Published in final edited form as:

Urology. 2017 February ; 100: 38–44. doi:10.1016/j.urology.2016.09.031.

X-ray–free Ultrasound-guided Percutaneous Nephrolithotomy: How to Select the Right Patient?

Manint Usawachintachit, David T. Tzou, Weiguo Hu, Jianxing Li, and Thomas Chi

Department of Urology, University of California, San Francisco, San Francisco, CA; Division of Urology, Faculty of Medicine, Chulalongkorn University, King Chulalongkorn Memorial Hospital, The Thai Red Cross Society, Rama IV Road, Patumwan, Bangkok, Thailand; Department of Urology, Tsinghua Changgung Hospital, Beijing, China

Abstract

OBJECTIVE—To identify factors associated with successful ultrasound guidance for each surgical step of ultrasound-guided percutaneous nephrolithotomy (PCNL).

PATIENTS AND METHODS—Consecutive patients undergoing PCNL between March 2015 and June 2016 were prospectively enrolled. An attempt was made to use ultrasound guidance in renal access, tract dilation, and nephrostomy tube placement for each patient. For steps during which ultrasound guidance was unsuccessful, fluoroscopic screening was applied. Regression analysis identified patient characteristics associated with successful use of ultrasound guidance.

RESULTS—A total of 96 patients composed this cohort, with a mean body mass index of 28.7 kg/m². Mean stone size was 33.1 ± 18.9 mm, and no hydronephrosis was found in 63.5% of cases. Fluoroscopic screening was required for renal access in 27 cases (28.1%), tract dilation in 38 (39.6%), and nephrostomy tube placement in 80 (83.3%). Multivariate analysis demonstrated that successful ultrasound guidance was significantly associated with the presence of hydronephrosis for renal access and the absence of staghorn calculi for tract dilation. Ultrasound-guided nephrostomy tube placement appeared linked to surgeon experience.

CONCLUSION—To achieve completely x-ray–free ultrasound-guided PCNL, the ideal patient should have a hydronephrotic collecting system with no staghorn stone present. For practitioners looking to adopt ultrasound guidance into their PCNL practice, these represent the most appropriate patients to safely initiate a surgical experience.

Percutaneous nephrolithotomy (PCNL) is currently the mainstay surgical treatment for renal stones larger than 2 cm and refractory to shockwave therapy.¹ Key steps in this procedure include percutaneous renal access, working tract dilation, stone fragmentation, stone clearance confirmation, and nephrostomy tube (NT) placement. Fluoroscopic guidance has been the primary imaging method used to guide these steps in the United States and around

Address correspondence to: Thomas Chi, M.D., Department of Urology, University of California, San Francisco, 400 Parnassus Avenue, Suite A610 Box 0330, San Francisco, CA 94143. Tom.Chi@ucsf.edu.

Financial Disclosure: The authors declare that they have no relevant financial interests.

APPENDIX

SUPPLEMENTARY DATA

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.urology.2016.09.031>.

the world.² Fluoroscopy requires ionizing radiation exposure that may be associated with potential longterm adverse effects for patients and medical personnel.³ In addition, fluoroscopy-directed PCNL is associated with a relatively long learning curve.^{4,5}

Ultrasound (US) guidance is a reliable alternative imaging method to direct PCNL without ionizing radiation exposure. In comparison with fluoroscopy-guided PCNL, US-guided PCNL can be adopted with a relatively short associated learning curve after approximately 20 cases.⁶ Whereas this technique has been widely used in China,⁷ adoption has only recently gained popularity in the United States. We have successfully implemented US guidance for PCNL at our institution since May 2014.⁸ As urologists move toward adopting US guidance, the following question arises: which patient is best for initiating their US experience? The purpose of this study is to identify perioperative factors influencing the success of US-guided PCNL for each step of the procedure.

PATIENTS AND METHODS

This was a prospective cohort study completed at 2 academic centers. The operative surgeon for all procedures is a fellowship-trained endourologist whose previous experience in PCNL was exclusively fluoroscopic guidance before May 2014. After institutional review board approval was obtained, perioperative clinical data for all patients with nephrolithiasis presenting between March 2015 and June 2016 and requiring treatment with PCNL were prospectively collected. Inclusion criteria were patients older than 18 years with renal or proximal ureteral stones scheduled for treatment with PCNL. Patients for whom no attempt at US guidance was made were excluded. Preoperative non-contrast computed tomography was used to determine stone characteristics. Skin-to-stone distance was calculated on computed tomography scan by 3 measured distances from the center of the stone to the skin (0°, 45°, and 90°) at the widest dimension of the stone on cross-sectional images.⁹ Kidney depth was determined by averaging the anterior and the posterior depths of the skin to the renal hilum on axial images.¹⁰ Staghorn stone was defined as a large stone occupying the entire renal pelvis and branching into at least 1 calyx.¹¹ Hydronephrosis was categorized as either absent or present based on the radiology report and confirmed at the time of surgery.¹²

All PCNLs were performed with an attempt to use US guidance in percutaneous renal access, tract dilation, and NT placement independently. We have previously published details regarding surgical technique.^{8,13} Before moving the patient to a prone position, we placed a 5-French externalized ureteral catheter into the ipsilateral ureter via a flexible cystoscope for retrograde instillation of saline to dilate the kidney as needed. We used a 3.5-MHz convex abdominal transducer (Hitachi Aloka Medical America, Wallingford, CT) to localize the stone position as well as the collecting system anatomy. Renal puncture was done with an 18-gauge EchoTip needle (Cook Medical) under real-time ultrasonographic monitoring freehand without the aid of a needle guide. A 10-French fascial dilator (Cook Medical) and 24-French high-pressure balloon dilator and sheath (BARD X-Force, Bard Medical) were used for working tract dilation. At the end of the procedure, a 10-French Cope loop NT (Cook Medical) was placed.

Renal access time (time elapsed from initial renal US imaging to successful needle placement into the collecting system), tract dilation time (time elapsed from wire insertion into the collecting system to access sheath advancement over the balloon), total operative time (time elapsed from initial cystoscopy for ureteral catheter placement until NT placement), and other perioperative outcomes were recorded. If US imaging was unable to safely guide any surgical step, this event was recorded, fluoroscopy was used at the operative surgeon's discretion, and total fluoroscopic screening time was recorded from the fluoroscopy machine.

To determine stone-free status, plain radiograph of the kidneys, ureters, and bladder and renal US were performed 30 days after surgery to evaluate stone-free status. Patients were categorized as being stone-free or having the presence of residual fragment at any size based on this 30-day follow-up. All perioperative complications occurring within 30 days postoperatively were recorded according to the Clavien-Dindo classification system.¹⁴

Chi-square test, Fisher exact test, simple regression, and multiple regression were used to identify patient factors associated with US guidance success for each surgical step. Statistical analyses were performed using Stata/IC version 14.1 (StataCorp, College Station, TX). Data were expressed as mean $\pm$ standard deviation and percentage with a significance level of $P < .05$.

RESULTS

This cohort comprised 98 consecutive patients who underwent US-guided PCNL during the study period. Two patients were excluded from the analysis, including 1 patient for whom US guidance was not attempted owing to anatomic complexity and 1 patient with a pre-placed NT not requiring a new collecting system puncture. Among the 96 patients included, mean age was 50.8 ± 17.0 years, mean body mass index was 28.7 ± 7.9 kg/m², and 54.2% were women. Mean stone size was 33.1 ± 18.9 mm, 55.2% of stones were left-sided, and 30.2% were staghorn stones. Hydronephrosis was found on preoperative imaging in 36.4% of cases (Table 1).

Of 96 patients, 55 cases (57.3%) were performed with renal access and tract dilation solely under US guidance. Of the remaining 41 cases (42.7%, group A), 27 cases (28.1%, group B) required fluoroscopy for renal access and 38 cases (39.6%, group C) required fluoroscopy for tract dilation. Twenty-four cases (25.0%) required fluoroscopy for both renal access and tract dilation (Table 2). NT placement was performed under US guidance in the final 16 consecutive cases of this cohort. Completely x-ray-free PCNL thus represented 16.7% of the entire cohort.

Mean renal access time was 2.5 ± 3.0 minutes (95% confidence interval 1.9–3.1 minutes) and was significantly longer if fluoroscopy was needed (1.4 ± 1.6 vs 5.4 ± 3.8 minutes, $P < .01$). If only US was used to guide renal tract access and dilation, total operative time was shortened (119.1 ± 38.5 vs 154.0 ± 56.9 minutes, $P < .05$). Mean tract dilation time was 10.4 ± 4.1 minutes (95% confidence interval 9.6–11.2 minutes), and although prolonged if

fluoroscopy was required, this difference did not reach statistical significance (9.5 ± 3.6 vs 11.0 ± 4.0 minutes, $P = .07$) (Table 1 and Supplementary Table S1).

For the procedure as a whole as well as the individual steps of renal puncture and tract dilation, univariate analysis demonstrated that longer skin-to-stone distance ($P < .05$), increased kidney depth ($P < .05$), presence of staghorn stone ($P < .05$), and the absence of hydronephrosis ($P < .05$) were significantly associated with the need for fluoroscopic screening. Controlling for each of these variables, multivariate analysis demonstrated hydronephrosis ($P < .05$) as the single variable significantly associated with fluoroscopy requirement during renal access. For tract dilation, only the presence of staghorn stone remained statistically significant with multivariate analysis ($P < .05$) (Table 3).

Postoperatively, fluoroscopy use during PCNL did not significantly affect surgical outcomes. Mean hematocrit change was $5.0 \pm 4.5\%$, and blood transfusion was required in 3 patients (3.1%). Postoperative complications were found in 7 patients (7.4%), mostly characterized as Clavien-Dindo class 1 or 2. Mean hospital stay was 2.9 ± 1.3 days. Stone-free status was achieved in 84 patients (87.5%) and a secondary procedure was required in 2 patients (2.1%) (Table 4).

DISCUSSION

Fluoroscopy remains the mainstay imaging modality used to guide all steps of PCNL.² It provides a clear mapping of the collecting system,¹⁵ but is associated with a relatively long learning curve driven by difficulty identifying posterior calices and collecting system depth.¹⁶ Moreover, the ionizing radiation exposures required by fluoroscopy, although individually relatively small, have been shown to be cumulative and affect both patients and intraoperative personnel, with potential adverse health effects including cataracts or even secondary malignancies.^{3,17}

US guidance has gained popularity as an alternative imaging modality to direct PCNL.⁷ Overall success and surgical outcomes are comparable with those performed under fluoroscopic guidance.² US-guided imaging offers distinct advantages over fluoroscopy, including freedom from radiation, easier differentiation of posterior from anterior calices, an ability to safely avoid renal vasculature, and real-time imaging of other organs surrounding the kidney such as bowel and pleura.¹⁵ A contemporary large series in US-guided PCNL has shown a pleural complication rate of 0.19%.⁷ It is also the ideal imaging modality for pediatric or pregnant patients.^{18,19}

The predominant use of fluoroscopy in the United States is likely explained by several reasons. First, although the transition from fluoroscopic- to US-guided PCNL requires a relatively short learning curve,⁶ it can be daunting to adopt a new surgical technique into clinical practice. Second, only recently have teaching institutions begun instructing urology trainees on how to obtain their own renal access under US guidance. Third, in the current practice environment, urologists have few opportunities to gain proficiency in US-guided renal access. Urologists may have some skill in office-based diagnostic US,²⁰ but the majority of US-guided percutaneous procedures are performed by intervention

radiologists,²¹ including obtaining renal access.²² Urologists therefore have few opportunities to acquire proficiency via repetition. We have demonstrated that US guidance proficiency can be obtained using a training phantom.²³ However, to use US guidance in clinical practice, interested urologists will eventually have to apply their skills in the operating room environment. Defining the patient characteristics associated with success in using US guidance for each step of PCNL is important to facilitate urologists' comfort with acquiring this skill set.

The first report of US-guided PCNL was from Desai et al in 1999, with 45 procedures in pediatric patients.²⁴ Initial renal puncture was done under US guidance, but tract dilation and the rest of the procedure were completed under fluoroscopic guidance. To facilitate the utilization of US in all steps of PCNL, others have adapted techniques for tract dilation. These include the use of Teflon dilators²⁵; a small scope to confirm proper dilator placement⁷; and more recently, balloon dilators to perform radiation-free US-guided PCNL.²⁶ All of these studies demonstrate the power of how US can be used to guide the process of renal tract dilation, a technical step of PCNL that has been relatively understudied.

To this end, our study aimed to examine each PCNL step separately with the goal of identifying factors associated with successful US guidance. We demonstrated an overall success rate of 71.9% for renal access and 60.4% for percutaneous tract dilation with a high-pressure balloon under US guidance alone. These 2 important steps of PCNL present particular challenges to perform exclusively under ultrasonographic monitoring. Although an access needle and a guidewire can usually be seen clearly with US, fascial dilators, an uninflated balloon, and an NT are sometimes visible only to a variable degree.

PCNL on a kidney with no hydronephrosis was associated with fluoroscopy requirement during renal access using a multivariate analysis model. This finding reflects works by Gamal et al and Basiri et al who reported a success rate of 94% and 100% respectively in US-guided renal puncture. However, only patients who demonstrated hydronephrosis on preoperative imaging were included in their studies, the majority of whom had moderate and severe degrees of hydronephrosis.^{25,27} Our study found a lower success rate of 71.9%, but almost two thirds of patients demonstrated no hydronephrosis. In 27 patients who required fluoroscopy for renal access, the majority demonstrated no collecting system dilatation, and for the 3 patients with hydronephrosis, all had only a mild degree.

For tract dilation, the presence of a staghorn stone was significantly associated with fluoroscopy utilization in our study. With staghorn stones, stone branches usually occupy the majority of the collecting system. Thus, a relatively limited space is left between the stone and the adjacent collecting system lining, making it difficult to advance excess wire into the collecting system. With less wire present in the urinary space, ultrasonographic visualization of the dilation process can be challenging. Moreover, most instruments used for tract dilation have been designed to be visible by fluoroscopy, and can be difficult to visualize using US. Placing these instruments and imaging them continuously is critical for safe tract dilation. For our study, when US failed to provide adequate live imaging, fluoroscopy was used to preserve patient safety. Similarly, the surgeon looking to adopt US for guidance of tract

dilation, in the presence of staghorn stones, should be prepared for employment of fluoroscopic screening to verify instrument positioning as needed.

Our series suggests that the ideal patient in which to use US guidance and optimize success is one with a hydronephrotic kidney and no staghorn stone, but that starting with the intention to use US guidance during PCNL, regardless of success, eliminates a significant amount of ionizing radiation exposure to patients and medical personnel. Although using US guidance in every step of PCNL may not be achievable in all cases, the mean total fluoroscopic screening time in our study was 48.4 seconds, a relatively low number when compared with other published fluoroscopic series that generally demonstrate a screening time of more than 200 seconds.^{28,29} Furthermore, more than half of patients in our series had zero radiation exposure during renal access and tract dilation. Interestingly, these findings were relevant regardless of patient body habitus, as patient body mass index was not associated with success of US guidance.³⁰ Therefore, starting a case with the intention to use US carries a distinct advantage in reducing radiation exposure.

We selected cases for this cohort that were performed 1 year after the operative surgeon began his experience with US guidance for PCNL to minimize the effect of the learning curve on study outcomes. NT placement as a PCNL step was performed under fluoroscopic guidance during the majority of this series. These tubes are difficult to visualize with US imaging. Once the operative surgeon gained proficiency in performing this step under US guidance, fluoroscopy was subsequently eliminated, and this represented the last 16 cases. With such a clear temporal relationship, success with using US for NT placement is likely most closely associated with surgeon learning curve in this series. This particular step of the procedure warrants further study to optimize US guidance.

Improved US machines with higher resolution real-time images, and instruments composed of proper acoustic surfaces, all could lead to improved visualization for US-guided PCNL. Thus, our series reflects applying US imaging to a procedure using instruments not originally designed for this purpose. With time and technological advances, US guidance for PCNL may become even easier to perform.

Some limitations warrant remark in our study. Although this was a prospective study, lack of a control group limits our ability to generalize our findings for clinical efficacy of US-guided PCNL. In addition, our sample size is relatively small, and all operative data were derived from a single surgeon trained in endourology. A larger scale multiinstitutional study including surgeons with various experience levels would validate the finding from this study. In all, however, our aim was to help the practicing urologist interested in adopting US guidance for PCNL identify how to optimize their success in making this transition while preserving safe outcomes for their patients.

CONCLUSION

US can be used successfully to provide imaging guidance for renal access, tract dilation, and NT placement with preservation of safe clinical outcomes and immediate reduction in patient and practitioner exposure to ionizing radiation. Among several patient factors, a non-

dilated collecting system and the presence of staghorn stones are predictive for the need for additional fluoroscopic screening in renal access and tract dilation, respectively. An awareness of these factors would facilitate optimal patient selection and benefit practitioners looking to adopt US guidance into their practice.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding Support: T.C. was supported by grants from the National Institutes of Health (P20-DK-100863 and R21-DK-109433 and the Multidisciplinary K12 Urologic Research Career Development Program K12-DK-07-006).

References

1. Patel SR, Nakada SY. The modern history and evolution of percutaneous nephrolithotomy. *J Endourol.* 2015; 29:153–157. [PubMed: 25093997]
2. Andonian S, Scoffone CM, Louie MK, et al. Does imaging modality used for percutaneous renal access make a difference? A matched case analysis. *J Endourol.* 2013; 27:24–28. [PubMed: 22834999]
3. Majidpour HS. Risk of radiation exposure during PCNL. *Urol J.* 2010; 7:87–89. [PubMed: 20535693]
4. Mishra S, Jagtap J, Sabnis RB, et al. Training in percutaneous nephrolithotomy. *Curr Opin Urol.* 2013; 23:147–151. [PubMed: 23357932]
5. de la Rosette JJ, Laguna MP, Rassweiler JJ, et al. Training in percutaneous nephrolithotomy—a critical review. *Eur Urol.* 2008; 54:994–1001. [PubMed: 18394783]
6. Usawachintachit M, Masic S, Allen IE, et al. Adopting ultrasound guidance for prone percutaneous nephrolithotomy: evaluating the learning curve for the experienced surgeon. *J Endourol.* 2016; 30:856–863. [PubMed: 27150671]
7. 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.* 2014; 127:4184–4189. [PubMed: 25533819]
8. Chi T, Masic S, Li J, et al. Ultrasound guidance for renal tract access and dilation reduces radiation exposure during percutaneous nephrolithotomy. *Adv Urol.* 2016; 2016:3840697. [PubMed: 27042176]
9. Pareek G, Hedican SP, Lee FT Jr, et al. Shock wave lithotripsy success determined by skin-to-stone distance on computed tomography. *Urology.* 2005; 66:941–944. [PubMed: 16286099]
10. Taylor A, Lewis C, Giacometti A, et al. Improved formulas for the estimation of renal depth in adults. *J Nucl Med.* 1993; 34:1766–1769. [PubMed: 8410296]
11. Preminger GM, Assimos DG, Lingeman JE, et al. Chapter 1: AUA guideline on management of staghorn calculi: diagnosis and treatment recommendations. *J Urol.* 2005; 173:1991–2000. [PubMed: 15879803]
12. Kennish SJ, Wah TM, Irving HC. Unenhanced CT for the evaluation of acute ureteric colic: the essential pictorial guide. *Postgrad Med J.* 2010; 86:428–436. [PubMed: 20634253]
13. Chu C, Masic S, Usawachintachit M, et al. Ultrasound-guided renal access for percutaneous nephrolithotomy: a description of three novel ultrasound-guided needle techniques. *J Endourol.* 2016; 30:153–158. [PubMed: 26414304]
14. Clavien PA, Barkun J, de Oliveira ML, et al. The Clavien-Dindo classification of surgical complications: five-year experience. *Ann Surg.* 2009; 250:187–196. [PubMed: 19638912]
15. Lojanapiwat B. The ideal puncture approach for PCNL: fluoroscopy, ultrasound or endoscopy? *Indian J Urol.* 2013; 29:208–213. [PubMed: 24082442]

16. Sharma GR, Maheshwari PN, Sharma AG, et al. Fluoroscopy guided percutaneous renal access in prone position. *World J Clin Cases*. 2015; 3:245–264. [PubMed: 25789297]
17. National Research Council (U.S.), Committee to Assess Health Risks from Exposure to Low Level of Ionizing Radiation. Health risks from exposure to low levels of ionizing radiation: BEIR VII Phase 2. Washington, DC: National Academies Press; 2006.
18. Sharifiaghdas F, Tabibi A, Nouralizadeh A, et al. Our experience with totally ultrasonography-guided percutaneous nephrolithotomy in children. *J Endourol*. 2015; [accessed August 15, 2016] [Epub ahead of print]. doi: 10.1089/end.2014.0660
19. Fregonesi A, Dias FG, Saade RD, et al. Challenges on percutaneous nephrolithotomy in pregnancy: supine position approach through ultrasound guidance. *Urol Ann*. 2013; 5:197–199. [PubMed: 24049385]
20. Goldenberg E, Gilbert BR. Office ultrasound for the urologist. *Curr Urol Rep*. 2012; 13:460–466. [PubMed: 23054506]
21. Uppot RN, Gervais DA, Mueller PR. Interventional urology. *Radiol Clin North Am*. 2008; 46:45–64. vi. [PubMed: 18328879]
22. Bird VG, Fallon B, Winfield HN. Practice patterns in the treatment of large renal stones. *J Endourol*. 2003; 17:355–363. [PubMed: 12965059]
23. Filippou P, Odisho A, Ramaswamy K, et al. Using an abdominal phantom to teach urology residents ultrasound-guided percutaneous needle placement. *Int Braz J Urol*. 2016; 42:717–726. [PubMed: 27564282]
24. Desai M, Ridhorkar V, Patel S, et al. Pediatric percutaneous nephrolithotomy: assessing impact of technical innovations on safety and efficacy. *J Endourol*. 1999; 13:359–364. [PubMed: 10446796]
25. Gamal WM, Hussein M, Aldahshoury M, et al. Solo ultrasonography-guided percutaneous nephrolithotomy for single stone pelvis. *J Endourol*. 2011; 25:593–596. [PubMed: 21395489]
26. Zhou T, Chen G, Gao X, et al. “X-ray”-free balloon dilation for totally ultrasound-guided percutaneous nephrolithotomy. *Urolithiasis*. 2015; 43:189–195. [PubMed: 25655249]
27. Basiri A, Ziaee AM, Kianian HR, et al. Ultrasonographic versus fluoroscopic access for percutaneous nephrolithotomy: a randomized clinical trial. *J Endourol*. 2008; 22:281–284. [PubMed: 18294034]
28. Jagtap J, Mishra S, Bhattu A, et al. Which is the preferred modality of renal access for a trainee urologist: ultrasonography or fluoroscopy? Results of a prospective randomized trial. *J Endourol*. 2014; 28:1464–1469. [PubMed: 25393358]
29. Lipkin ME, Mancini JG, Toncheva G, et al. Organ-specific radiation dose rates and effective dose rates during percutaneous nephrolithotomy. *J Endourol*. 2012; 26:439–443. [PubMed: 21942800]
30. Usawachintachit M, Masic S, Chang HC, Allen IE, Chi T. Ultrasound guidance to assist percutaneous nephrolithotomy reduces radiation exposure in obese patients. *Urology*. 2016; [accessed August 15, 2016] [Epub ahead of print]. doi: 10.1016/j.urology.2016.04.012

Table 1

Demographic and perioperative variables

Variables	Values
Age (y), mean $\pm$ SD	50.8 $\pm$ 17.0
Gender, n (%)	
Female	52 (54.2)
Male	44 (45.8)
BMI (kg/m ²), mean $\pm$ SD	28.7 $\pm$ 7.9
Skin-to-stone distance (mm), mean $\pm$ SD	105.6 $\pm$ 30.0
Kidney depth (mm)	91.8 $\pm$ 27.1
ASA class, n (%)	
1	10 (10.4)
2	54 (56.3)
3	31 (32.3)
4	1 (1.0)
Stone laterality, n (%)	
Left	53 (55.2)
Right	43 (44.8)
Stone size (mm), mean $\pm$ SD	33.1 $\pm$ 18.9
Presence of staghorn stone, n (%)	29 (30.2)
Presence of hydronephrosis, n (%)	35 (36.4)
Preoperative serum creatinine level (mg/dL), mean $\pm$ SD	0.94 $\pm$ 0.40
Preoperative serum hematocrit (%), mean $\pm$ SD	39.9 $\pm$ 5.3
Renal access time (min), mean $\pm$ SD	2.5 $\pm$ 3.0
Puncture approach	
Lower	39 (40.6)
Middle	17 (17.7)
Upper	40 (41.7)
Tract dilation time (min), mean $\pm$ SD	10.4 $\pm$ 4.1
Total operative time (min), mean $\pm$ SD	134.0 $\pm$ 50.1
Total fluoroscopic screening time (s), mean $\pm$ SD	48.4 $\pm$ 86.8

ASA, American Society of Anesthesiologists; BMI, body mass index; SD, standard deviation.

Table 2

Fluoroscopic screening requirement for renal access or tract dilation during ultrasound-guided PCNL

		Fluoroscopy Required for Tract Dilation		
		Yes	No	Total
Fluoroscopy required for renal access	Yes	24 *	3 *	27
	No	14 *	55	69
Total		38	58	96
		Group C		

PCNL, percutaneous nephrolithotomy.

* A total of 41 patients, defined as group A, required fluoroscopy for renal access or tract dilation.

Table 3

Impact of perioperative parameters on need for fluoroscopy

Variables	Ultrasound Guidance for Renal Access			Ultrasound Guidance for Renal Tract Dilation		
	Fluoroscopy Required (Group B) (n = 27)	US Successful (n = 69)	P Value	Fluoroscopy Required (Group C) (n = 38)	US Successful (n = 58)	P Value
Age (y), mean $\pm$ SD	50.8 $\pm$ 15.6	50.8 $\pm$ 17.6	.99	49.2 $\pm$ 15.6	51.9 $\pm$ 17.9	.45
Gender, n (%)			.53			.81
Female	16 (59.3)	36 (52.2)		20 (52.6)	32 (55.2)	
Male	11 (40.7)	33 (47.8)		18 (47.4)	26 (44.8)	
BMI (kg/m ²), mean $\pm$ SD	30.8 $\pm$ 8.8	27.9 $\pm$ 7.5	.10	30.1 $\pm$ 8.9	27.8 $\pm$ 7.2	.17
Skin to stone distance (mm), mean $\pm$ SD	119.2 $\pm$ 33.8	101.6 $\pm$ 27.9	<.05	116.2 $\pm$ 36.1	99.7 $\pm$ 24.5	<.05
Kidney depth (mm), mean $\pm$ SD	103.7 $\pm$ 28.4	88.1 $\pm$ 25.8	<.05	102.9 $\pm$ 32.7	85.4 $\pm$ 21.1	<.05
ASA class, n (%)						
Class 1	1 (3.7)	9 (13.0)	.29	3 (7.9)	7 (12.1)	.79
Class 2	14 (51.9)	40 (58.0)		21 (55.3)	33 (56.9)	
Class 3	12 (44.4)	19 (27.5)		14 (36.8)	17 (29.3)	
Class 4	0	1 (1.5)		0	1 (1.7)	
Stone laterality, n (%)						
Left	13 (48.2)	40 (58.0)	.38	20 (52.6)	33 (56.9)	.68
Right	14 (51.8)	29 (42.0)		18 (47.4)	25 (43.1)	
Stone size (mm), mean $\pm$ SD	36.4 $\pm$ 20.5	31.8 $\pm$ 18.2	.28	37.6 $\pm$ 20.9	30.1 $\pm$ 17.0	.06
Presence of staghorn stone, n (%)	13 (48.2)	16 (23.2)	<.05	19 (50.0)	10 (17.2)	<.05 [†]
Presence of hydronephrosis, n (%)	3 (11.1)	32 (46.4)	<.05 [*]	9 (23.7)	26 (44.8)	<.05

Abbreviations as in Table 1.

^{*} Controlling for skin-to-stone distance, kidney depth, and presence of staghorn stone, multivariate analysis demonstrated hydronephrosis ($P < .05$) as the single variable significantly associated with fluoroscopy requirement for renal access.

[†] Controlling for skin-to-stone distance, kidney depth, and the presence of hydronephrosis, multivariate analysis demonstrated presence of staghorn stone ($P < .05$) as the single variable significantly associated with fluoroscopy requirement for tract dilation.

Impact of fluoroscopy use on postoperative outcomes

Variables	Total (n = 96)	Ultrasound Guidance for Renal Access			Ultrasound Guidance for Tract Dilation		
		Fluoroscopy Required (Group B) (n = 27)	US Successful (n = 69)	P Value	Fluoroscopy Required (Group C) (n = 38)	US Successful (n = 58)	P Value
Change in serum hematocrit (%), mean $\pm$ SD	5.0 $\pm$ 4.5		4.9 $\pm$ 4.4	.65	5.6 $\pm$ 4.6	4.6 $\pm$ 4.5	.32
Blood transfusion, n (%)	3 (3.1)	1 (3.7)	2 (2.9)	.84	1 (2.6)	2 (3.5)	.82
Postoperative complication, n (%)	7 (7.3)	2 (7.7)	5 (7.3)	.94	3 (8.1)	4 (6.9)	.83
Hospital stay (d), mean $\pm$ SD	2.9 $\pm$ 1.3	3.0 $\pm$ 1.4	2.8 $\pm$ 1.2	.51	2.9 $\pm$ 1.2	2.8 $\pm$ 1.3	.60
Stone free status, n (%)	84 (87.5)	23 (85.2)	61 (88.4)	.63	31 (81.6)	53 (91.4)	.20
Secondary procedure, n (%)	2 (2.1)	2 (7.4)	0	.08	2 (5.3)	0	.15

US, ultrasound; other abbreviation as in Table 1.