Urol Res (2011) 39:467–475
DOI 10.1007/s00240-011-0366-x

ORIGINAL PAPER

Percutaneous nephrolithotomy in semisupine position: a modified approach for renal calculus

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Received: 25 September 2010 / Accepted: 5 February 2011 / Published online: 19 February 2011

Abstract Conventional percutaneous nephrolithotomy (PCNL) is usually performed in a prone position, which compresses the thorax and results in difficulty in rescue during operation. When PCNL is performed in a supine position, the flank renal puncture area is limited, so it is difficult to treat disseminated and complex renal calculi. Herein, we introduce a modified semisupine position for performing PCNL, which has numerous benefits as well as safe and effective. Between May 2002 and May 2009, a total of 452 patients with renal calculi were treated with semisupine PCNL. The patient was placed in 45° semisupine position during the procedure, with the affected flank arched as much as possible. In this series, no one converted to open surgery. The average operating time was (115.2 ± 44.5) min. Single tract PCNL was performed for 80.97% of the cases, two tracts 13.94%, three tracts 4.65%, and four tracts 0.44%. The upper, middle, and lower calix tracts accounted for 12.1, 63.0, and 24.9%, of procedures, respectively. Stone-free rate was 85.7% overall, 92.2% for single calculus (83/90), and 72.9% for staghorn calculi (78/107). Major postoperative complications occurred in 3.3% of the cases. This study demonstrated PCNL in a semisupine position is an effective alternative for treating renal calculi, which combines the advantages of PCNL in a prone position, and PCNL in a supine position. The semisupine position allows easier irrigation of stone fragments, is more comfortable for the patient, and facilitates monitoring of anesthesia.

Keywords Renal calculus · Percutaneous nephrolithotomy · Semisupine position

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Introduction

Percutaneous nephrolithotomy (PCNL) is currently considered the treatment of choice for most renal stones because of superior outcomes and acceptably low-morbidity [1]. PCNL in the prone position is widely accepted because of its familiarity, and because urologists have an excellent understanding of the anatomy in this position. In addition, it provides a larger surface area for the choice of puncture site, and a wider space for instrument manipulation [2]; however, the disadvantages of this approach are well known, including patient discomfort and circulatory and ventilatory difficulties, especially, in the obese and the elderly with compromised cardiopulmonary status [3]. Another disadvantage is the necessity of position changes during the procedure, because retrograde ureteral catheterization is commonly performed in the lithotomy position prior to turning the patient to a prone position [4].

To overcome these drawbacks and to simplify the procedure, PCNL in the supine position has been described. As shown by Valdivia Uria et al. [5], PCNL in a supine position could make patients feel more comfortable, and it is safe and easy, especially for patients at high-risk of complications of anesthesia. But when PCNL was performed in a supine position, the flank renal puncture area was limited to between the anterior axillary line and the posterior axillary line, or a slightly wider area. The puncture site and angle might also be restricted. In most cases documented by Falahatkar et al. [6], the inferior calyx was targeted. In addition, in such a limited area it may be difficult to set up multiple tracts to treat disseminated and complex renal calculi.

With the above background and the potential benefits of PCNL in a supine position, we modified the supine position to a semisupine. Accordingly, patients were set at an angle of 45° to perform PCNL. Herein, we report our experience with 452 patients treated in the semisupine position.

Patients and methods

Patient information

Between May 2002 and May 2009, a total of 452 cases, including 282 males and 170 females, underwent PCNL in semisupine position in our department. The inclusion criteria were cases with single or multiple renal stones need surgical intervention. Exclusion criteria: (1) ≤3 years; ≥90 years, (2) affected renal GFR ≤ 10% of the total GFR, (3) serious heart and lung diseases, (4) hemorrhagic disease, (5) pelvic ectopic kidney. Patients' age ranged from 8 to 84 years (mean 47.7 years) and weight from 31 to 103 kg. Ultrasonic examination, intravenous urogram (IVU), and computer tomography (CT) were performed preoperatively to confirm the diagnosis. The demographic patient data and characteristics of the stones are presented in Table 1.

Of the patients, 33 were solitary renal calculi cases, 14 cases were complicated with pyonephrosis, 81 patients had a history of open surgery of the affected kidney, and 64 patients had a history of extracorporeal shock-wave lithotripsy (SWL). The same well-experienced urologic team in our department performed all of the procedures.

Table 1 Patients' characteristics

	Number of cases
Sex	
Male	282
Female	170
Mean age (year)	47.7 ± 13.0 (8 ~ 84)
Body mass index	23.6 ± 4.6 (13.2 ~ 39.6)
Side of the stone	
Right	265
Left	187
Multiplicity of stones (*n*)	
Single	90
Multiple	255
Staghorn	107
Stone location (*n*)	
Renal pelvis	51
Upper calyx	8
Middle calyx	10
Lower calyx	21
Renal pelvis and upper calyx	32
Renal pelvis and middle calyx	54
Renal pelvis and lower calyx	74
Renal pelvis and upper calyx and middle calyx	48
Renal pelvis and upper calyx and lower calyx	38
Renal pelvis and middle calyx and lower calyx	69
Renal pelvis and upper calyx and middle calyx and lower calyx	47
Mean maximum stone diameter (cm)	4.2 ± 1.6
Radiopacity	
Radiopaque	412
Radiolucent	40

Methods

Initially, retrograde catheterization of the ureter was performed in the lithotomy position to expand the renal cavities and to prevent the stone fragments from migrating from the renal collecting system to the ureter. All procedures were performed under continuous epidural anesthesia (442/452, 97.8%) or general anesthesia (10/452, 2.2%).

In this series, three methods were introduced to set the patients in a 45° semisupine position. Method A employed a wooden position board constructed by the investigators. This board can be placed securely on the operating table and can be adjusted easily to any angle. In the center of the free edge of the board, a gap, 40 cm long by 20 cm wide, allowed skin exposure for the percutaneous procedure (Fig. 1). The patient was placed on the position board adjusted at a 45° angle, with the flank on the affected side of the patient arched out (Fig. 2). Method B employed a special operating table designed by our team (Fig. 3). The desk of the operating table can be adjusted easily to a 45° angle of inclination (Fig. 4). Method C employed only a standard operating table, onto which the patient was firmly secured initially in a 60° flank position. Then the kidney bridge was elevated moderately, and the operating table was flexed somewhat to increase the space between the lowermost rib and the iliac crest. Then the table was inclined 15° to the backside of the patient, thus, placing the patient in a 45° semisupine position. Two additional metal baffles were fixed onto the table to support the back and the hip of the patient (Fig. 5). Method C was adopted mainly for the complex cases needing multiple-tract PCNL.

Fig. 1 A homemade wooden position board. In the center of the free edge of the board, a gap, 40 cm long by 20 cm wide, allows skin exposure for the percutaneous procedure

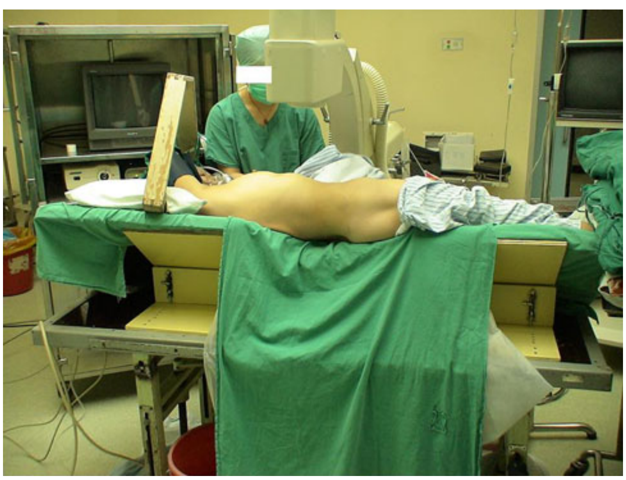

Fig. 2 The patient was placed on the position board adjusted at a 45° angle, with the flank on the affected side of the patient arched out

The renal puncture was made between the posterior axillary line and the subscapular angle line with an 18-gauge needle subcostally or supracostally. The puncture was guided by C-arm fluoroscopy or ultrasonography or both. Then the needle was advanced in the direction of the target calix or calculus. If the targeted calix was ambiguous under C-arm guidance, a 38% Urographic injection through the ureteral catheter was required. Usually, the direction of the needle was 5°–20° upward from a horizontal plane.

Once the renal puncture was completed satisfactorily, a 0.038-inch Zebra guide wire was inserted into the collecting system through the needle sheath. Subsequent tract dilation was accomplished to F16-24 with progressive fascial dilators intermittently along the guide wire. A matched peel-away sheath (Cook Incorporated, Bloomington, IN, USA) was introduced into the renal collecting system. An F8/9.8 rigid ureteroscope or F22 nephroscope entered the renal collective system through the PCN passage (Fig. 6). The calculus was lithotripsied by pneumatic lithotriptor, or Holmium laser lithotripter, or EMS lithotriptor. The

Fig. 3 A special operating table designed by our team

Fig. 4 The desk of the homemade operating table can be adjusted easily to a 45° angle of inclination

Fig. 5 Firmly secured on a standard operating table, the patient position was adjusted to a 45° angle of inclination

Fig. 6 An F8/9.8 rigid ureteroscope entered the renal collective system through the PCN passage

fragments were removed with irrigation by the perfusion pump through the downward passage. If residual stones were detected by C-arm fluoroscopy or ultrasonography during the procedure, two or more tracts might be introduced (Fig. 7). After lithotripsy was completed, a F6 Double-J stent was inserted anterograde through the working passage (Figs. 8, 9). At the end of procedure, an F10-16 catheter was placed as a nephrostomy tube.

KUB or ultrasonography was routinely rechecked postoperatively to ascertain the presence of residual stone fragments and assess the necessity for adjunctive therapy. If there was no need for further treatment, the nephrostomy tube was removed 3–5 days after the procedure, and the Double-J stent was removed 3–6 weeks postoperatively. Follow-up was at 3–12 months. The operative parameters,

Fig. 7 Four tracts were setup for a patient with renal staghorn calculi

Fig. 8 Complete staghorn calculi of the left kidney were demonstrated from KUB film before operation

number of tracts, stone-free rate, operating time, hospital stay, and complications were analyzed retrospectively. The data were statistically analyzed by PASW® Statistics 18 (Chicago, SPSS Inc., USA), $\alpha = 0.05$ was selected. Univariate techniques used included the 2×2 table specific formula, correction for continuity, Fisher exact probabilities for 2×2 tables, and Pearson χ^2.

Results

In this series, 449 PCNL procedures were performed semi-supine in one phase, and the other three procedures were

Fig. 9 By one-stage PCNL in semisupine position, staghorn calculi of the left kidney were removed completely, and a Double-J stent was indwelled

performed in two phases, in the earlier stage of this study. No one was converted to open surgery. The intraoperative data of patients, success rate, and complications are presented in Table 2.

Single tract PCNL accounted for 80.97% of the cases (366/452); two tracts, 13.94% (63/452); three tracts, 4.65% (21/452); and four tracts, 0.44% (2/452). Among all of these cases, the upper, middle and lower calix tracts were involved in 12.1% (68/563), 63.0% (355/563) and 24.9% (140/563) of cases, respectively.

In this study, as the average operating time (from the beginning of renal puncture to insertion of the nephrostomy tube) and stone-free rate were calculated, excluding the three cases performed PCNL in two phases. The average operating time of 449 cases was (115.2 ± 44.5) min. Complete clearance was confirmed by radiography and ultrasonography 48 or 72 h after surgery in 85.7% (385/449) of the patients. After PCNL, the stone-free rate was 92.2% in patients treated for a single calculus (83/90), and was 72.9% in patients treated for staghorn calculi (78/107).

No major intraoperative complications were noted. Blood transfusions of 200–600 ml were administered in 14 cases intraoperatively, when the patient's hemoglobin was <80 g/L.

There were major postoperative complications in 15 cases. Four patients developed urine extravasation for more than 24 h after nephrostomy removal, two of whom were cured after replacement of the Double-J stent, and two of whom were treated by inserting a nephrostomy tube for 5 days. Septicemia was diagnosed in two patients, who were treated subsequently with Imipenem injection. One patient developed a perinephric hematoma, which was managed conservatively. Six patients had a postoperative course complicated by secondary hemorrhage 5–14 days postoperatively, and four patients were rehabilitated with conservative therapy. Each of two patients had a pseudoaneurysm, which was confirmed by super-selective renal angiography, and embolized. Each of two additional patients had a hydrothorax, for which a chest tube was introduced for 5 and 7 days, respectively. None of the patients suffered injury of other abdominal organs such as colon, small intestine, liver, or spleen.

Table 2 Intraoperative data of patients, success rate, and complications

	Value
Anesthesia	
General	6
Epidural	446
Operating time (min)	115.2 ± 44.5 min
Guidance method	
X-ray	164
Contrast media needed (%)	56.7% (93/164)
Ultrasonography	298
Mainly calix punctured	
Upper	68
Middle	355
Lower	140
Site of puncture	
Subcostal	201
Supracostal	362
Dilation difficulties	3
Methods of stone disintegration	
Pneumatic lithotripter	211
Holmium laser	52
EMS	189
Conversion to open surgery	0
Transfusion	3.1%
Stone-free rate (%)	85.7%
Postoperative PCS drainage	
Patients with nephrostomy tube	403
Patients without nephrostomy tube (tubeless)	49
Follow-up time	5.5 ± 1.9 months
Major postoperative complications	
Urinary leakage	6
Delayed bleeding	4
Perinephric haematoma	1
Septicaemia/Sepsis	2
Hydrothorax	2
Colon injury	0

Table 3 Comparison of different groups

Group	Patient (n)	Operating time (min)	Transfusion (n)	Stone-free rate (n)	Major postoperative complications (n)
Children (≤15 years)					
Yes	4	105.00 ± 19.15	0	3	1
No	445	88.60 ± 46.32	14	380	14
p		0.188	1.000	0.472	0.127
Previous history of open surgery					
Yes	81	92.22 ± 52.96	5	69	7
No	368	87.98 ± 44.57	9	314	8
p		0.902	0.163	0.974	0.010
Previous history of SWL					
Yes	64	84.45 ± 45.70	4	45	2
No	385	89.45 ± 46.261	10	338	13
p		0.298	0.243	<0.001	1.000
Pyonephrosis					
Yes	14	75.00 ± 29.02	0	13	4
No	435	89.18 ± 46.57	14	370	11
p		0.357	1.000	0.669	0.001

According to the age, previous history of open surgery and SWL, and presence of pyonephrosis, the patients were divided into different groups. The same parameters in two age groups (the children group and the adult group) had no statistical difference ($p > 0.05$). There was significant difference in the stone-free rate between the groups with and without the previous history of SWL ($p < 0.001$). In terms of major postoperative complication rate, there was remarkable difference in the groups with and without the previous history of open surgery ($p = 0.01$), as did the groups with and without the presence of pyonephrosis ($p = 0.001$). The comparison data of different groups is list in Table 3.

Discussion

Fernström and Johansson [7] performed the first PCNL in 1976. A few years later, Alken et al. [8] developed the clinical technique of PCNL. Now, PCNL is the major method of treating complex renal stones, and is traditionally performed in the prone position [1, 9]; however, the original article provides no rationale for the prone approach [10]. Prone positioning is widely applied because it is believed to avoid abdominal visceral injuries, and because it allows a wide field for renal puncture and simple execution of multiple access tracts, and imposes no limits on instrument manipulation [11].

However, PCNL in a prone position has several disadvantages [3, 4]. Firstly, the prone position imposes pressure on the thorax, which may result in ventilatory difficulties during the procedure, especially, after the application of anaesthetics, sedatives, and analgesics. Respiratory complications are well documented in the literature after use of the prone position [12]. Secondly, when PCNL is performed in the prone position, it is difficult for the anesthetist to observe the patient effectively. Moreover, the prone position may not be conducive to resuscitation when acute syndromes such as obstruction of respiratory passages or acute myocardial ischemia occur during the procedure. We have experienced a case of sudden cardiac arrest during prone PCNL. Patients with severe kyphosis, morbidly obese patients, and patients with marginal lung and heart function do not tolerate the prone position well [13].

Some investigators have begun to explore methods of carrying out PCNL in a more comfortable and safe operating position. Valdivia Uria et al. [5] reported 557 cases of PCN performed in the supine position. Subsequently, Shoma et al. [4] and Ng et al. [14] confirmed the feasibility of performing PCNL with patient in a supine position; however, there were drawbacks of supine PCNL noted as well. Due to the restricted exposure of the surgical field, the surface for renal puncture would be quite narrow, thus resulting in obvious restriction in access and angle of entry. To reduce the damage of puncture and dilation, Valdivia Uria et al. [5] and Ng et al. [14] chose the 90% PCN pathway accessed through the lower pole calices; however, it was quite difficult to treat multiple calculi or staghorn calculi.

Gofrit et al. [15] reported performing PCNL in patients in the lateral decubitus flank position in three morbidly obese and kyphotic patients. Kerbl et al. [16] suggested performing PCNL with the patient in the flank position. The lateral position is very familiar to urologists, and is usually well tolerated by patients; however, the lateral position is inconvenient for PCN guided by C-arm, and the working tract is nearly vertical to the operating table, which limits the evacuation of stone fragments.

In order to avoid the inconvenience caused by a prone or supine position, we attempted to perform the PCNL procedure with the patient in a semisupine position. The patient was able to remain more comfortable during the procedure, and anaesthesia monitoring was comparable to that of the supine position. In addition, there was enough space (from the anterior axillary line to the subscapular angle line) to set up the PCN tract as is done in the prone position. This position also facilitated the ability to achieve an adequate sterile field. Our series included cases of many types of renal calculi, including single stone, multiple stones in pelvis and calix, partial staghorn stone, and complete staghorn stone. In our series, the semisupine position did not present additional difficulties in setting up multiple tracts. Two tracts were required in 13.94% of our cases, three tracts in 4.65%, and four tracts in 0.44% (Fig. 7). The larger area for the establishment of PCN tracts is the advantage of the semisupine position over the supine position.

Based on our experience, the middle calyx PCN tract was a very convenient approach in patients with multiple stones or staghorn stone. Due to the high-percentage of patients with complex calculi, an exceptionally high-rate of the middle calyx tract was adapted in our series (63%). The middle calyx tract was also convenient for placing a Double-J stent during surgery. Most internal drainage was placed easily through the PCN tract during the procedure, although this intervention failed in 11/452 patients (2.43%). Compared with that in prone position, the renal puncture site was more laterally in semisupine position; as a result, a middle calyx was more commonly and more directly accessed by supracostal renal puncture. The positioning of the patient has some impact on more supracostal puncture in our series.

In supine position, the medial aspect of each kidney is rotated anteriorly at an angle of approximately 30°, so many of the posterior calyces are dependent. Thus, it should be inconvenient to advance the needle through the posterior calices when the patient is supine. When the patient is set in a 45° semisupine position, the kidney was rotated, and the posterior calyx project more laterally. As a result, the tracts are often horizontal or slightly inclined downward (5°–20°), which would be convenient for establishing posterior PCN tracts and washing-out the fragment (Fig. 10). The pyelocalyceal system in the semisupine position is constantly collapsed, and the pressure of the collecting system is very low, which decreases the chance

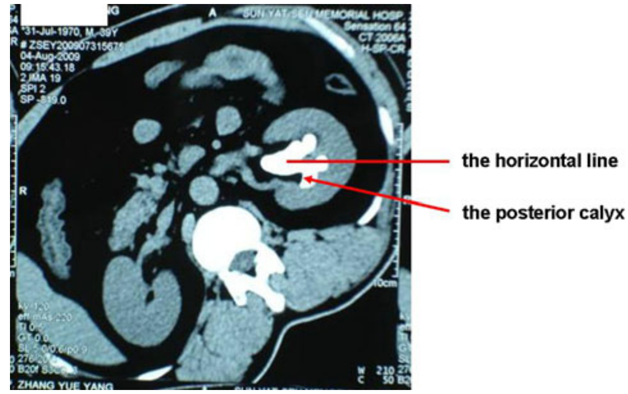

Fig. 10 A CT film, with the patient in semisupine position, indicated that elevation of the flank to 45° caused the posterior calyx to project more laterally, often becoming nearly parallel (about 15°) to the operation table

of purulent urine entering the circulation. In our series, the incidence of postoperative fever and sepsis is low.

The kidney would tend to slide cephalad by the abdominal saddle in a prone position. Preminger et al. [17] demonstrated that, on average, the kidney location is 2.2 cm more cephalad in a prone position than in supine position with reference to the position of the renal pelvis during the procedure. In a semisupine position, with no additional pressure on the abdomen, the kidney location is the same as in a supine position. The rate of complicated hydrothorax is very low in our series.

Compared with that of supine position, in the prone position the kidneys are pulled ventrally by gravity, and the colon moves to a relatively more dorsal position, which might increase the chance of colon injury [5]. When the patient is in the semisupine position, while the kidneys have a little movement, the colon anterior to the kidneys may move medially. Therefore, during an operation in the semisupine position, the colon falls anteromedially and thus well apart from the puncture paths. In addition, the application of preoperative CT scan and intraoperative ultrasonography may help to detect the presence of a retrorenal colon, further reducing the risk of intraoperative colon perforation. The low-incidence of colonic perforation might be regarded as one of the advantages of semisupine position.

In semisupine PCNL, the procedure of puncture and dilation was performed in a field perpendicular to the X-ray without interposing the hands of operators (Fig. 11), which reduced radiation exposure, and decreased the radiologic hazard to the operators as compared with the prone position [18].

Our series of semisupine PCNL showed results similar to those of this procedure performed in the prone position and in terms of surgical operating time, stone-free rates after a single procedure, and the relief rates of pelvic obstruction [14, 15].

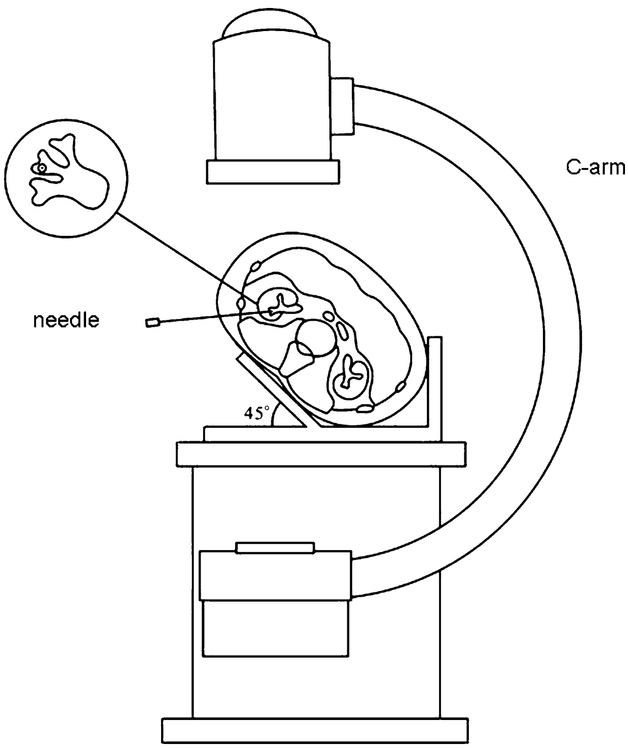

Fig. 11 An ideograph of PCNL with the guidance of C-arm in a semisupine position. These procedures of puncture and dilation were performed in a field perpendicular to the X-ray without interposing the hands of operators

In our cases, we found that there was no significant difference in the same parameters between the children group and the adult group, which might suggest that semisupine PCNL was feasible and safe for not only adults but also children. When compared with the group without the previous history of SWL, the stone-free rate decreased in the group with the previous SWL ($p < 0.001$), which might be resulting from more distributed stones attributable to the previous SWL. In terms of major postoperative complication rate, there was a remarkable difference in the groups with and without the previous history of open surgery ($p = 0.01$), as did the groups with and without the presence of pyonephrosis ($p = 0.001$). We thought that scar tissue around the kidney and distortion of the anatomy of the collecting system caused by the previous open surgery [19], and the friable infected tissue attributable to pyonephrosis may affect subsequent PCNL. Therefore, one needs to take caution when manipulating the kidney in patients with history of prior open surgery or pyonephrosis.

In this series, three methods were introduced to allow the patients maintaining a 45° semisupine position during operation. The advantage of Method A was suitable for C-arm guidance conveniently, and the position board was easy to make. Method B was very convenient for the guidance of both C-arm and ultrasonography, but it needs special operation table. Method C was superior to perform semisupine PCNL with ordinary operating table guided by ultrasonography. Furthermore, it can increase the space between the lowermost rib and the iliac crest by raising the lumbar bridge, which was to facilitate multi-tracts PCNL.

Because the affected kidney had been lifted as the patient in semisupine, when the renal puncture and tract dilation were performed, the kidney might be displaced inward. Thus, it was important to perform the procedure quickly as the needle or dilator was advanced. In order to reduce the blind area of the renal collecting system, the flank with the affected kidney should be arched outwardly as much as possible.

In conclusion, PCNL in semisupine position has advantages in irrigating stone fragments more easily, lessening the patient discomfort, and facilitating intraoperative observation by the anesthesiologist. Therefore, we recommend the semisupine position for PCNL as an effective alternative for treating renal calculi.

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