

Percutaneous Nephrolithotomy With X-Ray Free Technique in Morbidly obese Patients: Outcomes and Skills From A Large High-Volume Stone Management Center

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Abstract

Objectives

This study was performed to investigate the feasibility and safety of complete ultrasound (US)-guided percutaneous nephrolithotomy (PNL) in morbidly obese patients and to introduce the US skills used in a high-volume stone management center.

Methods

We retrospectively reviewed consecutive patients with a body mass index (BMI) of ≥ 40 kg/m² who underwent X-ray-free PNL for treatment of upper urinary tract stones from October 2013 to March 2020. The patients' demographic information and intraoperative and postoperative parameters were collected and analyzed. Surgical complications were recorded and classified according to the modified Clavien classification system.

Results

In total, 52 patients were included. Their mean BMI was 45.5 kg/m² (range, 40.3–61.6 kg/m²), and their mean age was 46 years (range, 28–58 years). The mean stone burden was 2.8 cm (range, 2.1–8.8 cm). Thirty-nine patients underwent surgery in the prone position, and the remaining 13 underwent surgery in the lateral position. All procedures were completed successfully with no major intraoperative complications. The mean operative duration was 68 min (range, 38–97 min). The mean time required for establishment of each access was 6.6 min (range, 3.5–14.7 min). No blood transfusion or embolization was needed for any patient. The initial stone-free rate was 80.8% (42/52 patients). Five patients required second-look PNL. Two patients underwent flexible ureteroscopic lithotripsy. The final stone-free rate was 90.4% (47/52 patients).

Conclusions

Complete US-guided PNL was technically feasible and safe in morbidly obese patients. The stone-free rate and complication rate were acceptable and comparable with those in non-obese patients.

Introduction

Morbid obesity is defined as a body mass index (BMI) of ≥ 40 kg/m² according to the World Health Organization. A high BMI is associated with multiple chronic diseases and is a dependent risk factor for urolithiasis.¹ Although the exact association between obesity and nephrolithiasis is unclear, stone formation is closely linked to metabolic syndrome.² Alterations in urinary citrate, electrolytes, oxalate, uric

acid, and urinary pH may also contribute to stone formation. Some studies have shown that a high BMI might be correlated with increased stone size, which indicates that stones in these patients might be much more difficult to manage than in patients of normal weight.³

Percutaneous nephrolithotomy (PNL) is the first-line treatment for complex and staghorn stones. Performing PNL in morbidly obese patients is challenging because of the potent risks and higher morbidity rate.⁴ Previous studies have confirmed the safety and feasibility of PNL under fluoroscopy. However, the efficiency of total ultrasound (US) guidance in morbidly obese patients has not been proven; the traditional view is that obesity is a risk factor for more difficult US-guided access to the renal collecting system. US is sometimes used to reduce radiation exposure in some Western countries, while X-ray-free techniques for PNL have been widespread in China for > 10 years. Most urologists in China use US as the only method for PNL guidance. Although China has a relatively low proportion of morbidly obese patients, the prevalence of obesity has been increasing worldwide, including in China, during the past several years. This study was performed to investigate the feasibility and safety of total US-guided PNL in morbidly obese patients and highlight the difficulties and problems that can be encountered and effectively resolved.

Materials And Methods

The medical records of 59 obese patients who underwent PNL from October 2013 to March 2020 were retrospectively reviewed. Seven patients were excluded because of incomplete data. All procedures were performed by one experienced urologist. The preoperative demographic data reviewed were age, sex, BMI, stone size (maximum length on computed tomography [CT]), and operative position. The stone size was determined by a preoperative CT scan.

All procedures were performed under general anesthesia. The prone position was preferred, but the lateral position was selected for patients who could not tolerate the prone position [Fig. 1]. A retrograde 5-Fr ureteric catheter was first inserted into the renal pelvis with the patient in the lithotomy position, and a 16-Fr Foley bladder catheter was placed. The distal end of the ureteric catheter was connected to a saline bag for gravity infusion to create artificial hydronephrosis. The patient was then placed in a suitable position with appropriate padding of pressure points. A 3.5-MHz convex abdominal US transducer (Esaote, Genoa, Italy) was used to detect the kidneys and surrounding organs. Percutaneous access was established using a 15-cm-long 18-gauge needle (Urotech, Bad Aibling, Germany). The ideal target calyx was determined totally by US. The transducer was fixed and the needle was inserted in front of it when the calyx was confirmed. The needle tract could be visualized on the screen. The tract was dilated with either Alken coaxial telescopic dilators (Richard Wolf GmbH, Knittlingen, Germany) or a high-pressure balloon dilator (X Force® N30 balloon dilator; Bard Urological, Covington, GA, USA) to standard 24 Fr. Nephroscopy was performed using an 18-Fr rigid nephroscope. Successful US-guided access was defined as arrival at the target calyx with the ability to perform fragmenting procedures. Stones were disintegrated and suctioned with a combined ultrasonic/pneumatic lithotripter (Swiss LithoClast; EMS Electro Medical Systems, Nyon, Switzerland). Additional accesses were established if needed. US was

then used to recheck the collecting system and confirm whether residual stones were left. A 6-Fr indwelling ureteral stent was routinely placed in an antegrade manner and kept in place for 2 to 4 weeks after surgery. A 14-Fr nephrostomy tube was routinely placed at the end of surgery and removed 3 to 4 days later if no complications occurred.

The stone-free status was evaluated 2 to 3 days after surgery with a kidney, ureter, and bladder (KUB) radiograph or non-enhanced CT scan [Supplementary Fig. 1]. The number of access tracts, time required to establish each access, operative duration, postoperative hospital stay, related complications, stone composition analysis, and auxiliary therapy were recorded. Estimated blood loss was evaluated 24 hours postoperatively. The modified Clavien classification system was used to grade the perioperative complications. A stone-free status was defined as the presence of clinically insignificant (≤ 4 -mm) residual stone fragments on the postoperative KUB radiograph or CT scan.

Results

In total, 52 patients (32 men, 20 women) were included in our study. Their mean age was 46 years (range, 28–58 years), and their mean BMI was 45.5 ± 5.2 kg/m² (range, 40.3–61.6 kg/m²). The mean stone burden was 2.8 cm (range, 2.1–8.8 cm). Thirty-two patients were diagnosed with urinary tract infection by urinalysis, and *Escherichia coli* and *Proteus mirabilis* were the most common bacteria grown from urine culture. All patients with urinary tract infections underwent antibiotic therapy before surgery. Thirty-nine patients underwent surgery in the prone position and 13 underwent surgery in the lateral position according to their anesthetic requirement or preoperative CT image. Percutaneous access was successfully established in all patients, and fluoroscopy was not needed to assist the guidance. The mean operative duration was 68 min (range, 38–97 min). Sixty-three tracts were established during the first-stage surgery (single in 42 patients, double in 9 patients, and triple in 1 patient), and the mean time required for each access establishment was 6.6 min (range, 3.5–14.7 min). Six tracts were lost during the primary procedure, requiring re-puncture; all occurred in the course of the second or third tract establishment. Twenty-five patients (48%) had an upper pole tract to the preferred calyx. No severe complications occurred during the procedures. The mean hemoglobin drop 24 hours postoperatively was 1.6 g/dl (range, 0.5–3.7 g/dl). The mean postoperative hospital stay was 6.7 days (range, 4–10 days). The complication rate using the modified Clavien classification system was 25%, including grade I complications in 10 patients (fever in 6, pain in 4) and grade II complications in 3 patients (transient bleeding in 2, subcapsular hematoma in 1). No septic shock or embolization occurred. The initial stone-free rate was 80.8% (42/52 patients) after the first-stage surgery (40 with CT scan, 12 with KUB radiograph). Five patients required second-look PNL (four additional tracts): two patients underwent flexible ureteroscopic lithotripsy to remove the residual stones after a 7-day interval, and three patients with residual stone fragments were observed with medical expulsive therapy. The final stone-free rate was 90.4% (47/52 patients) when the ureteral stent was removed (Table 1).

Table 1
Preoperative, intraoperative and postoperative variables in patients

Gender, n (%)	32 (61.5)
Male	20 (38.5)
Female	
BMI (kg/m ²), mean ± SD	45.5 ± 5.2
Age (y), mean (range)	46 (28–58)
Stone size (cm), mean ± SD	2.8 ± 1.2
UTI, n (%)	32 (61.5)
Surgical position, n (%)	13 (25)
Lateral	39 (75)
Prone	
Operative time (min), mean (range)	68 (38–97)
Access number, n (%)	42 (80.8)
Single	9 (17.3)
Double	1 (1.9)
Triple	
Each access establishment time (min), mean (range)	6.6 (3.5–14.7)
Primary access, n (%)	25 (48)
Upper pole tract	15 (29)
Middle calyx tract	12 (23)
Lower pole tract	
Hemoglobin loss (g/dl), mean (range)	1.6 (0.5–3.7)
Postoperative hospital stay (d), mean (range)	6.7 (4–10)
Perioperative complications, n (%)	10 (28.8)
Grade I	3 (5.8)
Grade II	0
Grade III	

Gender, n (%)	32 (61.5)
Male	20 (38.5)
Female	
Auxiliary procedures, n	5
Second-look PNL	2
Flexible ureteroscopic lithotripsy	3
MET	
Stone-free rate, %	80.8
After first-stage surgery	90.4
Final	

Discussion

Obesity has been linked to many metabolic disorders, such as type 2 diabetes mellitus, hypertension, and urolithiasis. Excessive consumption of purine and carbohydrates and a low urinary pH may contribute to the relationship between stone formation and obesity.⁵ Clinical treatment of these patients can be very challenging. The efficiency of shock wave lithotripsy may be influenced by the increased skin-to-stone distance.⁶ Flexible ureteroscopy can provide a satisfactory therapeutic effect for small (< 2-cm) stones; Dash et al.⁷ found that flexible ureteroscopy for small stones could achieve a comparable stone-free rate between obese and non-obese patients. However, because of the limited flexion angle and poor vision provided by flexible ureteroscopes, large stones or stones in an unfavorable location in the renal calyx cannot be removed or even reached. It was suggested that PNL may be used to more effectively handle these situations.

PNL is challenging in morbidly obese patients because of poor radiographic and US images under unconventional conditions, ambiguous collecting system and stone locations, and an inadequate sheath length because of excessive fat tissue. Previous studies have proven the safety and efficiency of fluoroscopy-guided renal access establishment in obese patients, with an acceptable postoperative complication rate and stone clearance status. However, when using fluoroscopy, larger radiation doses are often required to penetrate the thick tissue and achieve the same image quality as that in non-obese patients; thus, both patients and intraoperative staff are exposed to a much higher level of radiation.⁸ Reducing the radiation dose is clinically valuable for both patients and medical staff. Compared with fluoroscopy, US has several significant advantages including the elimination of ionizing radiation exposure, accurate observation of the kidney structure and location of stones, distinction of the surrounding organs from the kidney, avoidance of major vessel injuries using Doppler flow imaging, and detection of radiolucent stones. During the past few decades, US-guided techniques have been widely promoted in China, and most centers use total US guidance throughout the whole course of PNL.

Although total US-guided PNL has been proven safe and feasible in special cases, such as in pediatric patients, patients with a solitary kidney, and even patients with spinal deformity, its use in morbidly obese patients has rarely been reported. The main concern is that excessive fat tissue surrounding the kidney can reduce the image quality under US because the distance between the puncture point and target calyx is increased and the US energy is absorbed by adipose tissue along the access route [Fig. 2]. Likewise, locating and adjusting the needle during the course of puncture may be adversely affected by the increased distance between the puncture point and calyx. For beginners, the barriers to successful establishment of renal access are both the difficulty in determining the depth of puncture and the lack of a clear image. We suggest the beginners start procedures after they complete the learning curve of US-guided PNL. Choosing patients with moderate or severe hydronephrosis and using a “two-step” method or balloon technique can improve the success rate. In the present study, access establishment failed in six cases, and all failures occurred in the course of establishing the second or third tract. This may be attributed to the unclear image caused by fluid extravasation after establishing the first access. Calyx selection might be another reason for loss of access. Puncture of the lower pole calyx always indicates a longer distance from the skin to the stone, which increases the risk of inaccurate puncture and guidewire displacement during US-guided procedures. A previous study indicated that the lower pole calyx is the preferred calyx under fluoroscopy⁹; however, we usually choose the upper calyx because the upper pole of the kidney is closer to the back and the lower pole is much closer to the ventral side in the sagittal view. In the prone position, the distance from the upper pole to the probe is much shorter, which can result in a better image. Additionally, access to the upper calyx provides an easier way to reach the lower calyx and upper ureter.

Anesthetic challenges can arise in the prone position. Previous studies have shown that hemodynamic and respiratory accidents, including carbon dioxide retention and obstructed venous drainage, may occur in the prone position.¹⁰ However, with the progress in anesthetic technology, various outcomes have been reported in this field. Siev et al.¹¹ found that prone positioning did not impact the peak inspiratory pressure compared with supine positioning, meaning that the prone position can be a safe and viable option in PNL. Karami et al.¹² found that the arterial partial pressure of oxygen was significantly increased in the prone position, while the arterial carbon dioxide pressure remained unchanged. These studies support the view that the prone position can improve, not impair, ventilation. Only five patients were converted to the lateral position because of high airway pressure in the prone position. Minor adjustments are always needed to make patients more stable and readings more reliable; the head should be well supported and turned to one side, a silicone mat should be inserted under the abdomen to fix the fat and internal organs, and a sponge cushion should be placed under the chest and iliac crests for padding. After securing the patient with a fixing belt, the bed can be tilted toward the left or right as needed.

Although the mortality rate of PNL is lower than that of open surgery, morbidly obese patients are still at a higher risk of complications than patients with a normal BMI.¹³ Streeper et al.¹⁴ reported that the rate of severe complications (Clavien grade \geq III) was 9.7%. El-Assmy et al.⁹ reported major complications in

6.4% of patients, including five cases of colon injuries. Our center has been performing US-guided PNL for > 15 years, and tens of thousands of patients, including patients with spinal deformity,¹⁵ patients with a solitary kidney,¹⁶ and pediatric patients,¹⁷ have been safely and efficiently treated by this technique. In a large-sample study, we found that the incidence of bleeding, embolization, or adjacent organ injury was significantly lower than that associated with fluoroscopy.^{18]} In the present study, no severe complications occurred during the procedures. Perioperative complications were seen in 25% of patients, and most were mild. Only two patients with transient bleeding and two patients with a subcapsular hematoma required pharmacological treatment. No patient required a blood transfusion or embolization, and no patients developed septic shock. A stone-free status was achieved in 42 patients after the first-stage surgery, but the stone-free rate was somewhat lower than what we had previously reported in general cases. This may be attributed to the indistinct images obtained under US, especially during the establishment of multiple tracts. The stone reflection may have been adversely affected by fluid extravasation and intra-renal speckles. Additionally, the working sheath was almost totally trapped under the skin, which limited the movement of the nephroscope and thus increased the possibility of leaving residual stones. Five patients underwent second-look PNL, and two underwent flexible ureteroscopic lithotripsy to remove the residual stones. Five patients had residual stones left until the last follow-up. The postoperative stay was much longer than that in previous studies. One reason is that a renal drainage tube was always routinely placed and taken out before discharge from the hospital. In addition, the patients preferred to recover well before returning home because of the traditional Chinese culture, which prolonged the duration of hospitalization.

Poor visualization of US images in obese patients may reduce the surgeon's confidence, but proper settings of US parameters will help to improve the clarity. Compared with fluoroscopy, US has significant advantages such as no radiation exposure, the ability to distinguish the surrounding organs from the kidney, avoidance of injury to major vessels using the Doppler flow mode, and detection of radiolucent stones. During the past few decades, US-guided techniques have been widely promoted and rapidly adopted in mainland China, and most centers use the total US technique in PNL. To shorten the learning curve for novices, we developed an innovative way to quickly master the US technique. We established guiding principles termed the "30-degree angle principles," which highlight the three important 30-degree angles during the procedure **[Fig. 3]**. These principles are applied to patients in different positions. The first 30-degree angle is the angle between the long axis of the transducer and the spine during the kidney scan prior to puncture. This principle is based on the anatomic concept that the connection between the upper and lower poles of the kidney presents a 30-degree angle with the spine in the coronal position. The overall structure of stones and their surroundings can be displayed clearly under this angle, providing a basis for selection of the ideal target calyx. The access numbers and the optimal calyx for puncture can be determined by the first 30-degree angle. If the target calyx is chosen, it must be moved to a suitable position in the US image for puncture. However, the best place to move this calyx is not always clear. Therefore, we proposed the second 30-degree angle. This angle is used for longitudinal needle insertion; the angle between the border of the ipsilateral US image and needle tract should be 30 degrees to ensure the shortest puncture path and almost vertical access from the parenchyma into the calyceal fornix. The

third 30-degree angle corresponds to the second one; after the needle enters the skin vertically, the needle handle is moved from the vertical to the head side (puncture from the front of the transducer) or tail side (puncture from the back of the transducer), and the tilt angle is about 30 degrees. This principle has promoted the development of ultrasonic PNL, and Western clinicians have begun to gradually accept and learn it.¹⁹⁻²¹ More importantly, US-guided PNL in morbidly obese patients is challenging even for experienced urologists; therefore, we advise beginners to complete the learning curve of the US-guided technique before handling these cases and to choose easy cases (patients with moderate hydronephrosis and a single stone) in the early stage.

This study was limited by its retrospective nature and the lack of a comparison group during the same period of time. Additionally, stone composition analysis was not included in our study because we did not consider that the stone analysis results would influence the outcome of the procedures. Finally, the follow-up and evaluation of the stone-free status were not performed by CT scan in 12 patients, which may have resulted in overestimation of the final stone-free rate to some extent.

Conclusion

Total US-guided PNL was feasible and safe in this population of morbidly obese patients. We recommend that this procedure be carried out after completion of the learning curve because of the risk of technical problems.

Declarations

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Author contributions

Xiao: project development, manuscript writing

Zeng: data analysis

Jl: manuscript editing

Zhang: data analysis, manuscript writing

Hu: data management;

Jin: data collection

Su: data analysis

Tang: data collection;

Li: project development, manuscript editing

All authors read and approved the final manuscript.

Conflict of interest

All authors declare that they have no conflict of interest.

Funding statement

None

Ethical approval

This study was a retrospective review of patients treated in our hospital. It was approved by the ethics committee of Beijing Tsinghua Changgung Hospital. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed Consent to Publish

All of the images and clinical information has been approved by patients and agreed to be published.

Availability of data and materials

For more data and materials, please contact Xue Zeng (cengx12@tsinghua.org.cn)

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Figures



Figure 1

For obese patients, lateral position was preferred rather than traditional prone position.

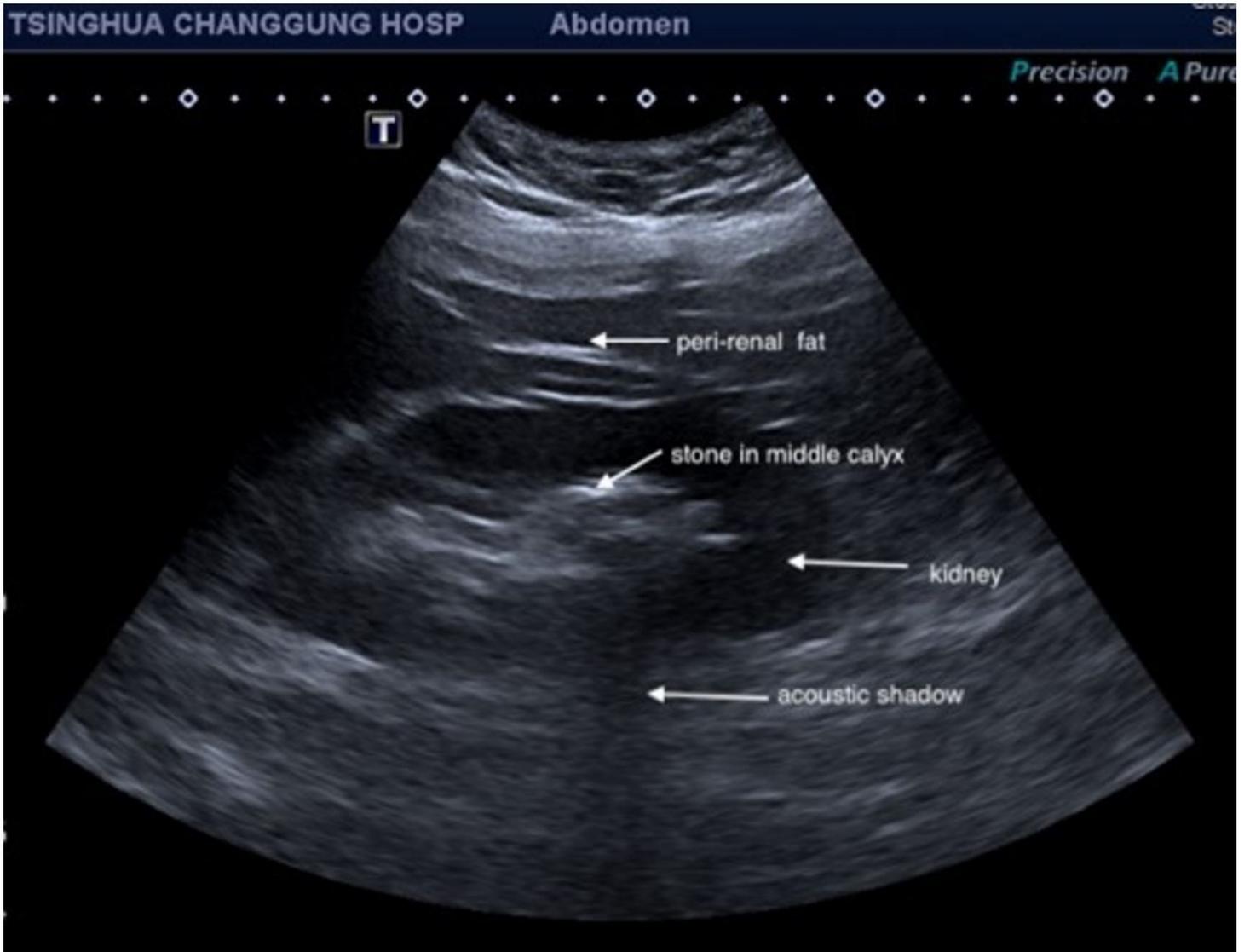


Figure 2

For obese patients, US-guide PNL was different since obese patients had excessive fat tissue.

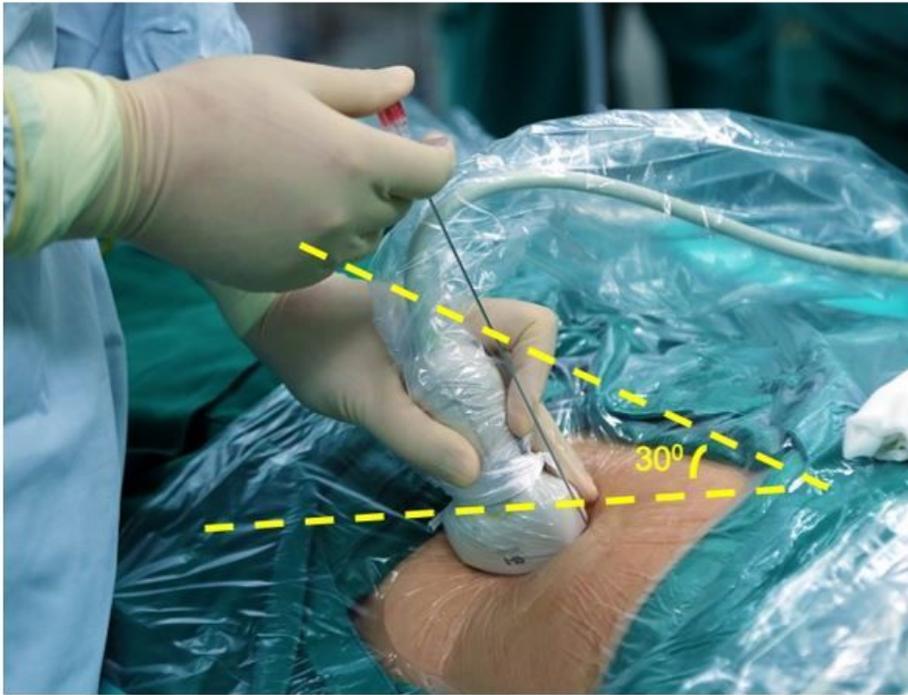


Figure 3a

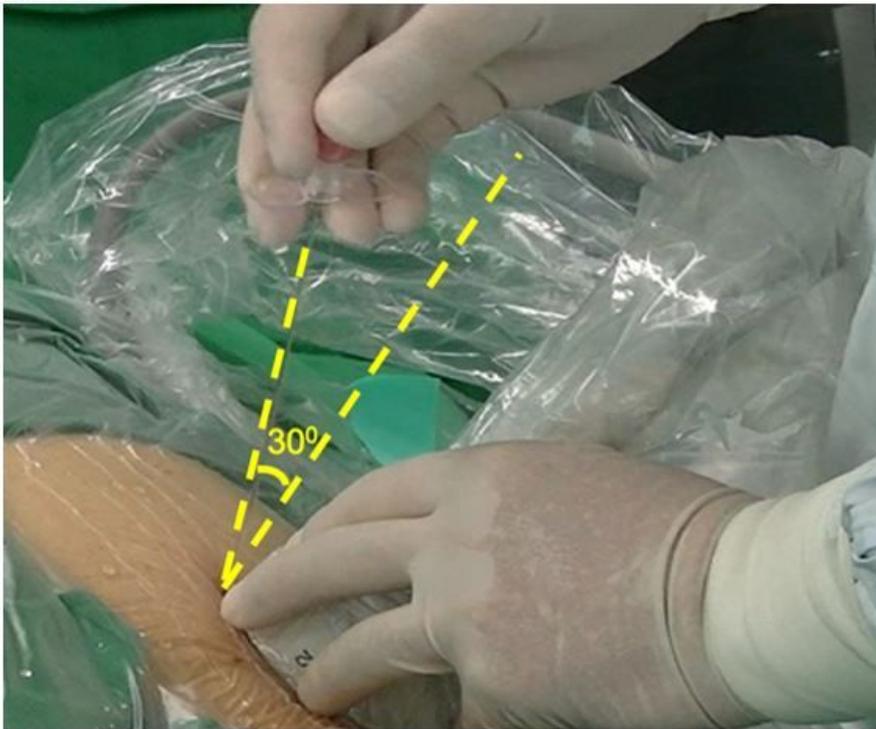


Figure 3b

Figure 3

3a The first 30-degree angle is the angle between the long axis of the transducer and the spine during the kidney scan prior to puncture. 3b The second 30-degree angle is used for longitudinal needle insertion; the angle between the border of the ipsilateral US image and needle tract should be 30 degrees to ensure the shortest puncture path and almost vertical access from the parenchyma into the calyceal fornix

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