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# Finger touching combined X-ray-guided percutaneous nephrolithotomy in 640 cases: an 8-years' experience

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**Abstract. – OBJECTIVE: We aimed to evaluate the safety and efficacy of finger touching combined X-ray-guided percutaneous nephrolithotomy, and the feasibility of avoiding damage in medical staff caused by X-ray.**

**PATIENTS AND METHODS: From January 2013 to December 2020, 640 cases of percutaneous nephrolithotomy were performed through the 18-24-F channel. Among those cases, 22 (3.4%) cases were double-sided kidney stones surgeries, 294 (45.8%) cases were on the right side and 324 (50.5%) cases were on the left side. The targeted renal calyceal puncture was carried out under the combined guidance of the doctor's finger and X-ray. We assessed the X-ray exposure time of patients and doctors, average number of punctures, postoperative hospitalization, calculus removal rates, and complications.**

**RESULTS: The average number of punctures was 2.8 ± 1.4. Average X-ray exposure time during procedure: 2.8 s (range: 2-8 s). Average surgical time: 106.5 ± 49.4 min. Postoperative hospitalization: 6.8 ± 4.2 d. Average reduced hemoglobin level: 5.9 g/day. Stone-free rate 4 weeks after surgeries: 95.6%. Patients with upper ureteral calculi: 395 cases (61.72%). The calculus residual rate of patients with staghorn renal calculi or multiple renal calculi complementary treatments was 82.9%, including 0 patients who received shock wave lithotripsy, 2 cases of repeated percutaneous nephrolithotomy (PCNL), and 18 cases of ureteroscopy. Postoperative placement of renal drainage tube occurred in 52 cases. As for complications, no perirenal infection occurred, two severe bleeding complication cases occurred, and one case of colon perforation occurred.**

**CONCLUSIONS: Finger touching combined X-ray-guided percutaneous nephrolithotomy in patients with renal calculus is safe and can accurately guide the puncture without radiation hazards. The placement of a renal drainage tube was beneficial to reduce renal effusion, hematocele, and infections.**

*Key Words:*
Percutaneous nephrolithotomy, Finger touching combined X-ray-guidance, Renal calculus, Calculus removal rate, Renal drainage.

## Introduction

Percutaneous nephrolithotomy (PCNL) is a minimally invasive technique that has been used clinically for nearly 50 years. Due to the improvement of surgical techniques and the reduction of access in recent years, PCNL has been widely accepted as a safe and efficient surgical technique[1,2]. Accurate entry of the puncture needle through the top of the renal fornix is the key step for the successful establishment of the PCNL channel and ensures the safety of surgery. In most cases, this step requires X-ray guidance. However, long-term exposure to X-ray causes radiative damage to patients and staff. The effects of X-ray are radiation-dose-dependent[3]. The X-ray-guided locating technique demonstrates significant advantages in patients without renal effusion and obese patients. However, it is not possible to accurately determine whether there are important organs on the puncture path. Moreover, the conduction of this technique is difficult in patients with ureteral diversion, and patients can-

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**Table I.** List of clinical features of patients.

| | | | |
|---|---|---|---|
| Average age (years) | 50.63 | | |
| Male:female | 382: 258 | | |
| Stone location | Left side | Upper ureter | 155 cases |
| | | Upper ureter + Kidney calyx | 51 cases |
| | | Renal pelvis | 49 cases |
| | | Staghorn stone | 29 cases |
| | | Others | 13 cases |
| | Right side | Upper ureter | 118 cases |
| | | Renal pelvis | 54 cases |
| | | Upper ureter + Kidney calyx | 47 cases |
| | | Kidney calyx | 41 cases |
| | | Others | 44 cases |
| | Bilateral | 22 cases | |

not receive ureteral retrograde intubation[4]. The ultrasound-guided locating technique is currently emerging and increasingly prevalent. Usage of the ultrasound-guided locating technique can avoid the radiation damage of X-ray, and also potentially reduce the false punctures rate due to accurate locating the renal artery[5,6]. However, its application can be limited due to increased surgical difficulties caused by obesity, low renal effusion, and complex renal structure[7]. Despite the evident advantages of X-ray-guided locating technique, its clinical usage is also limited due to the possible radiative damage. In addition, renal effusion and hematocele are often associated with PCNL. However, due to the limitation of the surgical route, the application of renal drainage is usually missed. Therefore, avoiding excessive radiation damage in patients and staff by X-ray and improving the safety and effectiveness of the surgery is a key factor in the application of the X-ray-guided technique in PCNL.

To solve the problems above, we carried out relevant research for 8 years. We performed the puncture route through a subcostal mini-incision, delivered the puncture needle to the surface of the kidney under the guidance of finger touching by the surgeon, and accomplished an accurate puncture under the guidance of X-ray. To the best of our knowledge, this new method has not been reported elsewhere. In this paper, we document the detailed surgical procedures of the finger touching combined X-ray-guided PCNL and assess the feasibility and effectiveness of this procedure.

## Patients and Methods

This prospective cohort study was conducted from January 2013 to December 2020.

This study was approved by the Institutional Ethics Committee of the Huazhong University of Science and Technology and Sichuan University. Written informed consent was obtained from all participants included in the study.

### Inclusion and Exclusion Criteria

The following criteria for participants recruitment were applied: renal calculus with diameter > 2.0 cm; multiple renal calculi or staghorn renal calculi; and failed extracorporeal shockwave lithotripsy (ESWL) with renal calculus > 1.5 cm in diameter. The criteria for exclusion were patients with previous renal calculus surgery, impaired kidney function, ectopic kidney(s), or urosepsis. Clinical features of all patients are listed in Tables I and II.

### Examination

All patients received a preoperative enhanced CT-scan to measure the size and location of the calculus and to evaluate the preoperative hydronephrosis. According to the postoperative CT-scan, patients with no detectable calculus were classified as calculus-free, patients with calculus residuals less than 4 mm and no symptoms of urinary system obstruction were classified as clinically insignificant residual fragments (CIRFs).

All patients were subjected to non-enhanced CT-scans 3-5 days and 3-4 weeks after the sur-

**Table II.** List of clinical features of patients.

| | Mean ± standard deviation |
|---|---|
| Weight | 62.481 ± 10.617 |
| Stone load (mm) | 13.873 ± 7.599 |
| Operative time (m) | 103.215 ± 40.539 |
| Postoperative hospital stay (days) | 6.881 ± 4.376 |

geries. The patient evaluation included medical history, physical examinations, urine analysis, urine culture, renal function examination, and blood coagulation tests.

During hospitalization, all patients received off-site antibiotics based on their urine culture to reduce urinary tract infections and urinary-source sepsis, especially in patients with casting calculus and a history of recurrent urinary tract infections. Immediately after surgery, serum procalcitonin tests were conducted for the early detection of early-stage urinary tract infections and urosepsis[8].

### Surgical Procedure

All surgeries were performed by the same surgical team. General or epidural anesthesia was used in the surgeries.

Before anesthesia, patients were in the lithotomy position. Disinfection and surgical towel preparations were carried out. After anaesthetization, the cook ultra-slip guidewire was inserted into the ureter at the diseased side using a wolf 8-9.8 ureteroscopy. The ureter catheter was inserted and secured by a Foley catheter. The patients were then moved to a prone position and properly secured.

To plan the puncture route, targeted renal calyces were selected for searching and retrieving the calculus. In single renal calyceal calculus, the puncture site was located at the renal calyces with calculus. Confirmation *via* X-ray guidance was required before the puncture to avoid calculus shifting due to position changes. The selection of the specific puncture routes was flexible and based on the clinical condition of the patient. In pyelolithiasis, rear-middle renal calyces were selected. In staghorn renal calculi or multiple renal calculi, multiple channels were selected. In the cases that part of the calculus was located in the renal calyces, and the length of the calix was ≤ 1.5 cm, the middle and lower renal calyces were targeted. In the cases that part of the calculus was located in the renal calyces, and the length of the calix was ≥ 1.5 cm, the middle and upper renal calyces were targeted. Generally, the rear-middle renal calyces were selected most often in the surgeries.

The X-ray machine used in this research was a Siemens C-arm X-ray machine and a No. 18 puncture needle. Due to the particularity of this technology, it was unnecessary to inject normal saline through a ureteral catheter to cause hydronephrosis in patients without hydronephrosis.

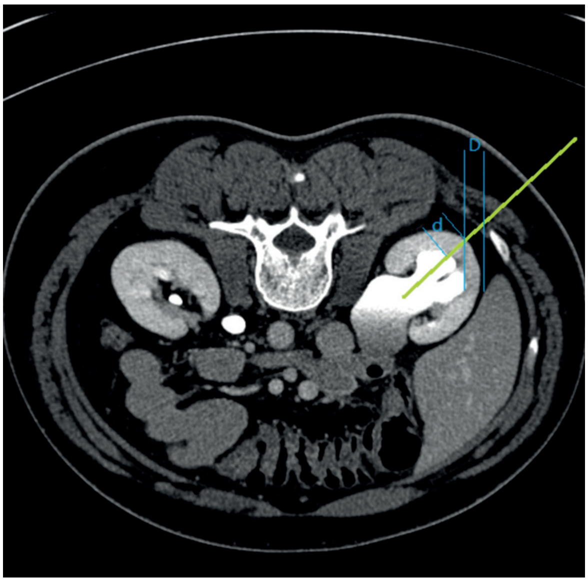


**Figure 1.** CT-scan of kidneys to plan puncture route, (d) distance between the predetermined puncture site and the target renal fornix; (D) distance between the predetermined puncture site and the outer edge of the kidney.

Before the start of the surgeries, puncture routes with the shortest length to the skin were planned. The distance between the predetermined puncture site and the target renal fornix (d) was measured, as well as the distance between the predetermined puncture site and the outer edge of the kidney (D) (Figure 1). The distance between the predetermined puncture site and the lower kidney surface (H) (Figure 2) was also measured. A mini-incision (1.5-2.5 cm) was carried out parallel to the lower rib

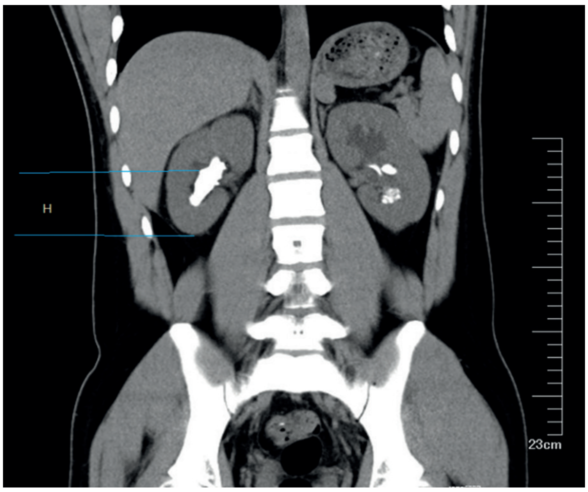


**Figure 2.** CT-scan of kidneys, (H) distance between the predetermined puncture site and the lower kidney surface.

**Figure 3.** A mini-incision (1.5-2.5 cm) was carried out parallel to the lower rib line, near the intersection of the site, and 1.5 cm lower than the edge of the rib and the posterior axillary line.

**Figure 5.** The kidney's adipose capsule was separated with the index finger, after which it was inserted into the renal peritoneal gap to touch the surface of the kidney.

line, near the intersection of the site, and 1.5 cm lower than the edge of the rib and the posterior axillary line (Figure 3). Hemostatic forceps were used to separate the subcutaneous tissue, lower back muscles, lumbar fascia, and renal fascia layer by layer (Figure 4). The kidney's adipose capsule was separated with the index finger, after which it was inserted into the renal peritoneal gap to touch the surface of the kidney (Figure 5). Then, combined with the results of the preoperative CT-scan, the projection of the target renal fornix on the surface of the kidney and the relative position of the lower and outer edges of the kidney was estimated (point A). The rear-middle renal calyces were generally selected as described above. The puncture needle was delivered through the area of the posterior axillary line and scapular line (Figure 6). In several cases, if the targeted renal calyces displayed a short front calix and long rear calix, and the rear renal fornix was found closer to the surface of the kidney, the front renal calyces were selected.

The puncture needle was delivered via the area of the posterior axillary line and midaxillary line, while avoiding the intestines, liver, spleen, and other organs under the guidance of a finger (Figure 7). An 18G puncture needle was penetrated through the A site (0.5-1 cm to the outer side) of the kidney surface (3-5 mm in-depth, the tip of the needle was not able to fall off). The contrast agent was retrogradely delivered through the urethral tube (Figure 8). Surgeons were under the protection of a radioactivity shield. The tip of the

**Figure 4.** Hemostatic forceps were used to separate the subcutaneous tissue, lower back muscles, lumbar fascia, and renal fascia layer by layer.

**Figure 6.** The puncture needle was delivered through the area of the posterior axillary line and scapular line.

**Figure 7.** The puncture needle was delivered via the area of the posterior axillary line and midaxillary line, while avoiding the intestines, liver, spleen, and other organs under the guidance of the finger.

puncture needle was located by the C-arm X-ray controlled by surgeons through remote or wire control. The location of the puncture needle tip was readjusted according to the 3D image captured by the C-arm X-ray and the finger touching of the surgeons. Under the surveillance of the image captured by the C-arm X-ray, the puncture needle was located accurately. The optimal angle and depth of the penetration were estimated according to the CT-scan. The dropping feeling of the needle indicated the position of the needle and the needle core was then removed. In case urine or liquid outflow was observed, a zebra guide wire (0.025 inches) or a soft-headed hard guidewire was inserted. X-ray images were taken to confirm the location of the guidewire. The tip of the finger was positioned at the penetration site and the puncture needle was retracted. The penetration depth was estimated (including the length between the tip of the needle and the penetration site on the skin, and the depth of the penetration into the kidney). The PCNL path was established by placing the wire on the peel-away outer sheath under the guidance of the finger using fascial dilators (initiated with F8, increased progressively by F2, and dilated to F18-F24 gradually). A hard nephroscope was delivered to the renal pelvis and calyces through the path to find the calculus. Nephrolithotomy was carried out using an EMS lithotripter (energy 70-90 J, duty cycle 80%-90%), or holmium laser fiber (energy 0.8-1.2 J, frequency 10-30 Hz). New paths were established based on previous procedures where needed. After the surgery, C-arm X-ray (could be combined with ultrasound) imaging was performed to evaluate the outcome of the PCNL. Then the tube of the ureter catheter was removed. The F4.8 or F5 double J tube was then inserted into the ureter catheter. Under certain circumstances, a renal fistula or blood drainage tube (through a small incision) was used to increase the drainage of the blood or fluid outflow (Figure 9). Conventional postoperative anti-infection treatments were given for 1-3 days. A postoperative CT-scan was carried out at 3-5 days after the surgery. If the residual calculus were not detectable, the renal fistula was removed. If residual calculus was detectable, and the renal fistula drainage fluid was clear in 5-7 days after the surgery, the second round of PCNL was conductible. The double J tube in the ureter was removed 4 weeks after the surgery.

### *Outcomes*

The outcomes included average surgical time, type of anesthesia, and surgery position. Furthermore, surgery details were also recorded includ-

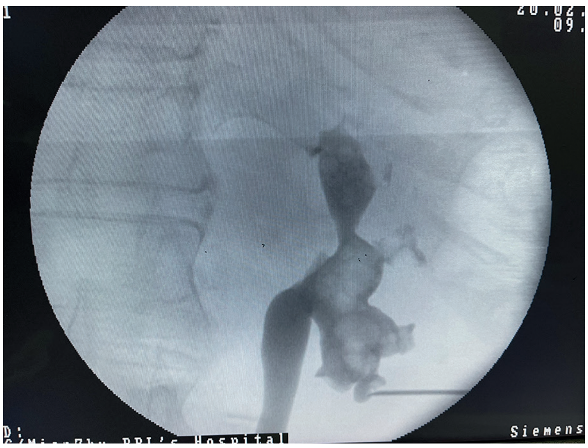


**Figure 8.** The contrast agent was retrogradely delivered through the urethral tube.

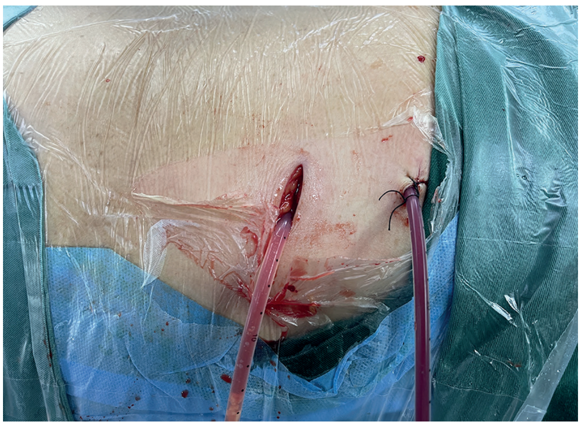

**Figure 9.** A renal fistula or blood drainage tube was used in certain circumstances to increase the drainage of the blood or fluid outflow.

ing, catheter usage, hospital stay, and recurrence. Postoperative complications were also recorded. The X-Ray exposure time was measured using a factory-calibrated Pioway Medical dosimeter (Pioway, FJ2000, China). During measurements, the dosimeter was positioned with a focus-detector distance (FDD) of 100 cm.

### *Statistical Analysis*

All data were recorded in SPSS 13.0 software (IBM Corporation, Armonk, NY, USA). The data consistent with normal distribution and homogeneity of variance are expressed as mean ± SD.

## Results

The average number of punctures: 2.8 ± 1.4. Average X-ray exposure time during procedure: 2.8 s. (range: 2-8 s). Average surgical time: 106.5 ± 49.4 min. Postoperative hospitalization: 6.8 ± 4.2 d. Average reduced hemoglobin level: 5.9 g/day. Stone-free rate 4 weeks after surgeries: 95.6%. Patients with upper ureteral calculi: 395 cases (61.72%). Postoperative placement of renal drainage tube: 52 cases, and no perirenal infection occurred.

The average surgical time of all patients was 106.5 ± 49.4 minutes. Among them, 3 cases received epidural anesthesia (0.5%), and 637 cases general anesthesia (99.5%). Six hundred and thirty-eight patients (99.7%) were operated in the prone position, and 2 patients (0.3%) in the prone position. Most cases were treated through a single path (592 cases, 92.5%), while in 43 cases (6.7%) a second catheter was used, and in 5 cases (0.8%) a third catheter. The average hospital stay of all cases was 6.84 (± 4.2) days, in which 5 cases (0.8%) received a blood transfusion, and a total of 597 cases (93.3%) had stones completely cleared 72h after surgery. The calculus residual rate of patients with staghorn renal calculi or multiple renal calculi was 82.9%. Some patients underwent supplementary treatment within 1-2 weeks after the first PCNL to remove residual stones with a diameter greater than 4 mm, including re-PCNL (2 cases) and ureteroscopy (18 cases). Due to the increased risk of bleeding during the operation, large residual stones were not removed in the first stage of treatment in some cases. The most common complication was postoperative fever (30 cases, 4.7%). Furthermore, 2 patients with renal hematoma who required intervention treatment were treated with selective renal artery embolization to stop the bleeding, and 1 patient experienced respiratory arrest due to acute coronary syndrome and died after failed cardiopulmonary resuscitation.

## Discussion

One study[9] has demonstrated the increased incidence of renal calculus since 1994 from 1/20 to 1/11. Fernstrom and Johansson[10] first described the PCNL under the guidance of X-ray in 1976. Since then, PCNL has developed rapidly and replaced the traditional pelviolithotomy globally[11]. For this reason, PCNL has become the standard procedure for the treatment of renal calculus ≤2 cm in diameter. Meanwhile, radiation exposure (RE) had become increasingly common in surgeons and patients.

In almost all the PCNL, the basic procedure includes percutaneous renal puncture, the establishment of the delivery path, and nephrolithotomy. The puncture process often requires guidance using a C-arm X-ray. Long-term exposure to X-ray is associated with genetic mutations and causes an increased incidence of tumors in both patients and surgeons. This effect is especially substantial in surgeons. To avoid the damage caused by X-ray, ultrasound guidance is widely used by experts. However, ultrasound-guided punctures require more practical experience of the surgeon and are limited in patients with no dilation in the collecting system and patients with obesity, causing increased difficulty during operations[7]. X-ray guidance provides a more intuitive imaging performance, has advantages in inaccurate positioning, clear imaging, is accordant with the preoperative positioning film, and operates under monitor surveillance. It is also applicable in monitoring the whole process of establishing a puncture path, which could effectively avoid the occurrences of wire escape, incorrect path depth, and false path formation[12,13]. Meanwhile, C-arm X-ray guidance displays advantages in determining the optimal puncture site for multiple calculus, which effectively reduces the number of unnecessary paths. The ultrasound guidance technique depends on artificial fluid accumulation. During the surgeries, when a second percutaneous path is required, the accuracy of ultrasound-guided locating is limited due to the disturbance of the ultrasound imaging caused by the creation of artificial fluid accumulation and the first path. Therefore, X-ray-guided percutaneous surgery has its unique practical value in clinical use. Also, the safety of PCNL can potentially be improved by combining it with a renal angiogram and intravenous pyelography in future clinical applications.

Improving the safety and accuracy of puncture path establishment is of critical importance in PCNL. Incidental accidents and complications mainly arise during this process. During our operation, we were able to touch the target kidney with our fingertips through a small incision. At the same time, based on the preoperative intravenous pyelogram (IVP) test and the lower outer edge of the kidney, we could estimate the projected area of the renal calix on the surface of the kidney. Followed by t the above, the tip of the puncture needle was penetrated under the surface (1-2 mm) of the kidney. Meanwhile, with the assistance of the contrast agent and the C-arm X-ray guidance, surgeons then confirmed the location of the needle. According to the renal cortex thickness measured by preoperative ultrasound, the needle was delivered to the kidney in the corresponding depth. The needle core was removed after the feeling of dropping, and if urine or liquid outflow was observed, the zebra guidewire was inserted. The puncture site and angle were confirmed by the finger through an incision and during the dilation of the path.

The amount of X-ray exposure time was mainly dependent on locating the puncture, the depth, and the angle of the monitoring equipment during fascia dilation. In this procedure, the puncture needle was located directly on the surface of the kidney. As the puncture path was short, continuous X-ray surveillance was not necessary. Also, during the fascia dilation, the location and the angle of the monitor were secured by the finger (breathing during this time produced only very limited influence). Meanwhile, the dilation length was only around 1-2 cm, which was applicable without X-ray surveillance. Due to these reasons, the accumulative exposure time of surgeons in this study was only 2-8 s.

The common complications of the PCNL technique include renal cortex tearing, renal calix tearing, pneumothorax, calculus residue, etc., which are almost all related to the establishment of the puncture path. Most common puncture techniques are performed under the guidance of ultrasound or X-ray, although surgeons are normally more familiar with X-ray guided locating. However, due to reasons such as radiation damage, non-3D imaging, experience-dependent operation, inappropriate puncture angle, and the effusion of contrast agent, the risk of surgery has increased and reduced the success rate.

Due to the inability to monitor the expansion process during ultrasound-guided puncture, there is a higher risk of aggravating collective system damage associated with increased renal parenchymal thickness and no fluid accumulation in the collective system. In this procedure, combined with finger touching, we solved the problem of a C-arm X-ray not being able to provide a 3D image. Furthermore, due to the short dilation and the discontinuous X-ray surveillance, the radiation damage was reduced. Through locating by finger touching, the colon, thoracic membrane, and large blood vessels were easily avoided. The finger touching accurately confirmed the depth of the dilator in the kidney, preventing the damage caused by a missed puncture. Finger touching assistance demonstrated no effect in the establishment of a puncture path during contrast agent overflow. Moreover, the incision (1.5-2 cm) was convenient for the operation and search of the calculus and reduced the extrusion of the wound on the kidney. Due to the above advantages of X-ray guidance, complications were clearly reduced. When guiding with the finger, the sharp needle can stab the operator, therefore, it is recommended to use the ton head needle. Our surgical experience has shown that the puncture needle can completely pierce the fascia, muscle, renal parenchyma, calyces mucosa, and other structures. Irrigation of the large incisions receded the renal pressure. During the operation, the drainage of fluid overflow from the edge of the working sheath and the renal effusion were carried out through the large incision, reducing the incidences of renal effusion.

In obese patients, it may be difficult to reach the renal surface with the finger, and the depth of the finger can be increased by enlarging the incision length to 4 cm. In patients whose kidney could not be touched, this technique can at least shorten the distance of the needle tip in the position space, increase surgical safety, and allows postoperative drainage.

Typically, the rear renal calix was commonly targeted in PCNL punctures performed in the prone position. The front renal calix was not commonly targeted as the puncture towards this part could potentially damage the intestines. In our procedure, organs such as the colon, spleen, and liver were pushed away by the finger of the surgeon via the small incision. In this way, the front renal calix could be targeted without the risks of damaging those organs. Multiple front renal calix-targeted cases have been successfully performed by our surgical team. To compare conventional techniques evidence-based, prospective randomized studies including finger touching combined X-ray-guided PCNL will be conducted further.

## Conclusions

Finger touching combined X-ray-guided PCNL is a novel technique that has been performed in our hospital for many years. Due to the increased adjustability of this technique and application in different type of patients, it is a feasible alternative. More importantly, finger touching combined X-ray-guided percutaneous nephrolithotomy in patients with renal calculus is safe and can accurately guide the puncture with minimal radiation damage.

### Conflict of Interest

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

### Acknowledgements

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