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ORIGINAL PAPER

# Clinical value of minimally invasive percutaneous nephrolithotomy in the supine position under the guidance of real-time ultrasound: report of 92 cases

**Xiangfu Zhou · Xin Gao · Jiling Wen · Cuilan Xiao**

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**Abstract** To determine the clinical value of the real-time-ultrasound-guided minimally invasive percutaneous nephrolithotomy (m-PCNL) technique in the supine position, 92 patients suffering from renal or upper ureteral stones were treated by m-PCNL with a nephroscope/ureteroscope in the supine position. The ipsilateral flanks of the patients with different body sizes were elevated with a 1,000 or 3,000-ml water bag. Under cystoscopy, a ureteral catheter was inserted into the kidney. Normal saline was infused into the kidney via the ureteral catheter to dilate the entire urinary system. Under the guidance of real-time ultrasound, the needle was inserted into the urinary system to dilate the tract and establish the 16F mini-tract for percutaneous nephrolithotomy. All 92 (100%) m-PCNL procedures were successfully performed in the supine position. Primary stone clearance was achieved in 64 cases (69.6%). Residual stones occurred in 28 cases (30.4%). M-PCNL was performed for a second time in 16 cases to clear the residual stones. In 4 cases, stones remained after the second m-PCNL. Two of them were treated further by extracorporeal shockwave lithotripsy (ESWL). The total stone clearance rate of m-PCNL was 82.6%. Only one case required blood transfusion. No other serious complications occurred. The supine position is a favorable position for the patients, the surgeons and the anesthesiologists during the m-PCNL procedure. Real-time ultrasound is a valuable technique for guiding of the m-PCNL.

X. Zhou (✉) · X. Gao · J. Wen · C. Xiao
Department of Urology,
The Third Affiliated Hospital of Sun Yat-Sen University,
Guangzhou, Guangdong 510630, China
e-mail: xiangfuzhou@126.com

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## Introduction

Since first described by Fernstr and Johansson in 1977, percutaneous nephrolithotomy (PCNL) has become an efficient technique for the treatment of renal or upper ureteral stones. Generally, PCNL is performed with the patient in the prone position. However, this conventional practice often causes patient discomfort, and respiratory and cardiac problems, especially in obese or elderly patients. Morbidly obese patients usually cannot tolerate this position and may develop respiratory and cardiac complications due to increased intra-abdominal pressure. To overcome these drawbacks, PCNL in the supine position has been described [1, 2]. We have adopted the supine position for PCNLs since October 2004. The purpose of this study was to investigate the clinical value of minimally invasive percutaneous nephrolithotomy (m-PCNL) technique in the supine position under the guidance of real-time ultrasound. We report our findings in this article.

## Patients and methods

This study was approved by the institutional review board. From October 2004 to October 2006, a total of 92 patients (61 men and 31 women; age: range 21–78 years old, mean 52.6 years old; weight: range 45–92 kg, mean 62.2 kg) who had suffered from renal and/or ureteral stones were treated by m-PCNLs in the supine position. Before the treatment, 73 patients had lumbago complaints while others had no clinical symptoms. The stones were detected by a series of routine check-ups. Twelve patients had renal surgical history. The m-PCNL was performed in the right kidney of 40 patients (43.5%), the left kidney of 38 patients (41.3%) and the upper ureter of 14 patients (15.2%). Severe hydronephrosis was found in 15 cases (16.3%) and moderate in 33 cases (35.6%). Preoperative imaging, including plain abdominal radiograph, intravenous urogram (IVU) and ultrasonography (US), and computed tomography (CT), was performed. The details of the multiplicity of stones are described in Table 1.

All m-PCNLs were performed under combined spinal epidural anaesthesia. Patients were placed in a lithotomy position. A 4F or 5F ureteral catheter was inserted into the ipsilateral ureteral orifice in a retrograde fashion, under the guidance of a cystoscopy. Then patients were placed in a supine position with the side harboring the stone close to the operation table. Skin surface was marked to indicate the lower rib margin, anterior axillary line, midaxillary line, postaxillary line and iliac crest (Fig. 1). The ipsilateral flank was elevated with a 1,000 or 3,000-ml water bag, depending on patients' body sizes. The ipsilateral arm was laid on the thorax, and intravenous accesses were established in the contralateral arm for fluid replacement.

**Table 1** Multiplicity of stones in the upper urinary tract

| Multiplicity of stones | Number of cases |
|---|---|
| Single | 30 |
| Multiple | 43 |
| Staghorn | 19 |

The stone volumes ranged from 1.2 to 18.5 $cm^3$, and the biggest staghorn stone was 18.5 $cm^3$

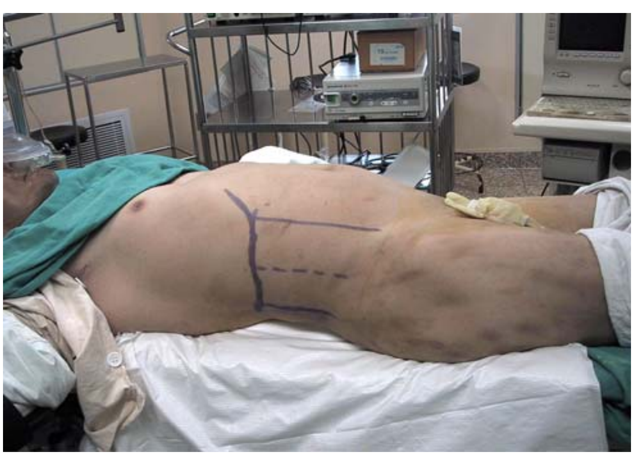

**Fig. 1** The patient was placed in the supine position with skin marked to indicate the lower rib margin, anterior axillary line, mid-axillary line, and post-axillary line. The ipsilateral flank was elevated with a 1,000–3,000-ml water bag

Following preoperative imaging, the targeted calyx was selected carefully in order to clean the stone effectively and completely. For the single calyx stone, in most cases, the calyx harboring the stone would be chosen. For the single pelvic stone, if the stone volume was less than 4 $cm^3$, the middle calyx would be chosen, which can access the renal pelvis and observe the collecting system all around more conveniently. But if the stone volume was larger than 4 $cm^3$, a second tract would be included to clean the stone completely. The second targeted calyx was chosen, based on the stone position. For the staghorn stone, the middle or upper calyx would be chosen, which is convenient for a ureteroscope to access the ureter and other calyces. And a second tract was usually needed in this situation. Percutaneous puncture in a selected calyx was carried out with an 18-G PTC needle under the guidance of real-time ultrasound (Fig. 2). A real-time grayscale ultrasound system with 3.5 MHz transducer (Aloka, Japan) was employed in this study. A 0.025-in guide wire was passed through the needle, and threaded to the renal pelvis. A set of telescopic dilators (OptiMed, OptiMed Medizinische Instrumente GmbH, Germany) was used to dilate the tract. A 16F sheath (OptiMed, OptiMed Medizinische Instrumente GmbH) was passed through the tract. A holmium laser or pneumatic lithotripsy with a 9.8F rigid ureteroscope (Olympus, Japan) was used to fragment the stone in the standard fashion. For the remnant stones that were difficult to be removed by single tract or large staghorn stones occupying certain calyx parallel to the tract, a second tract was set up in the same way to help remove the stones. After completely cleaning the stones, a ureteroscope was inserted into the ureter under the guidance of guide wire; the ureteral catheter was pulled out; a pigtail stent was placed in the ureter from renal pelvis to urinary bladder; and finally a 14F or 16F nephrostomy tube was fixed for drainage. The whole procedure was completed by the surgeon in a sitting position (Fig. 3).

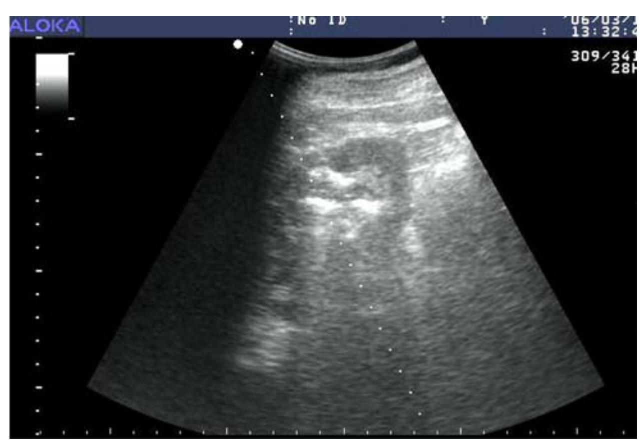


**Fig. 2** Percutaneous puncture of a selected calyx was performed under real-time ultrasound guidance

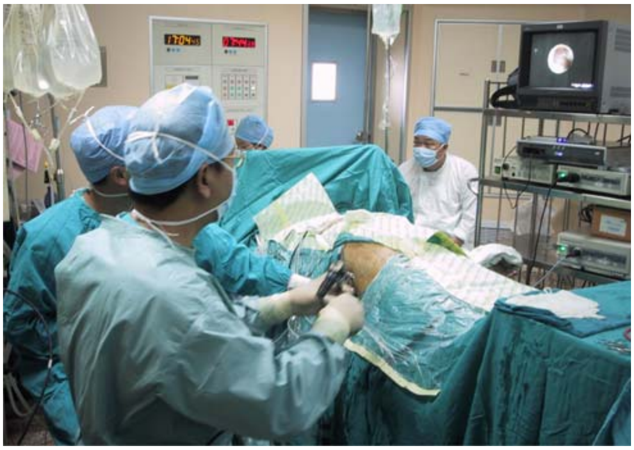

**Fig. 3** The surgeon can sit on a stool during the procedure

## Results

All m-PCNL procedures were successful. No patients were switched to open surgery. Mean operation time was $120 \pm 68$ min (range 45–350 min). Real-time ultrasound imaging provided reliable information to guide the percutaneous puncture. Primary stone clearance was achieved in 64 cases (69.6%). Residual stones were observed in 28 cases (30.4%); 16 of them received a second m-PCNL treatment. Four of the 16 patients still had residual stone (<10 $mm^3$) after the second m-PCNL; two of them were treated further by ESWL to clear the stone. The total stone clearance rate of m-PCNL was 82.6%.

Although most of the cases (71/92) were managed satisfactorily by a single tract, a second tract was used in 21 cases. Blood loss during the operation was $100 \pm 45$ ml. Only one patient who had severe hemorrhage during the procedure received a blood transfusion (transfusion rate was 1.1%). The nephrostomy tube was kept for 5 days and a second m-PCNL was performed on this patient. No other severe complications such as colon damage, pneumothorax or hydrothorax occurred.

## Discussion

The PCNL, ureterorenoscopy (URS) and extracorporeal shockwave lithotripsy (ESWL) have been the main procedures for the management of upper tract stones in the past 20 years. These techniques have revolutionized the treatment of upper urinary tract stones from traditional open surgery.

The PCNL is generally performed with the patient in a prone position. However, the prone position has several disadvantages. Adequate prone positioning requires a special operation table, and the patients often feel uncomfortable during the procedure (with a conscious sedation) even if they have practiced this positioning preoperatively. Therefore, some patients cannot tolerate a long operation in the prone position. In addition, the prone position limits respiratory movement, especially in morbidly obese patients and those with pulmonary diseases. Moreover, position changing prolongs the duration of the procedure, due to the placement of a ureteral catheter before m-PCNL is in the lithotomy position. Finally, if effusion of peritoneum or pleura appears, switching to general anesthesia with endotracheal intubation is more difficult for the anesthetist. Thus, the prone position may not be the best choice for high-risk patients.

Although the lateral decubitus position for PCNL has been reported in the literature [3, 4], it still suffers from drawbacks. For example, patients in this position might feel uncomfortable, and sometimes the stones are difficult to be rushed out because of the relatively large angle between the horizontal plane and the working tract.

Valdivia-Uria et al. [2] reported a study in 1988 in which a total of 557 consecutive percutaneous nephroscopies were attempted in the supine position. Nephroscopy was performed in 519 cases (93.1%). In our study, the rate of successful calyceal puncture for m-PCNL in the supine position was 100%. The sufficient preoperative examination (plain films, including orthotropic view, lateral view and antero-posterior view, and/or three-dimensional computed tomography scan) and intraoperative selection of ideal PCNL tract by real-time ultrasound were key factors for us to achieve the success of the procedure. Shoma [5] evaluated a total of 130 patients who underwent percutaneous nephrolithotomy for renal or upper ureteral stones in a prospective and non-randomized manner. Their procedure was carried out in supine and prone positions and the stone clearance rate was 89 and 84%, respectively. In our study, only four (4.3%) patients had residual stones after the second m-PCNL.

Colon injury is considered as a severe complication of PCNL. Although this complication occurred rarely, such problems have been described in some percutaneous nephroscopies performed in the prone position [6–8]. We note that the risk of damaging the colon of the patient in the supine position could be minimized by carefully reviewing pre-operative images (plain films, IVU and 3D CT) and, more importantly, by guiding the puncture with real-time US imaging to select an ideal tract. In our study of 92 cases, no colon injuries were observed. From an anatomic point of view, if the colon is located anterior to the line or on the line of the percutaneous nephrostomy tube, colon injury is inevitable. It means there is a potential risk of colon injury because of its posterior position to the line.

Hopper et al. [9] found that in a series of 90 prone and 500 supine abdominal CT scans, the bowel was posterior to the kidneys in 10 and 1.9% of cases, respectively. They suggested that the bowel might be more often encountered in the posterior of the kidney in the prone position compared to the supine position. Therefore, performing PCNL in the prone position may increase the risk of colon injury. Boon [10] stimulated the percutaneous nephroscopies guided by CT scan. They found that, when the upper pole or renal hilum or the lower pole of the kidney was punctured, the potential risk of injuring the descending colon was 1.1, 5.2, 16.1%, respectively, while the potential risk of injuring the ascending colon was 0.4, 2.8, 9.0%, respectively. They concluded that the risk of injuring the colon increased when puncturing was performed at the lower pole of the kidneys.

In order to identify anatomy variations and choose the appropriate puncture site, it is necessary to obtain a preoperative plain abdominal radiograph (including lateral and anteroposterior views) or CT scan. For a single pelvic stone, the middle calyces should be chosen; for staghorn stone, the middle or upper calyces should be selected. It is more convenient for the ureteroscope to access the ureter and other calyces. In general, two tracts for PCNL were enough. A third tract was not advocated in our study, because there was not enough space for the third tract in the supine position. In addition, the more PCNL tracts set up, the more injuries. In order to avoid injuring the colon, renal pedicle or pleura, the area margin within the lower ribs, iliac crest, midaxillary line and angulus inferior scapulae line should be chosen as the puncture site. Compared to the prone position, the safe area can be extended to the midaxillary line because of the anterior displacement of kidney by elevating ipsilateral flank and a small angle between the lateral axis of the kidney and the horizontal plane.

Real-time ultrasound is a useful and reliable tool for m-PCNL. It can not only dynamically monitor the whole procedure of puncture, but also allow us to detect residual stones at the end of the surgery.

There are several advantages of the supine position. First, patients are comfortable and they do not need to practice the position before surgery. Second, this position does not disturb blood circulation and respiration as the prone position does. Therefore, PCNL can be performed in patients with poor cardiorespiratory function or under intensive care. Third, the patients can tolerate a longer period of operation in this position. In our study, one patient had a large stone of 60 g. The procedure of this patient took 350 min to remove the entire stone in the supine position. Fourth, the risk of iatrogenic colon injury is lower in the supine position. Fifth, this position is convenient for the anesthetist to observe the patient and switch to general anesthesia with endotracheal intubation if necessary. Moreover, a retrograde catheter can be placed in the same position at the beginning of the procedure. Finally, because the angle between the horizontal plane and working tract is small, it is easier to wash out stone fragments through the working sheath. In addition, urologists are comfortable as they can sit while performing the operation.

There are also certain disadvantages in the supine position. One of them is that there is not enough space for a third tract if needed. In addition, the mobility of kidneys in the supine position is larger than in the prone position or lateral decubitus position. Therefore, the kidneys are easy to move anteromedially during the tract dilation in the supine position. The PCNL procedures are relatively difficult for anterior calyceal stones and the cases with severe hydronephrosis, because it is difficult to dilate the renal pelvis and calyces after puncture due to gravity. As the angle between the plane of the operation table and the anterior calyces is smaller than other positions, it is difficult to access the anterior calyces.

## Conclusions

In conclusion, the supine position is a very good alternative position for the patients and surgeons. The risk of iatrogenic spleen injury is rare with this method and the fragmented stones are easier to be washed out. The position is convenient for the anesthetists to observe the patient and switch to general anesthesia with endotracheal intubation if necessary. This position is especially suitable for stones in the upper ureter, renal pelvis and posterior calyces. Disadvantages of the supine position include kidney movement anteromedially during the tract dilation.

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