

Prospective evaluation of kidney displacement during supine mini-percutaneous nephrolithotomy: Incidence, significance, and analysis of predictive factors

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Abstract

Introduction: Kidney displacement may alter the quality of renal puncture during percutaneous nephrolithotomy (PCNL). The aim of this study was to identify the rate of kidney displacement and parameters associated with kidney displacement in patients who underwent supine mini-PCNL.

Methods: Data of 98 consecutive patients who underwent mini-PCNL was collected prospectively. The patients were grouped as displacement-positive vs. -negative. The parameters collected were age, gender, body mass index, side of the kidney, punctured calyx, fluoroscopy time to successful puncture and tract dilation, stone-free and complication rates, stone diameter, length of the renal artery, and quantity of peri-renal and abdominal fat. Groups were compared for the above listed parameters and logistic regression analysis was performed to identify factors associated with kidney displacement.

Results: There were 34 and 64 patients in the displacement-positive and -negative groups, respectively. Groups were similar for stone-free and complication rates. Fluoroscopy time to puncture and tract dilation were longer in the displacement-positive group. Groups were different for renal artery length and peri-renal fat measurements. In multivariate analysis, lower pole puncture, renal artery length, and peri-renal fat measurement were found to be independent predictors of kidney displacement.

Conclusions: Kidney displacement does not alter the success and complication rates, but is associated with longer fluoroscopy times during supine PCNL. In the current study, parameters in preoperative non-contrast computerized tomography (NCCT) associated with kidney displacement were identified. We recommend surgeons evaluate and take into account these parameters during preoperative planning to establish better outcomes and diminish fluoroscopy times.

Introduction

Percutaneous nephrolithotomy (PCNL) is the golden standard treatment option for management of stones >20 mm in diameter.^{1,2} Although prone position is currently the most commonly preferred position, performing the procedure in the supine position with various modifications has been reported to be equally effective and safe.³⁻⁶

Supine position has important advantages over prone position. First, the total operative times are shorter, as patient repositioning is not needed. Also, injuries during patient repositioning and cardiopulmonary effects of prone position are avoided. Finally, supine position is more convenient for endoscopy combined intrarenal surgery and, allows easier upper pole access through a lower pole puncture.⁷⁻⁹

Access to the collecting system is the most important step in PCNL and an important problem during access is the kidney displacement. Due to the lack of support on the anterior body wall, kidney displacement has been hypothesized to be a problem in modified supine position. The current literature lacks studies evaluating the importance of kidney displacement. In one study, Falahatkar et al analyzed the factors associated with kidney displacement and identified body mass index (BMI) and prone position as significant factors. However, this study included relatively lower number of patients (33 in total) and included only age, gender, patient position, and BMI in the regression analysis.¹⁰

In the current study, we aimed to identify the rate of kidney displacement, its effect on achievement of a successful puncture, and parameters associated with kidney displacement in a prospective cohort of patients who underwent PCNL in modified supine position.

Methods

In this study, the data of 98 consecutive patients who underwent mini-PCNL in our department for renal stones between September 2016 and August 2017 was collected prospec-

tively. Informed consent was obtained from all individual participants included in the study. All of the operations were performed by a single experienced surgeon (MIG) in the Galdakao-modified supine Valdivia position. In all cases, the tract was dilated to 16 Fr and a 12 Fr nephroscope (Karl Storz, Tuttlingen, Germany) was used. Patients who underwent PCNL with a greater tract size were excluded due to fact that dilation method and the tract size has significant impact on kidney displacement. Patients with a history of previous percutaneous or open stone surgery were also excluded, as this parameter may also result in fixation of the kidney due to fibrosis of the peri-renal tissues.

All of the patients underwent a non-contrast-enhanced computerized tomography (NCCT) prior to operation as a routine imaging prior to surgery. All examinations were performed with a 64 multidetector CT (Aquillion 64, Toshiba, Tokyo, Japan). Scan parameters included: 64x0.5 mm collimeters, pitch value 1.484, 5 mm section thickness, 1 mm reconstruction interval, 120 kV, automatic mA value, and 0.5 seconds rotation time. After axial images were assessed, coronal and sagittal reformatted images and three-dimensional (3D) reconstructions were performed with the maximum intensity projection (MIP) and volume rendering methods. Axial thin-section MIP, curved coronal reformation across the renal arteries, and 3D volume-rendered images were used to assess renal arterial anatomy. A single radiologist (BG) performed the measurements on NCCT images and she was blinded to the results of kidney displacement. The measurements from the NCCT were stone diameter (3D), length of the renal artery, and quantity of the peri-renal and abdominal fat. Length of the renal artery was measured on the ipsilateral side.

The peri-renal and abdominal fat measurements were performed based on the methodology previously described by Anderson et al¹¹ The peri-renal fat was assessed at three locations: the anterior peri-renal fat (the distance between the nearest overlying bowel, where the main renal vein enters the renal hilum or the shortest distance from the anterior renal capsule to Gerota's fascia); the posterior peri-renal fat (the distance between the posterior renal capsule to the nearest posterior abdominal wall at the point where the main renal vein entering the renal hilum); and the lateral peri-renal fat (the shortest distance from the inferior tip of liver or spleen to kidney).

Abdominal wall fat was also measured at three sites: anterior abdominal fat (the distance from linea alba to the skin); lateral abdominal fat (the distance from the lateral abdominal wall muscles to the skin), and posterior abdominal fat (the distance from the tip of the vertebral spinous process to the skin). Abdominal wall fat was all assessed at the same CT level where the peri-renal fat measurements were performed.

The other parameters recorded for the analysis were age, gender, BMI, side of the kidney (right or left), stone location

(location of the most prominent stone in case of multiple stones), punctured calyx (upper, middle, or lower), fluoroscopy time to successful puncture, fluoroscopy time to tract dilation, stone-free rate (defined as no residual fragments), and complication rates. Stone volume (SV) was represented in mm³ and was calculated with the formula: $SV = \pi/6X$ (Anteroposterior X transverse X cranio-caudal diameters of the stone in mm). In case of multiple stones, the sum of volumes of all stones were analyzed.

The patients were separated into two groups for comparison: displacement-positive vs. displacement-negative. In order to define kidney displacement, we used the methodology that was previously reported by Falahatkar et al.¹⁰ A transparent graph paper of 5x5 mm squares was placed on the fluoroscopy monitor and amount of kidney displacement was measured during needle puncture and tract dilation. A displacement more than 10 mm in any of the stages was accepted as positive displacement. The cut of value of 10 mm was accepted as the mean value of kidney displacement was reported as 10.7 mm during tract dilation in the study by Flahatkar et al.¹⁰

Postoperative stone-free status was evaluated before JJ stent extraction by kidney, ureter, and bladder (KUB) or ultrasound, and NCCT was performed in the presence of a suspicious residual fragment. Stone-free was defined as absence of any residual fragments.

Statistical analysis

Statistical analysis was performed with SPSS v. 20.0 (IBM Corp. Released 2011. Armonk, NY, U.S.). Patient characteristics were summarized using mean \pm standard deviation for continuous variables and frequency (percentage) for categorical variables. The Chi-square test was used to compare the categorical variables and Mann-Whitney U-test was used to compare the continuous variables. Multivariate logistic regression analysis was performed to identify factors associated with kidney displacement. For statistical significance, p value of 0.05 was accepted.

Results

The data of 98 patients were evaluated and the mean age of the population was 46.8 \pm 5.3 years. There were 34 patients in the displacement-positive group and 64 patients in the displacement-negative group. The two groups were similar for mean age, gender, stone location, BMI, and mean SV. Demographic characteristics are summarized in Table 1.

The two groups were significantly different for the operated side and the punctured calyx. In the displacement-positive group, 21 of the 34 patients (61.8%) were operated for right kidney, whereas in the displacement-negative group 38 of the 64 patients (59.4%) were operated for the left kid-

Table 1. Comparison of demographic- and stone-related characteristics for the two groups

Parameters	Displacement positive (n=34)	Displacement negative (n=64)	p
Age, mean \pm SD	46.2 \pm 5.4	47.1 \pm 5.5	0.66
Gender, n (%)			0.61
Male	20 (58.8)	41 (64.1)	
Female	14 (41.2)	23 (35.9)	
Laterality, n (%)			0.04
Right	21 (61.8)	26 (40.6)	
Left	13 (38.2)	38 (59.4)	
Stone location, n (%)			0.99
Upper pole	1 (2.9)	2 (3.1)	
Renal pelvis/middle pole	18 (52.9)	33 (51.6)	
Lower pole	15 (44.2)	29 (45.3)	
Stone volume (mm), mean \pm SD	1880.8 \pm 765.5	1905.5 \pm 814.7	0.13
Body mass index, mean \pm SD	27.9 \pm 5.4	28.2 \pm 5.5	0.72

SD: standard deviation.

ney ($p=0.04$) (Table 1). Lower pole puncture was also more frequently performed in the displacement-positive group compared to the displacement negative group (94.2% vs. 75%; $p=0.04$) (Table 2).

The measurements from the NCCT studies are summarized in Table 3. The two groups were similar for stone size and abdominal fat measurements. However, the renal artery length was significantly longer in the displacement-positive group compared to the displacement-negative group (42.2 \pm 5.1 mm vs. 36.4 \pm 4.5 mm; $p=0.03$). Additionally, the mean peri-renal fat measurements in all three measurement sites were significantly lower in the displacement-positive group compared to the displacement-negative group (Table 3).

The factors that showed a significant difference between the two groups in the univariate analysis were involved in a multivariate logistic regression analysis. These parameters were: laterality (right vs. left), punctured calyx (lower calyx vs. other calices), length of the renal artery, and peri-renal fat measurement (average of the anterior, lateral, and posterior fat measurements). In the multivariate analysis, lower pole puncture, longer renal artery length, and lower peri-renal fat measurement were found to be independent predictors of kidney displacement. However, laterality was not found to be associated with kidney displacement. The results of the multivariate logistic regression analysis are summarized in Table 4.

The groups were similar for the stone-free rate (91.2% vs. 92.2%; $p=0.86$) and complication rates (8.8% vs. 6.3%; $p=0.63$) (Table 2). However, mean fluoroscopy time to successful puncture was significantly longer in the displacement positive group (18.8 \pm 5.4 seconds vs. 11.3 \pm 4.1 seconds; $p=0.01$). Similarly, mean fluoroscopy time to tract dilation was also significantly longer in the displacement positive

Table 2. Operative characteristics and results of the patients

Parameters	Displacement positive (n=34)	Displacement negative (n=64)	p
Punctured calyx, n (%)			0.04
Upper	1 (2.9)	2 (3.1)	
Middle	1 (2.9)	14 (21.9)	
Lower	32 (94.2)	48 (75)	
Fluoroscopy time to successful puncture (seconds), mean \pm SD	18.8 \pm 5.4	11.3 \pm 4.1	0.01
Fluoroscopy time to tract dilation (seconds), mean \pm SD	23.6 \pm 5.8	15.2 \pm 5.1	0.01
Stone-free rate, n (%)	31 (91.2)	59 (92.2)	0.86
Complication rate, n (%)			0.63
Grade I	2 (5.9)	3 (4.7)	
Grade II	1 (2.9)	1 (1.6)	
Grade III or higher	-	-	

SD: standard deviation.

group (23.6 \pm 5.8 seconds vs. 15.2 \pm 5.1 seconds; $p=0.01$). The results are summarized in Table 2. Additionally, in one of the patients in the displacement-positive group, puncture to the desired lower pole calyx was not possible due to the extreme mobility and displacement of the kidney. In this patient, renal access was established through an upper calyx, and flexible ureterorenoscope was employed for laser lithotripsy and fragment extraction; this patient was one of the three patients with a residual fragment in the displacement-positive group.

Discussion

Kidney displacement during PCNL in the supine position is a common condition and it is observed in about 1/3 of

Table 3. Comparison of the two groups for non-contrast-enhanced computerized tomography parameters

Parameters	Displacement positive (n=34)	Displacement negative (n=64)	p
Length of renal artery (mm), mean \pm SD	42.2 \pm 5.1	36.4 \pm 4.5	0.03
Peri-renal fat (mm), mean \pm SD			
Anterior peri-renal fat	11.2 \pm 2.8	14.1 \pm 3.1	0.04
Lateral peri-renal fat	10.1 \pm 2.7	12.5 \pm 3.0	0.04
Posterior peri-renal fat	11.1 \pm 2.9	14.4 \pm 3.7	0.04
Abdominal fat (mm), mean \pm SD			
Anterior	20.9 \pm 4.4	21.4 \pm 5.1	0.78
Lateral	16.4 \pm 3.8	16.8 \pm 3.9	0.82
Posterior	14.1 \pm 2.3	14.4 \pm 3.3	0.87

SD: standard deviation.

Table 4. Results of multivariate logistic regression analysis for kidney displacement

Parameter	OR	95% CI	p
Laterality (right vs. left),	1.155	0.675–1.343	0.81
Punctured calyx (lower calyx vs. other calices)	1.776	1.003–2.492	0.03
Length of the renal artery	2.160	1.218–5.354	0.007
Peri-renal fat measurement	2.067	1.183–4.708	0.009

CI: confidence interval; OR: odds ratio.

the cases in the current study. Although it was not found to be associated with lower success and higher complication rates, significantly longer fluoroscopy times were reported in the displacement-positive group, which makes this factor a surrogate for more difficult puncture. The current study also identified a longer renal artery, lower peri-renal fat measurement, and puncture through a lower pole calyx as factors associated with kidney displacement.

Anteromedial displacement of the kidney during PCNL in supine position was first reported in 2002 by Shoma et al. The authors compared supine and prone positions and anteromedial displacement was observed in 11% of the supine cases, but in none of the cases operated in prone position.¹² The rate of kidney displacement in this study was lower compared to our cohort and we believe that this is due to the difference in the definition of displacement.

Falahatkar et al reported their results in the complete supine position compared with the prone position in 2008. In this study, the authors mentioned that anterior displacement of the kidney was lower in the complete supine position, but neither definition of displacement nor data of patients with significant displacement was provided.¹³ The same group reported their comparative data for kidney displacement in complete supine and prone positions in 2011. In this study, the authors also attempted to identify factors associated with significant displacement and in order to determine the amount of displacement, a graph paper was placed on the fluoroscopic monitor and the kidney movements recorded.¹⁰ We also used this methodology in our study and grouped the patients in accordance with cutoff levels obtained from the study by Falahatkar et al.¹⁰

In addition to position, the authors also evaluated gender, age, and BMI as factors that may be associated with displacement. The only parameter that was found to be significant was patient position. Also, BMI was found to be associated with kidney displacement during the tract dilation stages.¹⁰ In our study, we evaluated other parameters and identified puncture of a lower pole calyx, a longer renal artery, and lesser peri-renal fat thickness as factors associated with significant kidney displacement. The BMI and abdominal fat measurements were not found to be significant, but lesser peri-renal fat measurements were significantly associated with kidney displacement. A possible explanation for this

finding is peri-renal fat tissue stabilizes the kidney and prevents displacement, but abdominal fat, which correlates with BMI, does not have a role.

In the univariate analysis, right-sided kidney was more prevalent in the displacement-positive group, but it was not found to be a significant factor in the multivariate analysis. We believe that this is associated with the renal artery measurement. The mean length of the renal artery was longer in the displacement-positive group and hypothetically, the renal artery, with its stiff structure, stabilizes the kidney. The renal artery is shorter in the left kidney and this explains the lower percentage of left-sided kidney in the displacement-positive group.

Puncture through a lower calyx was also found to be associated with significant displacement in multivariate analysis. Although we evaluated the displacement in two dimensions under fluoroscopy, the kidney moves in three dimensions. Lower pole puncture results in caudal to cranial movement of the kidney and, in some cases, the lower pole may rotate from lateral to medial, making puncture of the papilla of the desired calyx difficult. For this reason, in one of the cases, puncture of a lower calyx was not possible, and puncture of a middle calyx was performed.

We did not observe any difference in the stone-free rates and complication rates in the two groups. Although, kidney displacement was observed in about 1/3 of the cases, it did not have an effect on the final outcomes. However, in the present study, all operations were performed by an experienced endourologist (performing >150 PCNL cases per year) and therefore, kidney displacement may have an impact on outcomes of PCNL when performed by an unexperienced surgeon.

The fluoroscopy time to successful puncture and tract dilation were longer in the displacement-positive group and we believe that kidney displacement is one of the factors responsible for more difficult percutaneous access. Therefore, during preoperative planning, the factors identified as being associated with significant displacement should be kept in mind. For instance, in the case of a renal pelvis stone with long renal artery and less peri-renal fat, puncture through a middle calyx instead of a lower calyx may prevent kidney displacement and aid in easier puncture of the collecting system.

The most important limitation of our study is the inclusion of only mini-PCNL cases. With the increased tract size, amount of displacement may increase as well. Also, there are other factors associated with more difficult puncture and access to the collecting system, such as dilation of the target calyx, space around the stone, and abnormal anatomy or malrotation of the kidney. We also excluded patients with history of previous surgery for standardization, but this parameter also has potential to be an independent factor. These parameters were not evaluated in the current study. Also, there are no universally accepted criteria for signifi-

cant kidney displacement. To the best of our knowledge, there is only one study that objectively measured the amount of displacement¹⁰ and we used the data from this study to group our patients. Another important point is that kidney displacement has been studied in two-dimensional fluoroscopic views. However, the kidney can move in all three dimensions and we could not evaluate displacement in the anterior-posterior plane. Additionally, presence of residual stones was not evaluated with NCCT in all patients, which is the gold standard imaging modality.

Conclusion

Kidney displacement can occur in up to 1/3 of PCNL cases operated in supine position. Although, it does not alter the success and complication rates, it is associated with longer fluoroscopy times and, therefore, more difficult access. Puncture through a lower calyx, longer renal artery, and lesser peri-renal fat measurement were identified as factors associated with significant displacement. These parameters can be evaluated in preoperative NCCT studies and we recommend surgeons take into account these parameters during preoperative planning.

Competing interests: The authors report no competing personal or financial interests.

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