The Clinical Application of Puncture Frame in Establishing Ultrasound Guided Percutaneous Nephrolithotomy Access

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Purpose: To investigate the clinical efficacy and safety of ultrasound-guided percutaneous nephrolithotomy (PCNL) assisted by a puncture frame.

Materials and Methods: Clinical data of 106 patients with nephrolithiasis who underwent ultrasound-guided percutaneous nephrolithotomy from October 2016 to December 2017 in our hospital were analyzed retrospectively. The channels were established by the assistance of the puncture frame.

Results: The mean puncture time was 35 ± 18 seconds, the puncture was performed 1.3 ± 0.9 times on average. The puncture was successfully performed at first attempt in 73 cases. The mean operation time was 67.3 ± 39.2 min, and the mean intraoperative blood loss was 48 ± 22 mL. The stones were located on the left in 50 (47.2%) cases, and on the right in 56 (52.8%) cases. Channels were established through the upper, middle and lower calyces of the kidney in 78 (73.6%), 20 (18.9%), and 8 (7.5%) cases, respectively. The puncture sites were located on the upper and lower of 12th rib in 81 (76.4%) and 25 (23.6%) cases. Intraoperative and postoperative blood transfusion was given in four cases. Pleural injury occurred in two cases, and hydropneumothorax occurred in one case in whom closed thoracic drainage was performed. The stone free rate after a single surgery was 87.7% (93/106).

Conclusion: Establishing a percutaneous nephrolithotomy access tract under ultrasound guidance using the puncture frame is an efficacious and safe approach.

Keywords: puncture frame; ultrasound; percutaneous nephrolithotomy; puncture; complications

INTRODUCTION

The application of ultrasound-guided percutaneous nephrolithotomy access tract was first reported by Karamcheti[1] in 1977. Its main utility lies in the establishment of a percutaneous tract before the operation and intraoperative stone localization and postoperative calculus examination. Fluoroscopic-guided access percutaneous nephrolithotomy is also widely used. Its advantage lies in the accuracy of puncture guidance. However, surgeons, assistants, nurses and patients, all have to endure various levels of radiation exposure. Numerous studies have shown that frequent radiation exposure is harmful to the human body, even under the aegis of protective aprons and thyroid shileds[2]. Establishing the access tract is the most critical step in PCNL and renal puncture[3]. It does not only affect the operation time, intraoperative blood loss, surgical complications, but also affects successful stone removal rate of a single operation, postoperative sepsis incidence, mortality, etc. For the surgeons who are not familiar with the surgery, the intraoperative and postoperative complications increase correspondingly. The safe and effective establishment of percutaneous nephroscope channel urgently requires a certain real-time positioning and needle insertion technology to achieve.

As a result, we decided to perform an analysis based on the clinical data of patients who underwent PCNL surgery from October 2016 to December 2017 in our hospital. All operations are performed by the same surgical team, and the establishments of percutaneous renal channels were completed with ultrasound guidance assisted by puncture frame.

PATIENTS AND METHODS

Study population

All patients from Sichuan Province were treated with PCNL in our hospital. PCNL is typically done by our team for renal stones ≥ 2 cm, smaller stones refractory to extracorporeal shock wave lithotripsy (ESWL), and large upper ureteral stones. The exclusion criteria were ureteral stones which underwent ureteroscopy or flexible ureteroscopic lithotripsy before or after PCNL. The surgical indications conform to the 2014 Chinese guidelines for the diagnosis and treatment of urological diseases [4]. Preoperative blood biochemical examination, electrocardiogram, chest X-ray, echocardiography, pulmonary function and other routine preoperative tests and preparation were completed in advance, excluding surgical contraindications, such as cardiopulmonary and cerebral lesions, coagulation abnormalities, etc. As

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Table 1. Patients' charchteristics.

Variable	
Gender (M/F)	62/44
Age (years), mean±SD	45 ± 7
BMI(kg/cm2), mean±SD	23.1 ± 2.5
Side of kidney stone (R/L)	56/50
Stone surface area (mm2), mean±SD	637 ± 169

Table 2. Operations' characteristics.

Parameters	
Duration of establising channel (s), mean±SD	35 ± 18
Access, N, mean±SD	1.3 ± 0.8
Operation time (min), mean±SD	67 ± 39
Upper/ middle/ lower pole	78,20,8
Upper and lower 12th rib	81,25
Intraoperative blood loss (mL), mean±SD	48 ± 22
Hounsefiled units(HU), mean±SD	659 ± 315

for specialist examination, color Doppler ultrasound, plain Kidney-Ureter-Bladder X-ray (KUB), intravenous pyelography (IVP), and computed tomography (CT) were used to determine the location and size of stones. Furthermore, preoperative CT scans were used to design puncture targets for calyces, focusing on the location of calculi and calyces, as well as the relationship between the kidney and surrounding organs, such as lower pleura, liver, spleen, and posterior colon.

Study design

Equipment mainly included digital ultrasonic diagnostic imaging system (Mindray, DP-30; Mindray Bio-Medical Electronic Co, Ltd, Shenzhen, China), and matching puncture frame (Mindray, 18G; Mindray Bio-Medical Electronic Co, Ltd, Shenzhen, China) (**Figure 1**), PCNL kits (Reborn Medical, 18G, F8-F22; Hunan Reborn Medical Science and Technology Development Co. Ltd, Hunan, China), guidewire (Zebra™, 0.032in×150cm; Boston Scientific Corporation, USA) and ureteral stent (Percuflex™ Plus, 4.8Fr-6Fr×26cm; Boston Scientific Corporation, USA), ureteroscope (Wolf, 9.8 Fr. ; Richard Wolf Inc., Germany), and nephroscope (Wolf, 20 Fr. ; Richard Wolf Inc., Germany), holmium: YAG laser lithotripsy unit (P.S. INT-60W Holmium Laser System; Lumenis GmbH, Dieburg, Germany), and ultrasonic lithotripter (EMS; Swiss Master Lithoclast, Bern, Switzerland).

All operations were performed under general anesthesia with endotracheal intubation. The patient was firstly placed in a lithotomy position, routinely sterilized and

Figure 1. Ultrasonic probe and matching puncture frame.

laid with operation towels, and placed 5F or 6F ureteral catheter on the affected side under cystoscopy and ureteroscopy. The ureteral catheter was retained to fix the ureteral catheter, and the 3-liter bag (3000ml saline) was externally connected for continuous irrigation. The patients' posture adjustment for the prone position, raise the waist with a cushion, the surgical bed was adjusted for "⌒" to expose the lower back. The ultrasonic probe was firstly positioned, and puncture channel was designed in combination with CT, KUB, and IVP to determine the approximate range of puncture points. Routine disinfection and towel laying were performed again, Preoperative preparation of instruments such as ureteroscope was performed by the assistant simultaneously. A three-way tube was placed in the ureteral catheter, and methylene blue was used as an indicator during the operation. The puncture frame was fixed on the ultrasonic probe, and the puncture angle was adjusted to 23°. The puncture point was determined at the preoperative puncture range, and the puncture path, puncture angle, puncture safe depth interval (and the length between the deepest and shallowest puncture) were emphatically determined. After determining the puncture point, the anesthesiologist adjusted the patient's breathing to the end of expiration, in order to raise the pleura and lower lung lobe to the highest level, and avoid injury to pleura and lung, and help reduce the influence of respiratory activity on the position of the kidney. The assistant then penetrated the puncture needle slowly into the puncture frame, observing the path of the puncture needle. After the tip of the puncture needle entered the target cup, the inner core of the puncture needle was removed, and the scrub nurse injected methylene blue. When the blue urine overflowed from the puncture needle, the urinary guide wire was inserted, and the puncture frame and ultrasonic probe were removed, and the patient was allowed to resume breathing. The remaining steps included expanding the puncture site to F18~F22 by fascial dilatation, and establishing percutaneous nephroscope channels routinely, then a holmium laser or ultrasonic lithotripsy was used. Ureteral stent and renal fistula were placed after the operation. (**Figure 2**)

Surgical technique

Techniques and precautions for the establishment of percutaneous nephroscope channels included:

(1) CT films were read before surgery to preliminarily determine the target calyces, puncture range, puncture route, puncture depth, and puncture angle, so as to facilitate comparison with those before puncture;(2) Preoperative ultrasound localization was performed again, and the puncture location was determined again in combination with preoperative estimated puncture parameters. For the target of the shallower water can be marked "+" on the patient's body surface.(3) The puncture frame was fixed on the ultrasonic probe, the distance from the

Table 3. Complications of operations.

Clavien Classification	Complications	Cases
Grade I	Residual stones	13 (12.3%)
Grade II	Blood transfusion	4 (3.8%)
	sepsis	0
	Perirenal hematuria	0
Grade III-a	Hemopneumothrax	2 (1.9%)
	Intervention embolization	0
Grade IV-a	Abdominal organs injury	0

skin to the target calyces was measured again and kept stable, and the puncture needle was slowly inserted by the assistant at the "distance plus 4cm" (the distance from the proximal end of the puncture frame to the skin was 4cm). After the needle tip entered the target renal calyces, the inner core was removed and the urinary guidewire was inserted sequentially.[(4)] During the puncture, the patient's breathing was adjusted to stop at the end of expiration, which was particularly important for the puncture of the upper calyx; [(5)]. Methylene blue was routinely used as an indicator; [(6)] In the process of fascia dilation, the two-step dilation method was mainly adopted. After the depth is determined by 8F, the channel is directly expanded to 18F~22F, however, the one-step expansion method was performed for mild hydrocephalus target calyx, to prevent the displacement of the urinary guide wire and even channel loss in the repeated expansion process.

Outcome assessment

The observation indicators of the research mainly include puncture time and frequency, intraoperative blood loss, puncture site, intraoperative and postoperative complications. Data were entered into EXCEL ver. 2017 software. The puncture time is defined as the time when the tip of the puncture needle penetrates the skin until the inner core of the puncture needle flows out from the needle sheath or the syringe draws out blue-dyed urine. If the puncture fails or the location is not ideal, the time is up to the puncture satisfaction. The number of punctures is defined as the number of puncture needle penetrating the skin, and the adjustment of puncture depth is not included in the number of punctures. Calculation method of intraoperative blood loss: blood loss (ml)= total intraoperative perfusion fluid (ml)* hemoglobin concentration of lavage fluid (g/L)/ preoperative hemoglobin concentration (g/L)(5).

RESULTS

In this study, there were 62 (58.5%) male patients and 44 (41.5%) female patients, aged from 21 to 73 years old, with an average age of (45.3 ± 6.7) years old. The course of disease lasted from 2 weeks to 10 years. The BMIs of patients were 19~27 (23.1 ± 2.5). The stones were located in the left side of 50 (47.2%) cases and the right side in 56 (52.8%) cases. Other detailed information could be found in **Table 1**. All patients successfully completed the operation and all procedures were performed with a single-channel surgery. 21 (19.8%) patients were treated with 22F channel and 85 (81.2%) patients were treated with 18F channel. The puncture time was 35 ± 18 seconds, the average number of punctures was 1.3 ± 0.9. There were 73 (68.9%) successful cases of single puncture, and the operative time was 67 ± 39 minutes. The operative blood loss was 48 ± 22 mL. The channels were established through the upper, middle and lower calyces of the kidney in 78 (73.6%), 20 (18.9%), and 8 (7.5%) cases, respectively. The puncture sites were located on the upper and lower 12th rib in 81 (76.4%) and 25 (23.6%) cases, respectively (Table 2). Intraoperative and postoperative blood transfusion was given in four cases, pleural injuries occurred in two patients, and hydropneumothorax occurred in one case and closed thoracic drainage was performed. The stone removal rate after a single surgery was 87.7% (93/106) (**Table 3**). Patients were advised to rest in bed for 3 days after the operation, and KUB was reexamined 5-7 days postoperatively to determine the removal of calculi. In general, renal fistula and urethral catheter were extracted 6-8 days after the surgery, and ureteral stent tube was removed 1-2 months post-operation. None of the patients in this study required phase ii PCNL surgery. For the patients with residual stones, extracorporeal shock wave lithotripsy was performed after returning to the hospital about one month after the surgery. After one week of follow-up and reexamination, stones were removed after treatment (defined as residual stones with a diameter of less than 0.4cm). The follow-up period was 3-9 months. The patients were in stable condition

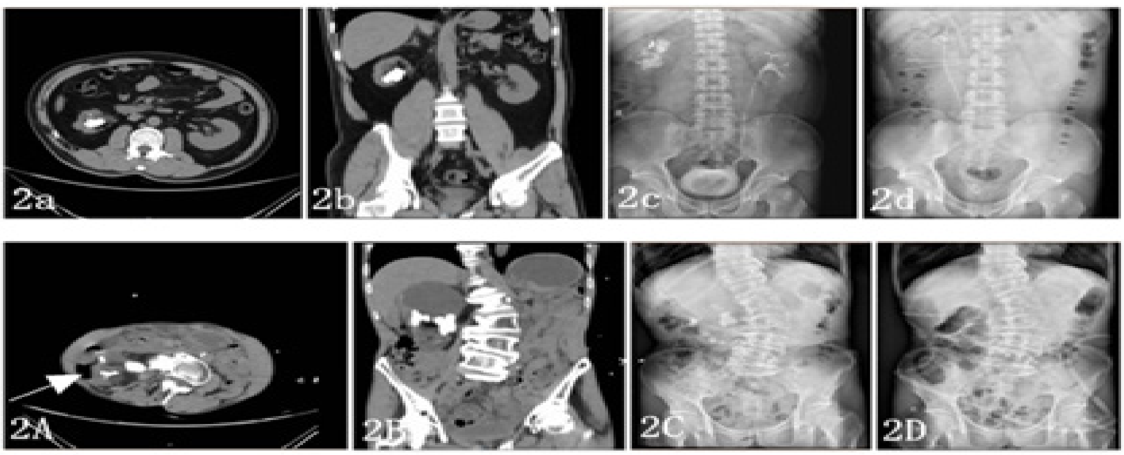

Figure 2. Patient A, Image pre-operation.**(2A, 2B,)** CT, arrows point to the posterior colon; **(2c)** KUB; post-surgery **(2D)** KUB.

and did not complain of special discomfort.

DISCUSSION

Percutaneous nephrolithotomy is still an important method for the treatment of renal calculi larger than 2 cm and upper ureteral obstructive calculi, especially suitable for the treatment of complex kidney stones such as cast stones, multiple stones in the kidney and recurrent kidney stones. At present, with the continuous progress of technology and update of ideas, treatment methods such as micro-channel and ultramicro-channel percutaneous nephroscopy, visual puncture technology, flexible ureteroscopy, and multi-lens combination have gradually emerged [5-8]. However, for most hospitals, it is still particularly important to master the conventional percutaneous nephroscope technology.

The key to this technology is the selection and establishment of surgical channels, and the key point of establishing channels is the mastery of puncture technique [9]. Puncture technique guided by X-ray fluoroscopy, as an important method, is still widely used at present, but cumulative X-ray exposure is harmful to medical personnel. Furthermore, due to the unsatisfactory display of important adjacent organs of the human body, such as liver, spleen, intestine, pleura and lung lobe under fluoroscopy, the difficulty and risk of puncture are increased. A real-time ultrasound-guided puncture technique can be used instead allowing synchronous and multi-dimensional dynamic observation [10-12]). However, with this technique the optimal target of puncture may be missed, leading to increased blood loss and reduced stone free rate[13].

Through observation and statistics, we observed and calculated that the use of puncture frame to fix the puncture needle for operation can effectively improve the puncture accuracy, quantify each step in the puncture process, and try to achieve precise puncture, improve the efficiency and effect of the operation, and reduce the incidence of surgical complications. Meanwhile, puncture angle, depth, and other indicators can be quantified by fixing a puncture frame, which is easy to learn and master and reduce the difficulty of learning. During the puncture process, the puncture needle is fixed by the frame, which can effectively avoid the deviation of the puncture needle. The needle can be accurately inserted according to the predetermined puncture line of the ultrasonic probe, and the endoscopic puncture of the patient can be temporarily determined, thereby reducing the respiratory activity to the position of the kidney. The effect can also reduce damage to surrounding organs, especially the pleura or lower lobe of the lung. In addition, the ultrasonic probe matched with the puncture frame is generally a small probe, so that the contact area with the patient's body surface is small, the position of the puncture point is adjusted, and the needle insertion on the twelfth rib is more convenient and accurate.

Through rational design and successful establishment of percutaneous renal access, the single-surgery rate of stone removal reached 87.7% (93/106), and in terms of complications, there were four cases of intraoperative and postoperative blood transfusion, including one case of postoperative cervical cancer with mild-moderate anemia. One patient had multiple renal stones that recurred on the same side. Two patients had secondary bleeding due to postoperative pain. None of the above patients underwent renal artery embolization but were improved by blood transfusion, hemostasis, and conservative treatment. Pleural injury occurred in two cases: A case of hydropneumothorax underwent closed thoracic drainage, and the other patient recovered by conservative treatment. There were no serious cases of vascular embolism, renal perforation, intestinal injury, septic shock and death, and the overall effect was satisfactory.

The main concerns of percutaneous nephrolithotomy include bleeding, infection, and stone clearing rate, and these are closely related to each other. In general, intraoperative bleeding is obvious, the visual field is not good, the irrigation pressure and flushing volume increase correspondingly, and the sinus opening is increased. The bacteria and lavage fluid enter the blood in a short period of time, increasing the risk of serious infection and internal environment disorder. The stone clearing rate is also affected accordingly, so that the second phase, or even multiple stages of surgery, is needed. The key point of the operation lies in the rational selection of the target and the successful establishment of the surgical channel. Firstly, the selection of the target calyx needs to take into account the safety and practicability of the establishment of the surgical channel. Before the operation, careful reading of angiogram or CT films should be carried out to select the optimal target calyces and cutaneous and renal channels based on the individual differences of patients and the location of calculi and hydronephrosis, so as to reduce the risk of bleeding and peripheral organ injury and improve the stone removal rate[14]. However, due to intraoperative changes in vitro and different respiratory activities, corresponding adjustments should be made in time[15]. And as the effect of gravity, the stones are generally in the low position, and irrigation is in the high position[16]. Therefore, in this study, the puncture sputum generally selects the upper part of the upper pole of the kidney with a higher position as the target renal pelvis (98/106). The water is located on the ventral side, so there is no need to deliberately pursue the accumulation of water. The successful establishment of the skin to the target calyx is the key to the surgical process.

In combination with the surgical techniques described above, and due to the intraoperative positioning of the ultrasound probe to reduce the skin to the renal pelvis distance, the needle should be as uniform as possible during the needle insertion process, observe the needle tip and needle position change, to ensure that the needle depth lies within security depths[17]. The puncture needle fixed by the puncture frame can effectively avoid the angle change caused by human operation and so on, and can make the puncture needle enter the renal pelvis through the vault - lamp neck into calyx according to the estimated route [18], which can effectively reduce the renal column and the neck injury leading to bleeding, and it is convenient to place the urinary guide wire into the direction of the renal pelvis, even into the ureteral cavity, and at the same time, it can improve the safety of the fascia expansion, as well as the scope and efficiency of the clear stone[19]. For the target renal hydronephrosis is light or filled with stones, the highest point of the curved back of the stone can be used as the puncture needle target, and the puncture accuracy and success rate can be improved by quantifying the depth[20]. It can even be used to treat urolithiasis in pregnancy[21].

CONCLUSIONS

In conclusion, the main function of the puncture frame is to establish an ideal operating channel by restricting the movement of the puncture needle, which can not only improve the surgical effect but also significantly reduce the occurrence of serious complications.

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CONFLICT OF INTEREST

The authors report no conflict of interest.

REFERENCES

1. Karamcheti A, O'Donnell WF. Percutaneous nephrolithotomy: an innovative extraction technique. J Urol, 1977 ; 118 : 671-2.
2. Thomas Chi, Selma Masic, Jianxing Li, et al. Ultrasound guidance for renal tract acccess and dilation reduces radiation exposure during percutaneous nephrolithotomy. Adv in Urol, 2016;2016:1-8.
3. Fang YQ, Wu JY, Li TC,et al. Computer tomography urography assisted real-time ultrasound-guided percutaneous nephrolithotomy on renal calculus. Medicine(Baltimore). 2017;96(24):1-7.
4. Na Yanqun, Ye Zhangqun, Sun Yinghao, et al. Guidelines for the diagnosis and treatment of urological diseases in China 2014. Beijing: People's Medical Publishing House, 2014: 169- 170.
5. Xiao Longming, Yang Qiaozhi, Chen Jianfa, et al. Comparison of standard channels for percutaneous nephrolithotomy with balloon and fascia dilatation [J/CD]. Chinese Journal of Endoscopy and Urology: Electronic Edition, 2016, 10(4): 255 -258.
6. Dong Chuanjiang, Xie Zonglan, Zhang Lusheng, et al. Comparison of the efficacy of soft ureteroscopy and percutaneous nephrolithotomy in the treatment of renal calculi with a diameter of ≥ 2 cm . Journal of Minimally Invasive Urology, 2016, 5(4): 196-198.
7. Hongshi Xu, Anna L Zisman, Fredric L Coe, et al. Kidney stones: an update on current pharmacological management and future directions. Expert Opin Pharmacother, 2013, 14 (4), 435-447.
8. Chau HL, Chan HC, Li TB, et al. An innovative free-hand puncture technique to reduce radiation in percutaneous nephrolithotomy using ultrasound with navigation system under magnetic field: a single-center experience in Hong Kong. J Endourol. 2016, 30(2): 160-4.
9. Jian Li, JiSheng Lin, JunChuan Xu, et al. A novel approach for percutaneous vertebroplasty based on preoperative computed tomography-based three-dimensional model design. World Neurosurg. 2017; 105: 20-26.
10. Zheng Jianzhong, Liang Fulu, Fan Xianming, et al. Comparison of multi-channel percutaneous nephrolithotomy and single-channel percutaneous nephrolithotomy combined with ureteroscopy for the treatment of complex renal calculi[J]. Journal of Modern Urology, 2016, 21(8): 593-596.
11. Foo Cheong Ng, Wai Loon Yam, Tze Ying Benjamin Lim, et al. Ultrasound-guided percutaneous nephrolithotomy: Advantages and limitations. Investig Clin Urol , 2017; 58: 346-352.
12. 10. Zhao Huacai, Jia Li, Chen Yuangang, et al. Application of ultrasound localization in percutaneous nephrolithotomy. Hainan Medical Journal, 2016, 27(6): 987-990.
13. Long Qingzhi, Li Xiang, He Dalin, et al. Complications and management of 1584 patients with renal and ureteral calculi treated with percutaneous nephrolithotomy. Journal of Modern Urology, 2016, 21(7): 516-519 .
14. Chan CJ, Srougi V, Tanno FY, et al. Percutaneous puncture of renal calyxes guided by a novel device coupled with ultrasound. Int Braz J Urol. 2015, 41(5): 953-8.
15. Li J, Xiao B, Hu W, et al. Complication and safety of ultrasound guided percutaneous nephrolithotomy in 8,025 cases in China.Chin Med J (Engl). 2014;127(24):4184-9.
16. Patel SR, Nakada SY. The modern history and evolution of percutaneous nephrolithotomy. J Endourol. 2015;29(2):153-7.
17. Liu QM, Zhan XS, Wang YL, et al. The application of two point positioning puncture technique in percutaneous nephrolithotomy. Chin J Min Inv Surg, 2013;13:470-1.
18. Yu Weimin, Cao Jun, Zhai Yuan, et al. Ultrasound-guided "percutaneous renal pelvic-neck-two-step puncture method" to establish percutaneous renal channels [J/CD]. Chinese Journal of Endoscopy and Urology: Electronic Edition, 2016 , 10(3): 148-152.
19. Amirhassani S, Mousavi-Bahar SH, Iloon Kashkouli A, et al. Comparison of the safety and eficacy of one-shot and telescopic metal dilatation in percutaneous nephrolithotomy: a randomized controlled trial. Urolithiasis, 2014;42:269-73.
20. Liu QM, Zhan XS, Wang YL, et al. The application of two point positioning puncture technique in percutaneous nephrolithotomy. Chin J Min Inv Surg, 2013;13:470-1.
21. Basiri A, Nouralizadeh A, Kashi AH, et al. X-Ray Free Minimally Invasive Surgery for Urolithiasis in Pregnancy. J Urol. 2016;13(1):2496-501.