group 1 without performing GD. Dilation was achieved with 16 Fr, 20 Fr, 24 Fr and 30 Fr Amplatz dilators, respectively, in patients in group 2. In both groups, the stones were fragmented with the help of a pneumatic lithotripter after entering the collecting system with a 26 Fr rigid nephroscope (Karl Storz GmbH, Tuttlingen, Germany) through the 30Fr Amplatz sheath. The fragmented pieces were removed with the help of extractors. Since there was no flexible nephroscope in our clinic, it could not be used in any patient.

Statistical analysis

Data analysis was performed with SPSS version 22.0 (SPSS Inc., IBM, NY, USA). One-sample Kolmogorov–Smirnov test was used to evaluate the normality of distribution in quantitative data. The mean ± standard deviation (SD) was found in the normally distributed data. Median (interquartile range (IQR)) values were recorded in data that did not show normal distribution. Comparison of normally distributed independent quantitative variables such as age, weight and preoperative hemoglobin value between the two groups was evaluated with Student's *t* test, while the others were evaluated with the Mann–Whitney *U* Test. The differences between the two groups in terms of independent variables such as gender, side and location of the stone, presence of residual stone, complication, hydronephrosis and previous stone surgery history were analyzed with Pearson chi-square or Fisher's exact tests. The level of significance was defined as $p < 0.05$. Independent risk factors predicting success and complication of supine PCNL were determined by using binary logistic regression analysis. Multivariate analysis was performed using parameters with p value less than 0.100 in univariate analysis.

Results

Considering the exclusion criteria, 176 patients who underwent supine PCNL in GMVP in our clinic between November 2019 and June 2022 were included in the study. Eighty-seven patients who underwent OSD were defined as group 1, and 89 patients who underwent GD were defined as group 2.

When the data of the patients in both groups were examined, no difference was observed in BMI and stone skin distance. When the number, location, size, Hounsfield unit (HU) value, opacity of stones, the presence and severity of hydronephrosis and history of stone surgery were evaluated, no statistical difference was found. There was no significant difference in transfusion rate and hemoglobin

(Hb) and creatinine (Cre) values in the preoperative and postoperative period between two groups.

The mean operation time was 75.8 min in group 1 and 81 min in group 2 ($p = 0.126$). While the mean fluoroscopy time was 50.7 s in group 1, it was 62.6 s in group 2, and a statistically significant difference was found ($p < 0.001$).

The success rate was 86.2% in group 1 and 80.9% in group 2 ($p = 0.343$). There was no significant difference between the two groups in Clavien–Dindo classification grades ($p = 0.705$). Grade 4 and Grade 5 complications and access failure did not occur in any patient (Table 1).

In the univariate and multivariate logistic regression analysis of the factors predicting success in patients who underwent supine PCNL, it was shown that calyceal stones, increased stone size and number caused a decrease in success rate. Increased fluoroscopy and operation time and complications were associated with the presence of residual stones. Dilation technique, body mass index (BMI), presence and severity of hydronephrosis were not found to be associated with success rate (Table 2).

In the univariate and multivariate logistic regression analysis of the factors predicting complications in patients who underwent supine PCNL, a higher complication rate was found in patients with low BMI and severe hydronephrosis. Stone-skin distance, dilation technique, stone location, number, size, operation and fluoroscopy time were not associated with complications. It was determined that increased complication was associated with prolongation of time to removal of nephrostomy and length of hospital stay, decrease in stone-free rate, decrease in Hb and increase in Cre value at the postoperative 24 h (Table 3).

Discussion

The supine position has become popular in PCNL in recent years. In a study published in 2015, the Clinical Research Office of the Endourology Society Percutaneous Nephrolithotomy Global Study reported that 19.7% of patients were operated in the supine position [10]. Supine PCNL is being adopted more and more by urologists.

Davidoff et al. suggested that replacing each dilator during GD alleviates the tamponade effect in the renal parenchyma and more blood loss will occur during the dilator replacement procedure [11]. During GD with Amplatz dilators, insertion and removal of each dilator is time-consuming and can cause bleeding. The OSD technique was developed to reduce blood loss during the insertion of larger dilators and to skip this step quickly [12]. For fewer complications to occur, the most reliable dilation method must be found [13].

One of the most important disadvantages of the supine position is that the kidney is generally more mobile in the supine than in the prone position [14]. Particularly during GD, the rotational movement of the sheath leads to kidney mobilization. During the GD, renal mobilization may occur and the guide wire may be mispositioned or removed [15]. In addition, incorrect positioning of the Amplatz sheath, perforation of the collecting system and bleeding may occur during dilations [16].

All studies comparing GD and OSD were performed in the prone position. A high stone-free rate is an important indicator of the effectiveness of PCNL. In the meta-analysis of Peng et al. [8] in which they compared GD and OSD techniques in PCNL, the stone-free rate was found to be 89.9% in the GD arm and 88.5% in the OSD arm ($p = 0.52$). No significant difference was found between GD and OSD in terms of stone-free rate in any of the 7 studies included in the meta-analysis. These results are in line with other meta-analyses comparing the dilation technique [17, 18].

In a meta-analysis in which Wu et al. investigated the efficacy and safety of four different dilation methods in PCNL, it was stated that OSD is a safer method than GD in almost all adult patients [19]. In the study of Peng et al. in which the complication rates of GD and OSD techniques were compared, no significant difference was found between the groups, similar to our study [18]. However, it should be kept in mind that these studies in the literature are evaluations for patients who underwent prone PCNL.

Supine PCNL reduces the surgeon's exposure to radiation since the surgeon's hands are not directly under the X-ray. In prone PCNL, the probability of the surgeon's hands being within the radiation field is significantly higher [14]. The need to use fluoroscopy for the placement and control of each dilator during the GD procedure increases the radiation exposure [20]. In two different meta-analyses comparing GD and OSD techniques in prone PCNL, it was found that the fluoroscopy time was statistically significantly shorter in the OSD, similar to our study [8, 17].

In the first study in the literature in which OSD was applied in supine PCNL, the mean operation time was 54.8 min, and the mean fluoroscopy time was 142 s [21]. The results of the study are similar to the OSD-applied arm of our study. In this study, access success was found to be 97.8%, and failure of access was attributed to renal hypermobility in 4 patients and previous surgeries in 3 patients. However, the most important limitation of this study is that it is observational, there is no control group and it does not contain information about the stone-free rate. The only study comparing different dilation techniques in supine PCNL [22] used Barts flank-free modified supine position and compared OSD with metal telescopic dilation technique. In this study, the decrease in Hb value was lower, and fluoroscopy time and length of hospital stay were shorter in the OSD group. There was no difference between the complications.

Table 1 Demographic and clinical characteristics of the groups

	Group 1 (*n* = 87)	Group 2 (*n* = 89)	*P* value
Mean age, year ± SD	45.6 ± 11.6	47.2 ± 13.7	0.393 T
Gender, *n* (%)			0,148P
Female	28 (32.2)	20 (22.5)	
Male	59 (67.8)	69 (77.5)	
ASA score, *n* (%)			0.510 M
ASA 1	17 (19.5)	22 (24.7)	
ASA 2	60 (69)	57 (64)	
ASA 3	10 (11.5)	10 (11.2)	
Mean BMI, kg/m^2 ± SD	27.4 ± 3.8	26.8 ± 3.3	0.277 T
CCI, median (min–max)	0 (1–7)	0 (1–6)	0.235 M
Surgical history, *n* (%)			0.996P
Primary	42 (48.3)	43 (48.3)	
Secondary	45 (51.7)	46 (51.7)	
Mean number of stones ± SD	1.8 ± 1.0	1.7 ± 0.8	0.477 T
Multiplicity, *n* (%)	47 (54)	46 (51.7)	0.756P
Side (Right/Left)	52/35	35/54	**0.007P**
Location, *n* (%)			0.427P
Renal pelvis	31 (35.6)	36 (40.4)	
Calyceal	8 (9.2)	12 (13.5)	
Renal pelvis + Calyceal	48 (55.2)	41 (46.1)	
Mean size, mm ± SD			
Length	27.0 ± 7.3	26.1 ± 6.4	0.394 T
Width	16.3 ± 6.0	15.7 ± 5.2	0.485 T
Mean HU value ± SD	1015.2 ± 316.2	1037.1 ± 305.5	0.641 T
Opacity, *n* (%)			0.445P
Opaque	81 (93.1)	80 (89.9)	
Non-opaque	6 (6.9)	9 (10.1)	
Mean stone-skin distance, mm ± SD	99.3 ± 22.5	99.2 ± 19.7	0.964 T
Presence of hydronephrosis, *n* (%)	67 (77)	69 (77.5)	0.935P
Hydronephrosis, *n* (%)			0.798P
No	20 (23)	20 (22.5)	
Mild (Grade 1–2)	43 (49.4)	48 (53.9)	
Severe (Grade 3–4)	24 (27.6)	21 (23.6)	
Access site, *n* (%)			0.553P
Upper calyces	1 (1.1)	0	
Middle calyces	9 (10.3)	11 (12.4)	
Lower calyces	77 (88.5)	78 (87.6)	
Mean fluoroscopy time, sec ± SD	50.7 ± 20.4	62.6 ± 23.8	**< 0.001 T**
Drainage method, *n* (%)			0.690P
Nephrostomy	77 (88.5)	77 (86.5)	
Totally tubeless	10 (11.5)	12 (13.5)	
Mean operation time, min ± SD	75.8 ± 22.1	81.0 ± 23.1	0.126 T
Mean preoperative Hb (gr/dL) ± SD	14.4 ± 1.4	14.4 ± 1.8	0.979 T
Mean postoperative 1-h Hb (gr/dL) ± SD	13.4 ± 1.5	13.6 ± 1.8	0.384 T
Postoperative 24-h Hb (gr/dL) ± SD	12.4 ± 1.6	12.6 ± 1.7	0.331 T
Preoperative Cre (mg/dL), median (min–max)	0.86 (0.6–1.6)	0.90 (0.6–1.8)	**0.029 M**
Postoperative 1-h Cre (mg/dL), median (min–max)	0.90 (0.6–1.8)	0.97 (0.6–1.7)	0.093 M
Postoperative 24-h Cre (mg/dL), median (min–max)	0.90 (0.6–1.8)	1.0 (0.6–1.9)	0.167 M
Transfusion rate, *n* (%)	3 (3.4)	1 (1,1)	0.365F
Time to nephrostomy removal, day, median (min–max)	1 (1–7)	1 (1–7)	0.732 M
Clavien–Dindo complication grade, median (min–max)	0 (0–3)	0 (0–3)	0.705 M

Table 1 (continued)

	Group 1 ($n=87$)	Group 2 ($n=89$)	*P* value
Clavien–Dindo complication			
Grade 1	7	14	
Grade 2	3	1	
Grade 3	3	1	
Success rate, *n* (%)	75 (86.2)	72 (80.9)	0.343
Length of hospital stay, day, median (min–max)	1 (1–5)	1 (1–7)	0.124 M

ASA American Society of Anesthesiologists, *BMI* Body mass index, *CCI* Charlson comorbidity index, *HU* Hounsfield unit, *Hb* hemoglobin, *Cre* creatinine, *SD* standard deviation, *T* Student's *t* test, *M* Mann–Whitney *U* test, *P* Pearson chi-square test, *F* Fisher's exact test

Table 2 Univariate and multivariate logistic regression analysis of factors predicting success in patients undergoing supine PCNL

	Univariate analysis			Multivariate analysis		
	RR	%95CI	*P* value	RR	%95CI	*P* value
Age	1.014	0.982–1.047	0.404			
Gender (ref: Male)	0.981	0.402–2.394	0.967			
BMI	0.966	0.864–1.080	0.545			
CCI	1.033	0.798–1.338	0.804			
ASA score	1.879	0.918–3.846	0.084			
Surgical history	1.646	0.734–3.689	0.226			
Location (ref: renal pelvis)	0.382	0.215–0.681	**0.001**			
Side (ref: right)	1.116	0.503–2.476	0.787			
Number	0.515	0.342–0.777	**0.002**			
Size	0.895	0.844–0.948	**< 0.001**	0.881	0.828–0.939	**< 0.001**
HU value	1.000	0.999–1.002	0.657			
Stone-skin distance	0.996	0.977–1.014	0.643			
Non-opaque (ref: opaque)	0.770	0.203–2.921	0.701			
Presence of hydronephrosis	1.369	0.555–3.380	0.496			
Severe Hydronephrosis	0.904	0.509–1.606	0.731			
Access site (ref: lower calyx)	0.884	0.293–2.667	0.827			
One-shot dilation (ref: gradual)	0.678	0.302–1.518	0.344			
Nephrostomy (ref: totally tubeless)	1.458	0.685–3.105	0.328			
Fluoroscopy time	0.982	0.966–0.998	**0.031**	0.978	0.960–0.996	**0.018**
Operation time	0.981	0.964–0.997	**0.020**			
Time to nephrostomy removal	0.813	0.639–1.034	0.092			
Transfusion rate	0.186	0.025–1.379	0.100			
Complication	0.350	0.140–0.876	**0.025**	0.288	0.106–0.785	**0.015**
Length of hospital stay	1.251	0.839–1.863	0.272			
Preoperative Hb	0.843	0.648–1.097	0.204			
Preoperative Cre	1.755	0.206–14.951	0.607			
PO 1-h Hb	1.003	0.788–1.277	0.978			
PO 1-h Cre	0.486	0.081–2.904	0.429			
PO 24-h Hb	1.131	0.893–1.434	0.308			
PO 24-h Cre	1.231	0.200–7.589	0.823			

RR relative risk, *CI* confidence interval, *ASA* American Society of Anesthesiologists, *BMI* Body mass index, *CCI* Charlson comorbidity index, *HU* Hounsfield unit, *Hb* hemoglobin, *Cre* creatinine, *PO* postoperative

Table 3 Univariate and multivariate logistic regression analysis of factors predicting complications in patients undergoing supine PCNL

	Univariate analysis			Multivariate analysis		
	RR	%95CI	*P* value	RR	%95CI	*P* value
Age	0.969	0.937–1.001	0.061			
Gender (ref: Male)	0.652	0.248–1.715	0.386			
BMI	0.870	0.771–0.981	**0.024**	0.825	0.707–0.964	**0.015**
CCI	0.823	0.608–1.115	0.208			
ASA score	0.608	0.299–1.236	0.169			
Surgical history	0.719	0.323–1.600	0.419			
Location (ref: renal pelvis)	1.018	0.664–1.561	0.935			
Side (ref: right)	1.200	0.787–1.829	0.396			
Number	0.996	0.939–1.056	0.890			
Size	1.000	0.999–1.002	0.508			
HU value	0.992	0.973–1.012	0.447			
Stone-skin distance	0.764	0.163–3.580	0.732			
Non-opaque (ref: opaque)	0.910	0.357–2.316	0.843			
Presence of hydronephrosis	1.891	1.034–3.458	**0.039**	4.189	1.198–14.651	**0.025**
Severe Hydronephrosis	2.503	0.968–6.470	0.058			
Access site (ref: lower calyx)	1.248	0.561–2.777	0.588			
One-shot dilation (ref: gradual)	0.882	0.463–1.679	0.702			
Nephrostomy (ref: totally tubeless)	1.006	0.990–1.023	0.456			
Fluoroscopy time	1.010	0.994–1.027	0.223			
Operation time	1.516	1.189–1.931	**0.001**	1.546	1.143–2.090	**0.005**
Time to nephrostomy removal	0.350	0.140–0.876	**0.025**			
Transfusion rate	1.842	1.352–2.509	**< 0.001**			
Complication	0.974	0.761–1.247	0.863			
Length of hospital stay	2.952	0.448–19.452	0.260			
Preoperative Hb	0.913	0.719–1.158	0.452			
Preoperative Cre	2.040	0.341–12.196	0.434			
PO 24-h Hb	0.807	0.637–1.024	0.078	0.629	0.456–0.867	**0.005**
PO 24-h Cre	4.494	0.895–22.574	0.068	10.462	1.526–71.719	**0.017**

RR relative risk, *CI* confidence interval, *ASA* American Society of Anesthesiologists, *BMI* Body mass index, *CCI* Charlson comorbidity index, *HU* Hounsfield unit, *Hb* hemoglobin, *Cre* creatinine, *PO* postoperative

In the prospective study of Curry et al. in which they evaluated supine PCNL in GMVP, success rate was found to be 80.5%, similar to our study [23]. While the operation time was 79 min, similar to our results, the mean fluoroscopy time was 533 s, which was quite long compared to our results. This difference may be due to the continuous use of fluoroscopy during the dilation procedure. In order to shorten the fluoroscopy time, it may be appropriate to take images intermittently during the access and dilation procedure. Both Curry et al. [23] and Falahatkar et al. [24] emphasized the relationship between stone burden and stone-free rate in supine PNL.

In our study stone parameters (opacity, number, size, location) were found to be unrelated to complications, similar to studies in the literature [25, 26]. In a study in which complete supine PCNL was performed and the factors predicting complications were investigated, it was observed that as the complication rate increased, the stone-free rate and the Hb value decreased. In this study, the presence of severe hydronephrosis was associated with both Clavien–Dindo grade 0 and grade 3 and higher complications. Considering that our study is retrospective and nonrandomized, it is possible that drainage and hospital stay may be prolonged depending on the surgeon's preference due to perioperative complications.

Studies showing the effect of BMI on the success and complications of PCNL have been predominantly performed in the prone position [27]. Falahatkar et al. [24] showed that BMI has no effect on the stone-free rate as in our study. In our study, it was found that the complication rate was higher in patients with low BMI. In some patients, especially those with BMI < 25 kg/m^2, mobility of the kidney is evident during percutaneous puncture and dilation [14]. The high

complication rate in patients with low BMI in our study may be associated with increased renal mobility.

The most important limitation of our study is its retrospective design. In addition, the fact that our study was single-centered and the access time was not calculated separately from the operation time. In addition, the fact that our study was single-centered, the access time was not calculated separately from the operation time, the history of surgical intervention was not divided into endourological or open surgery and each of the endourologists did not perform the GD and OSD equally. Our study includes kidney stones 2–4 cm in size. Another limitation is that the results are not evaluated in stones defined as complex [9]. Due to the relatively small number of patients in our study, we have performed the analysis in our study according to the smaller number of samples. Multicentered, prospective, randomized studies in which complex stones are also evaluated will guide us in this context in the future.

Conclusion

This is the first study in the literature to compare GD with Amplatz and OSD in supine PCNL. When comparing OSD and GD in patients undergoing supine PCNL in GMVP, both techniques have similar stone-free rates and complications. When comparing OSD and GD in patients undergoing supine PCNL in GMVP, both techniques have similar success and complications. The OSD technique can be preferred primarily due to its shorter fluoroscopy time, compared to GD.

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Informed consent Informed consent form was obtained from all patients.

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