ORIGINAL RESEARCH ORİJİNAL ARAŞTIRMA

DOI: 10.5336/urology.2024-107810

Ultrasonography-Assisted Combined Puncture Technique in Supine Mini Percutaneous Nephrolithotomy: Descriptive Research

Supin Mini Perkütan Nefrolitotomide Ultrasonografi Yardımlı Kombine Giriş Tekniği: Tanımlayıcı Araştırma

Ahmet Yıldırım BALIK[a], Muammer BABAYİĞİT[b], Serdar GEYİK[b]

[a]Düzce University Faculty of Medicine, Department of Urology, Düzce, Türkiye
[b]Aksaray Training and Research Hospital, Clinic of Urology, Aksaray, Türkiye

ABSTRACT Objective: As surgeons in the early years of post-residency training, we aimed to share the clinical outcomes, safety, and efficacy of the entry method we implemented using ultrasound and fluoroscopy together in supine mini percutaneous nephrolithotomy (PNL) surgeries. **Material and Methods:** Between November 2022 and April 2024, 20 patients who underwent supine mini PNL with a combined entry method using ultrasonography and fluoroscopy were retrospectively evaluated. The imaging, laboratory, and surgical data of patients operated on by urologists in their early years following specialty training were collected. The demographic characteristics, age, gender, side of surgery, operative time, blood transfusion, length of hospital stay, complications, preoperative stone volumes, decrease in hemoglobin levels on postoperative day 1, stone removal rates, fluoroscopy times, total fluoroscopy doses, and complications were analyzed. **Results:** A total of 20 patients, including 12 men and 8 women, underwent supine mini PNL. The mean operative time was 64±14.33 minutes. Entry was successfully achieved in all patients using ultrasound and fluoroscopy guidance. No significant bleeding or organ injury related to the entry was observed. The stone-free rate determined by comparing preoperative and postoperative imaging was 87.6%±13.68%. The mean fluoroscopy duration was 65.8±22.4 seconds. According to the Clavien complication classification, Grade 1 complications were observed in 4 patients, Grade 2 in 4 patients, and Grade 3A in 1 patient. **Conclusion:** In conclusion, based on our experience, we believe that the combined use of ultrasound and fluoroscopy in supine mini PNL surgeries provides a safe, straightforward approach with low radiation exposure.

Keywords: Percutaneous nephrolithotomy; supine mini percutaneous nephrolithotomy; supine position; ultrasonography

ÖZET Amaç: Uzmanlık eğitimi sonrası ilk yıllarındaki cerrahlar olarak supin mini perkütan nefrolitotomi (PNL) cerrahisinde ultrason ve floroskopiyi birlikte kullanarak uyguladığımız giriş yönteminin klinik sonuçlarını, güvenirliğini ve etkinliğini paylaşmayı amaçladık. **Gereç ve Yöntemler:** Kasım 2022-Nisan 2024 tarihleri arasında ultrasonografi ve floroskopi birlikteliğinde kombine giriş yöntemi uygulanarak supin mini PNL uygulanan 20 hasta retrospektif olarak değerlendirildi. Uzmanlık eğitimi sonrası yeni uzman ürologlar tarafından yapılan cerrahilerdeki hastaların görüntüleme, laboratuvar ve cerrahi özellik kayıtları toplandı. Hastaların demografik özellikleri, yaş, cinsiyet, taraf, operasyon süresi, kan transfüzyonu, hastanede yatış süresi, komplikasyonları, preop taş büyüklükleri, postop 1. günde hemoglobindeki düşüş, taşların alınma oranları, floroskopi süreleri, toplam floroskopi dozları ve komplikasyonlar incelendi. **Bulgular:** 12 erkek 8 kadın olmak üzere toplam 20 hastaya supin mini PNL yapıldı. Ortalama operasyon süresi 64±14,33 dk idi. Tüm hastalara ultrasonografi ve floroskopi eşliğinde giriş yapıldı. Girişe bağlı ciddi bir kanama veya organ hasarı saptanmadı. Taşların preop ve postop görüntülemelerle karşılaştırılmasıyla saptanan taşların dışarı alınma oranları ise %87,6±13,68 olarak saptandı. Ortalama floroskopi kullanım süresi 65,8±22,4 sn saptandı. Clavien komplikasyon sınıflamasına göre 4 hastada Derece 1, 4 hastada Derece 2 ve 1 hastada Derece 3A komplikasyon saptandı. **Sonuç:** Sonuç olarak başlangıç deneyimlerimize göre supin mini PNL cerrahilerinde ultrasonografi ile floroskopinin kombine kullanımı ile yapılan girişin; güvenli, kolay ve düşük radyasyon maruziyetli olduğunu düşünmekteyiz.

Anahtar Kelimeler: Perkütan nefrolitotomi; supin mini perkütan nefrolitotomi; supin pozisyon; ultrasonografi

TO CITE THIS ARTICLE:
Balık AY, Babayiğit M, Geyik S. Ultrasonography-assisted combined puncture technique in supine mini percutaneous nephrolithotomy: Descriptive research. J Reconstr Urol. 2024;14(3):95-101.

Correspondence: Ahmet Yıldırım BALIK
Düzce University Faculty of Medicine, Department of Urology, Düzce, Türkiye
E-mail: ayildirimbalik@gmail.com

Peer review under responsibility of Journal of Reconstructive Urology.

Received: 23 Dec 2024 ***Accepted:*** 25 Dec 2024 ***Available online:*** 27 Dec 2024

Approximately 10% of the world population experiences complaints related to kidney stones. Nowadays, minimally invasive surgeries have replaced open surgeries for kidney stones. Percutaneous nephrolithotomy (PNL) has established itself as the primary recommended surgical method, especially for stones larger than 2 cm.[1] Supine mini can be effectively performed in elderly patients, those with spinal deformities, obese individuals, and pediatric patients. It offers several advantages, such as lower intrarenal pressure, easier positioning, fewer anesthesia-related complications, and easier stone extraction through negative pressure. Its popularity worldwide has increased, particularly due to the ease of positioning it provides for performing endoscopic combined retrograde intrarenal surgeries.[2,3]

In PNL, achieving an effective and safe access is considered the first and perhaps the most critical step of the procedure. A successful access also requires an effective and safe entry method. Various techniques for renal access have been described in the literature. These techniques use fluoroscopy, ultrasonography, or computed tomography, either individually or in combination. Among these, the most commonly employed method is access via fluoroscopy in a biplanar approach. However, this technique involves the use of fluoroscopy in two planes, leading to higher radiation exposure compared to ultrasonographic methods. Additionally, with this approach, the entry site is not evaluated using fluoroscopy beforehand to assess neighboring organs.[4-6]

The ultrasonographic entry method minimizes radiation exposure, thereby avoiding the long-term complications associated with radiation. By using ultrasonography to evaluate organs such as the liver, spleen, intestines, gallbladder, and pleura, the risk of injury to adjacent organs is significantly reduced. Ultrasonography is particularly valuable because it provides information about kidney structure, parenchymal thickness, and the position of calyces, and it is more effective for assessing renal anomalies like horseshoe kidneys. Additionally, the use of Doppler ultrasound is advantageous in preventing vascular injuries, enabling the differentiation of segmental arteries, and thereby reducing the risk of bleeding.[7] However, in the ultrasound-assisted entry and access method, disadvantages include difficulty in tracking the needle with ultrasound, a longer learning curve, and less clear differentiation during access compared to fluoroscopy.[8]

In the combined method we use, we aimed to integrate the experience gained by newly specialized urologists with ultrasonography, which they routinely use, and their familiarity with fluoroscopy in percutaneous surgeries. Our goal was to leverage the advantages of ultrasonography both before and during the access, while using fluoroscopy in only one plane to make the access more effective and minimize radiation exposure. In this study, we aimed to share the entry method and initial clinical outcomes we used in supine PNL surgery.

MATERIAL AND METHODS

Ethical committee approval was first obtained from the Aksaray University Health Sciences Scientific Research Ethics Committee with decision number 2024/120 (date: November 7, 2024) and the principles of the Helsinki Declaration 2008 have been followed. Between November 2022 and April 2024, 20 supine mini PNL surgeries performed at Aksaray Training and Research Hospital were retrospectively evaluated. The medical histories, preoperative computed tomography images, surgical details, and hospitalization characteristics of all patients were assessed. Preoperative routine hemogram, biochemistry, and coagulation tests were performed, and patients were consulted with anesthesiology. Sterility was ensured in the patients' urine cultures. The study included patients who underwent supine mini PNL surgeries using a combined access method with ultrasonography and fluoroscopy. All surgeries were performed by surgeons in the first two years of their mandatory service, after completing their specialty training. The demographic characteristics of the patients, including age, gender, side, operation duration, blood transfusion, length of hospital stay, complications, preoperative stone volume postoperative hemoglobin drop on day 1, stone removal rates, fluoroscopy times, and total fluoroscopy doses were reviewed. Postoperative complications were classified according to the validated Clavien classification for PNL.[9]

The preoperative (preop) and postoperative (postop) stone volumes of the patients were calculated in mm^2 by multiplying the longest axis of the stone by the largest perpendicular dimension. For patients with multiple stones, the stone volume was determined by calculating the area of each stone in mm^2 using the same method and summing up the results. The stone removal rates were calculated by subtracting the postop stone volume from the preop stone volume and determining the percentage of this difference relative to the preop stone volume.

Statistical analyses were obtained using SPSS (version 16, IBM, USA). Demographic characteristics and clinical parameters of the patients were summarized using descriptive statistics. Mean, standard deviation, median, interquartile ranges and standard deviation were calculated for variables.

SURGICAL TECHNIQUE

For prophylactic purposes, a third-generation cephalosporin was administered intravenously to the patients before surgery. The patients were positioned in the Galdakao-modified supine Valdivia position. Using a marker pen, the posterior axillary line, 12th rib, and anterior superior iliac spine were marked. Following appropriate draping and ensuring sterility, each patient underwent cystoscopy, during which a 6F ureteral catheter was placed. Subsequently, a 16F Foley urethral catheter was inserted, and the ureteral catheter was secured.

Before the procedure, ultrasound was performed on all patients on the operating table to confirm the entry site. For ultrasound imaging, the ACUSON S3000™ Ultrasound System with the HELX™ Evolution SIEMENS™ (Issaquah, WA, USA) system and a 6C1 HD Transducer probe were used. For fluoroscopy, a SIEMENS™ C-arm system was utilized.

Using the ureteral catheter, the calyceal system was filled with contrast material. Before the procedure, fluoroscopy was fixed at 0 degrees. The widest view of the calyx to be accessed in the transverse (horizontal) plane was identified and stabilized using ultrasound. An 18-gauge, 20 cm percutaneous access needle was aligned with the ultrasound and advanced towards the target calyx under fluoroscopic guidance by manipulating the needle in the coronal (frontal) plane with left-right movements. This technique allowed access to the calyx using ultrasound on one axis and fluoroscopy on another, without moving the fluoroscopy unit (Figure 1 and Figure 2).

Subsequently, a guidewire was inserted, and dilation was performed under fluoroscopic guidance. For dilation, a 15French (Fr) single metal dilator and a 15.5-16.5Fr metal sheath from the Amnotec© (Knittlingen, Germany) brand were used. Then, a 12Fr nephroscope (Amnotec©) and a Dornier© (Dornier Medizin Technik, Germany) 35-watt laser were employed to fragment the stones. In all patients, only a 4.8F double-J stent was placed, and no nephrostomy catheters were used.

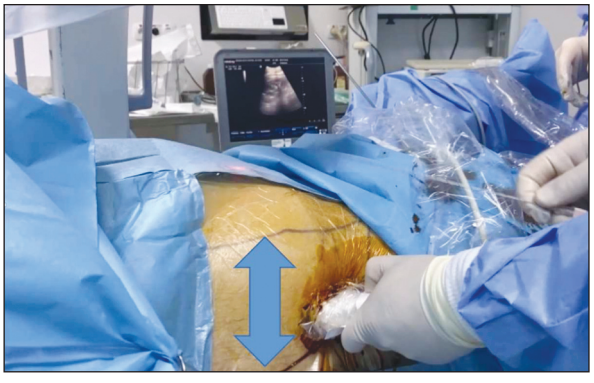

FIGURE 1: The widest view of the calyx to be accessed in the horizontal plane was stabilized using ultrasound.

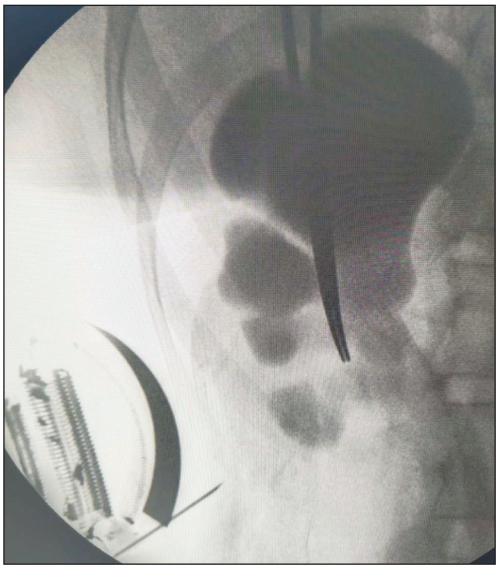

FIGURE 2: After stabilizing the ultrasound in the transverse plane, the needle was advanced towards the target calyx in the coronal plane under fluoroscopic guidance.

RESULTS

Between September 2022 and April 2024, supine mini-PNL was performed on a total of 20 patients, including 12 males and 8 females. Nine patients underwent right-sided PNL, while 11 had left-sided PNL. The mean age of the patients was 48±14.38 years (range: 26-76 years). The mean operative time was 64±14.33 minutes (range: 40-100 minutes), and the mean hospital stay was 4.2±2.6 days (range: 2-12 days).

Access was achieved in all patients under ultrasound and fluoroscopic guidance, with a 100% success rate. No significant bleeding or organ injury related to the access was observed. A single access tract was used for all patients, and double-J stents were placed at the end of each procedure. None of the patients required a nephrostomy catheter. Blood transfusion was performed for one patient (1 unit of erythrocyte suspension), while no transfusions were needed for the remaining patients. Based on preoperative hemoglobin values, the mean drop in hemoglobin levels on the morning of postoperative day 1 was calculated as 1.75±1.18 g/dL (range: 0-3.7 g/dL).

The mean preoperative stone volume was 1024±244 mm² (range: 441-2704 mm²), while the mean postoperative stone-free rate was 87.6%±13.68% (range: 65-100%). Stone removal rates, as determined by comparing preoperative and postoperative imaging, were also 87.6%±13.68% (range: 65-100%). The mean fluoroscopy duration was 65.8±22.4 seconds (range: 20-120 seconds), and the mean total fluoroscopy dose was 30.4±16.2 mGy (range: 4.2-95 mGy) (Demographic and surgical characteristics are summarized in Table 1).

Complications According to the Clavien-Dindo Classification Grade 1 complications were observed in 4 patients. These included postoperative flank pain symptoms, likely related to the double-J stent. These patients were treated successfully with a single dose of non-steroidal anti-inflammatory drugs. Grade 2 complications occurred in 4 patients. In 3 of these cases, broad-spectrum antibiotic therapy was administered due to postoperative resistant fever, and the patients were subsequently discharged. In one patient, a decrease in postoperative hemoglobin levels was noted, but the patient's vital signs remained stable. Based on the recommendation of the internal medicine team, a single unit of blood transfusion was given.

Grade 3 complications were observed in 1 patient. On postoperative day 1, direct urinary system radiography revealed spontaneous migration of the lower end of the double-J stent into the mid-ureter. The lower end of the stent was repositioned into the bladder under local anesthesia in the operating room. No Grade 3b or higher complications were observed in any patient. Additionally, none of the patients required intensive care, nephrectomy, or embolization (Complications are summarized in Table 2 according to the Clavien classification).

TABLE 1: Demographic and surgical characteristics of the patients.

	Results (n=20)
Mean age±SD (Range)	48±14.38 (26-76)
Sex (n, %)	
Female	8 (40)
Male	12 (60)
Side (Right/Left)	
Right (n, %)	9 (45)
Left (n, %)	11 (55)
Mean duration of surgery (minute)±SD (Range)	64 mn±14.33 (40-100)
Mean hospital stay (Day)±SD (Range)	4.2±**2.6** (2-12)
Blood transfusion	1 unit to one patient
Mean preoperation stone volume (mm^2)±SD (Range)	1024±244 **mm^2** (441-2704)
Mean postoperation stone volume (mm^2)±SD (Range)	39±**50.4 (0-144)**
Mean postoperation stone removal (%)	87.6%±13.68 (65-100)
Mean duration of floroscopy (second)	**65.8**±22.4 **(20-120)**
Mean total floroscopy dose (mGy)	**30.4**±16.2 **(4.2-95)**
Mean postoperative hemoglobin drop (g/dL)	1.75±1.18 (0-3.7)

SD: Standard deviation.

TABLE 2: Complications according to the clavien-dindo classification.

	Results
Clavien Grade 1 (n, %)	**4 (20%)**
Postoperative pain managed by nonopioid analgesics	**4 (20%)**
Clavien Grade 2 (n, %)	**4 (20%)**
Symptomatic urinary tract infection treated with antibiotics	**3 (15%)**
Blood transfusion	**1 (5%)**
Clavien Grade 3A (n, %)	
An ureteroscopy due to Double j catheter migration	**1 (5%)**
Clavien Grade 3B (n, %)	**0**
Clavien Grade 4 (n, %)	**0**

DISCUSSION

In PNL, achieving optimal access is crucial for the effectiveness, safety, and complication rates of the surgery. Several access techniques have been described in the literature. The ultrasound-guided access method has gained popularity recently due to its advantages. Studies have reported several benefits of ultrasound, such as reduced radiation exposure, lower transfusion rates, better visualization of surrounding organ structures, and providing a three-dimensional image of the calyceal system.[10-12]

The most commonly used access method worldwide is still the triangular fluoroscopy-assisted approach. Fluoroscopy has advantages such as being easier to apply, having a shorter learning curve, providing clearer visualization of the calyceal system in a single image, and enabling controlled access with continuous imaging.[6] In the fluoroscopy-assisted standard access technique, the failure rate or the inability to achieve access is reported to be approximately 2-3%.[13] In a series where a different biplanar fluoroscopy-assisted method was used, the complication rate was reported to be 4.5%.[14] In our study, this rate was found to be 0%, with successful access achieved in all patients. Although the small sample size represents a limitation, the failure rate in our study was lower compared to a different and newly used fluoroscopy-assisted method.

In a prospective randomized controlled study comparing access methods using fluoroscopy, fluoroscopy-ultrasound, and ultrasound alone, the rates of Grade 3 and higher complications were found to be 6%, 5.5%, and 4.8%, respectively. In the same study, the rate of blood transfusion in the group with ultrasound-fluoroscopy assisted access was found to be 2.7%.[13] In our study, Grade 3 and higher complications were observed in only one patient (5%). This patient experienced a complication, which was the incidental migration of the distal end of the double-J stent into the mid-ureter on postoperative imaging. However, this complication did not lead to significant morbidity. Blood transfusion was required for only one patient (5%). No complications such as organ injury, urinoma, or perinephritic hematoma, which could be related to the access, occurred in any of the patients. Additionally, no significant bleeding, which could have hindered visualization during the access or procedure, was observed. Despite the fact that our study includes the first 20 cases, our results regarding complications and transfusions were similar to those reported in the literature. However, in addition to the access method, we believe that performing mini-PNL with a 15.5-16.5 Fr sheath may have reduced the likelihood of complications and the need for transfusions.

According to the "As Low As Reasonably Achievable" (ALARA) principle, radiation is one of the primary concerns in percutaneous surgeries. Radiation affects many organs, including the gonads, bones, and thyroid, with the gonads being particularly sensitive. There are studies indicating that even low doses of fluoroscopy can impair spermatogenesis in the testes, and high doses can lead to sterility.[15,16] In a study by Pulido-Contreras et al., it was found that a surgeon performing PNL who transitioned from fluoroscopy-assisted access to ultrasound-assisted access reduced fluoroscopy usage time by 75% after the first 15 cases.[4] In the same study, it was found that the fluoroscopy time was 85 seconds when considering the first 15 cases. In our study, this time was found to be lower. Given that the procedures in our study were performed by surgeons who were new to the technique and early in their specialization, we anticipate that as experience and the number of cases increase, both fluoroscopy time and dose will decrease further. According to another radiation exposure mechanism, it has been demonstrated in the literature that the area affected by fluoroscopy in the anteroposterior view differs from the area affected in the lateral projection. In the biplanar fluoroscopy technique, it was found that fluoroscopy performed at a 30-degree angle increased the radiation exposure to the upper bodies and head regions of the surgical team. One study also showed that lateral fluoroscopy projections led to 3-4 times greater radiation exposure in the operating room and to the team compared to the anteroposterior projections.[17,18] In our study, by using fluoroscopy only in the anteroposterior projection and employing ultrasound in the other plane, the surgical team is further protected from radiation exposure.

There are methods in the literature similar to the combined method used in our study. However, the main purpose of our study is to show that newly specialized urologists can easily and safely enter PNL by combining ultrasonography, which they can use with basic radiology knowledge, with the fluoroscopy experience they are familiar with from urological stone surgery.

The limitations of our study include the fact that it is not a prospective randomized controlled and comparative study, the small sample size, and the existence of studies with similar applications, although not exactly the same.

CONCLUSION

In conclusion, our study has demonstrated the successful clinical outcomes of the combined access technique by integrating the advantages of fluoroscopy, which is straightforward to learn and apply, with the benefits of ultrasonography, which minimizes radiation exposure and reduces the risk of complications. Nonetheless, it is clear that further studies involving larger patient populations and comparative analyses with other methods are warranted to validate these findings.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Ahmet Yıldırım Balık, Muammer Babayiğit, Serdar Geyik;* ***Design:*** *Ahmet Yıldırım Balık, Muammer Babayiğit;* ***Control/Supervision:*** *Serdar Geyik;* ***Data Collection and/or Processing:*** *Ahmet Yıldırım Balık;* ***Analysis and/or Interpretation:*** *Ahmet Yıldırım Balık, Muammer Babayiğit;* ***Literature Review:*** *Muammer Babayiğit;* ***Writing the Article:*** *Ahmet Yıldırım Balık, Muammer Babayiğit;* ***Critical Review:*** *Serdar Geyik;* ***References and Fundings:*** *Serdar Geyik;* ***Materials:*** *Ahmet Yıldırım Balık, Muammer Babayiğit.*

REFERENCES

1. de la Rosette J, Assimos D, Desai M, Gutierrez J, Lingeman J, Scarpa R, et al; CROES PCNL Study Group. The Clinical Research Office of the Endourological Society Percutaneous Nephrolithotomy Global Study: indications, complications, and outcomes in 5803 patients. J Endourol. 2011;25(1):11-7. [Crossref] [PubMed]
2. Valdivia Uría JG, Lachares Santamaría E, Villarroya Rodríguez S, Taberner Llop J, Abril Baquero G, Aranda Lassa JM. Nefrolitectomía percutánea: técnica simplificada (nota previa) [Percutaneous nephrolithectomy: simplified technic (preliminary report)]. Arch Esp Urol. 1987;40(3):177-80. Spanish. [PubMed]
3. Valdivia JG, Valer J, Villarroya S, López JA, Bayo A, Lanchares E, et al. Why is percutaneous nephroscopy still performed with the patient prone? Journal of Endourology. 1990;4(3):269-77. [Crossref]
4. Pulido-Contreras E, Garcia-Padilla MA, Medrano-Sanchez J, Leon-Verdin G, Primo-Rivera MA, Sur RL. Percutaneous nephrolithotomy with ultrasound-assisted puncture: does the technique reduce dependence on fluoroscopic ionizing radiation? World J Urol. 2021;39(9):3579-85. [Crossref] [PubMed]
5. Matlaga BR, Shah OD, Zagoria RJ, Dyer RB, Streem SB, Assimos DG. Computerized tomography guided access for percutaneous nephrostolithotomy. J Urol. 2003;170(1):45-7. [Crossref] [PubMed]
6. Miller NL, Matlaga BR, Lingeman JE. Techniques for fluoroscopic percutaneous renal access. J Urol. 2007;178(1):15-23. [Crossref] [PubMed]
7. Chu C, Masic S, Usawachintachit M, Hu W, Yang W, Stoller M, et al. Ultrasound-guided renal access for percutaneous nephrolithotomy: a description of three novel ultrasound-guided needle techniques. J Endourol. 2016;30(2):153-8. [Crossref] [PubMed] [PMC]
8. Li X, Long Q, Chen X, He D, He H. Real-time ultrasound-guided PCNL using a novel SonixGPS needle tracking system. Urolithiasis. 2014;42(4):341-6. Erratum in: Urolithiasis. 2014;42(5):473. Dalin, He [corrected to He, Dalin]. [Crossref] [PubMed]
9. de la Rosette JJ, Opondo D, Daels FP, Giusti G, Serrano A, Kandasami SV, et al; CROES PCNL Study Group. Categorisation of complications and validation of the Clavien score for percutaneous nephrolithotomy. Eur Urol. 2012;62(2):246-55. [Crossref] [PubMed]
10. Ullah A, Khan MK, Rahman AU, Naeem M, Khan S, Rehman RU. Total ultrasound guided percutaneous nephrolithotomy: a novel technique. Gomal Journal of Medical Sciences. 2013;11(2):149-54. [Link]
11. Yan S, Xiang F, Yongsheng S. Percutaneous nephrolithotomy guided solely by ultrasonography: a 5-year study of >700 cases. BJU Int. 2013;112(7):965-71. [Crossref] [PubMed]
12. Karami H, Rezaei A, Mohammadhosseini M, Javanmard B, Mazloomfard M, Lotfi B. Ultrasonography-guided percutaneous nephrolithotomy in the flank position versus fluoroscopy-guided percutaneous nephrolithotomy in the prone position: a comparative study. J Endourol. 2010;24(8):1357-61. [Crossref] [PubMed]
13. Zhu W, Li J, Yuan J, Liu Y, Wan SP, Liu G, et al. A prospective and randomised trial comparing fluoroscopic, total ultrasonographic, and combined guidance for renal access in mini-percutaneous nephrolithotomy. BJU Int. 2017;119(4):612-8. [Crossref] [PubMed]

14. Basiri A, Shakiba B, Hoshyar H, Ansari A, Golshan A. Biplanar oblique access technique: a new approach to improve the success rate of percutaneous nephrolithotomy. Urologia. 2018;85(3):118-22. [Crossref] [PubMed]

15. Gamal WM, Hussein M, Aldahshoury M, Hammady A, Osman M, Moursy E, et al. Solo ultrasonography-guided percutanous nephrolithotomy for single stone pelvis. J Endourol. 2011;25(4):593-6. [Crossref] [PubMed]

16. Hall E. Hereditary effects of radiation. Radiobiology for the Radiologist. 4th ed. Philadelphia: JB Lippincott; 1994, Section 2. p.187-200.

17. Theocharopoulos N, Perisinakis K, Damilakis J, Papadokostakis G, Hadjipavlou A, Gourtsoyiannis N. Occupational exposure from common fluoroscopic projections used in orthopaedic surgery. J Bone Joint Surg Am. 2003;85(9):1698-703. [Crossref] [PubMed]

18. Miller ME, Davis ML, MacClean CR, Davis JG, Smith BL, Humphries JR. Radiation exposure and associated risks to operating-room personnel during use of fluoroscopic guidance for selected orthopaedic surgical procedures. J Bone Joint Surg Am. 1983;65(1):1-4. [Crossref] [PubMed]