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Ultrasound-guided percutaneous nephrolithotomy: Advantages and limitations

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Purpose: The use of ultrasound in percutaneous nephrolithotomy (PCNL) has not been shown to translate to better clinical and stone outcomes. To compare the operative outcomes, postoperative outcomes and complication rates of ultrasound-guided access PCNL (USGA-PCNL) versus fluoroscopy-guided access PCNL (FGA-PCNL).

Materials and Methods: A total of 184 consecutive patients who underwent PCNL from July 2008 to September 2014 were identified from our PCNL database. Seventy-two patients underwent USGA-PCNL and 112 FGA-PCNL.

Results: The patients were similar in age, sex, race, American Society of Anesthesiologists physical status classification, mean largest stone diameters, side of PCNL, number of stones and the degree of hydronephrosis between both groups. There were higher rates of upper pole (5.6% vs. 3.6%), mid pole (8.3% vs. 2.7%) and multiple pole punctures (4.2% vs. 0%) in USGA-PCNL compared to FGA-PCNL (p=0.027). There was no difference in the stone free rates of both groups in univariate analysis. Those who had FGA-PCNL were 2.26 (95% confidence interval, 1.09–4.75; p=0.029) times more likely to require a second-look procedure compared to USGA-PCNL on univariate analysis but not on multivariate analysis. There were no differences in Clavien-Dindo complications. No patient in the USGA-PCNL group experienced organ injuries during puncture compared to 1 patient in the FGA-PCNL group who had pneumothorax requiring urgent chest tube insertion.

Conclusions: The use of ultrasonography to guide access puncture during PCNL eliminates the risk of inadvertent organ injuries. Similar operative and stone outcomes show that the learning curve for USGA is minimal compared to conventional FGA.

Keywords: Fluoroscopy; Interventional ultrasonography; Percutaneous nephrostomy; Staghorn calculi; Urolithiasis

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) is the treatment of choice for staghorn stones and large renal stones. It is traditionally guided by fluoroscopy and may pose a risk of radiation to patient and staff especially in a high workload center [1,2]. The use of ultrasonography in PCNL was first described as early as the 1970s [3]. In the recent years, its popularity has grown with multiple case series being published, demonstrating its feasibility, safety and efficacy [4-7]. These have led to 2 randomised clinical trials that showed a more accurate puncture and less radiation exposure for the patients and staff in ultrasound-guided PCNL [8,9].

To perform a successful PCNL, accurate puncture into the desired calyx is of paramount importance.

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Although fluoroscopy allows accurate identification of the desired calyx for puncture, it does not allow for real-time simultaneous bi-plane fluoroscopy, making the process of obtaining accurate puncture into the desired calyx more difficult. In addition, important adjacent organs such as the pleura and the bowels are not visualised during the puncture, posing the risk of accidental injury to these organs [10-12]. Access with ultrasound-guided puncture during PCNL allows real-time simultaneous bi-plane tracking of the route of puncture into the desired calyx, while avoiding accidental injuries to vital adjacent organs. A less optimal entry into the collecting system will therefore lead to increased bleeding complications and decreased postoperative stone free rates [13].

To our knowledge, there had been only one publication focusing on the complications and stone free rates between ultrasound-guided access PCNL (USGA-PCNL) and fluoroscopy-guided access PCNL (FGA-PCNL) [14]. In this study, we aimed to compare the operative outcomes, postoperative outcomes and complication rates of USGA-PCNL versus FGA-PCNL during PCNL.

MATERIALS AND METHODS

1. Patient selection

A total of 184 consecutive patients who underwent PCNL between July 2008 and September 2014 were identified from our database. We included all patients who were older than 18 years with size of renal stone ≥10 mm. We excluded patients with congenital kidney anomalies, uncorrected coagulopathy and previous open surgery for renal stones. All patients underwent routine blood investigations and anesthesia assessment prior to operation. Preoperative computed tomography (CT) urogram or plain CT KUB (kidney, ureter, and bladder) were routinely performed to evaluate the anatomy of kidney, the locations of stones and the positions of adjacent structures in relation to the desired route of puncture. Every case was performed either by an associate consultant/consultant/senior consultant or a registrar-in-training under direct supervision by a consultant/senior consultant.

2. Surgical techniques

Under general anesthesia, the patient was first positioned in lithotomy when a ureteric catheter was inserted, if possible, past the stone into the upper calyx of the kidney. This was to allow infusion of methylene blue and radiographic contrast, diluted in normal saline, during needle puncture into the collecting system. The patient was then repositioned in prone. In the USGA-PCNL group, an ultrasound was used to identify the anatomy of the calyces, the position of the stones and the route of puncture. The adjacent structures i.e., lung, large bowel, liver, spleen were then surface-marked. The selected calyx to be punctured was then visualized with ultrasound and the puncture was made with Initial Puncture Needle 18 G/12 cm or 18 G/20 cm (Cook Medical, Bloomington, IN, USA) under ultrasound guidance. In the FGA-PCNL group, the needle puncture was performed with the triangulation method under fluoroscopic guidance.

Once the desired calyx was punctured, the subsequent steps were identical in the 2 approaches. Fluoroscopy was used for the subsequent steps. An Amplatz Super Stiff straight tip 0.035 inch guide-wire (Boston Scientific, Spencer, IN, USA) was inserted into the collecting system. Attempt was made to direct this guide-wire down the ureter into the bladder whenever possible. With the guide-wire in place, the skin incision was made and the tract was dilated with either the coaxial dilator 8F/10F (Boston Scientific) or the Super Arrow-Flex PSI Set (Arrow International, Reading, PA, USA). A second guide wire, 0.038-inch PTFE Amplatz Extra Stiff guide-wire (Cook Medical) (used for subsequent dilatation) was then inserted down the ureter into the bladder if possible. A NephroMax balloon dilator (Boston Scientific) was then used to dilate the tract to 30F. A 30F Amplatz sheath was then directed over the balloon into the selected calyx under fluoroscopy. Stone fragmentation was performed using an ultrasonic lithotripter (Olympus LUS-2, Tokyo, Japan) or CyberWand (Olympus, South borough, MA, USA). Flexible nephroscopy may be performed to identify and fragment residual stones with Holmium laser or retrieve stone fragments with dormia basket. None of the cases required the use of flexible ureteroscopy. At the end of operation, a double J stent may be inserted antegradely or retrogradely and a Jacque catheter was inserted. Finally an on-table check nephrostogram was performed to ascertain positions of the DJ stent and Jacque catheter.

3. Statistical analysis

We compared patients' demographics, stone characteristics, operative and postoperative outcomes in patients who underwent USGA-PCNL or FGA-PCNL using the Student t-test for continuous variables and the Pearson chi-square test for categorical variables. Multivariate analysis was performed with logistic regression for the need for second-look procedure and linear regression for the mean length of hospital stay. Statistical analysis was conducted using IBM SPSS Statistics ver. 21.0 (IBM Co., Armonk, NY, USA); $p<0.05$

from use of 2-side statistical tests was considered statistically significant.

RESULTS

There were 72 patients in the USGA-PCNL group versus 112 patients in the FGA-PCNL group. The baseline patient demographics are presented in Table 1. The major parameters for both USGA-PCNL and FGA-PCNL groups were similar at baseline. As USGA-PCNL was a newer technique that we more recently adopted, the mean follow-up duration was shorter in USGA-PCNL than in FGA-PCNL (14.8±16.1 months vs. 24.7±21.3 months, p=0.001).

The operative outcomes are shown in Table 2. There were higher rates of upper pole (5.6% vs. 3.6%), mid pole (8.3% vs. 2.7%) and multiple pole punctures (4.2% vs. 0%) in USGA-PCNL compared to FGA-PCNL (p=0.027). The mean size of Jacques catheter used was smaller in USGA-PCNL than in FGA-PCNL (17.6F vs. 22.0F, p=0.053). There were no statistically significant differences in duration of surgery or types of ureteric stents used.

Table 3 summarizes the postoperative outcomes. We defined our stone free rate as level 4 according to Somani et al. [15] i.e., ≤4 mm on plain KUB X-ray. The stone free rate of USGA-PCNL was 66.7% vs. FGA-PCNL 43.7% on univariate analysis (p=0.159). USGA-PCNL was found to require fewer second-look procedures (16.7%) vs. FGA-PCNL (31.2%) on univariate analysis (p=0.027). Those who had FGA-PCNL were 2.26 (95% confidence interval, 1.09–4.75; p=0.029) times more likely to require a second-look procedure compared to USGA-PCNL. However, this is not significant on multivariate analysis (p=0.090). For those who needed a second-look procedure, 2 patients in the FGA-PCNL group had to undergo a repeat PCNL, 1 patient ureteroscopy and laser lithotripsy, and 32 (91.4%) required extracorporeal shockwave lithotripsy (ESWL); while 3 patients in the

Table 1. Patient demographics

Variable	USGA-PCNL (n=72)	FGA-PCNL (n=112)	p-value
Age (y)	55.6±12.0	52.6±11.5	0.965
Sex			0.229
Male	50 (69.4)	87 (77.7)	
Female	22 (30.6)	25 (22.3)	
Race			0.500
Chinese	42 (58.3)	61 (54.5)	
Malay	25 (34.7)	35 (31.3)	
Indian	3 (4.2)	9 (8.0)	
Others	2 (2.8)	7 (6.3)	
ASA PS classification			0.415
I	8 (11.1)	7 (6.3)	
II	31 (43.1)	54 (48.2)	
III	33 (45.8)	49 (43.8)	
IV	0 (0)	2 (1.8)	
Side of stone			0.627
Left	34 (47.2)	57 (50.9)	
Right	38 (52.8)	55 (49.1)	
Classification of stone			0.517
Nonstaghorn	23 (31.9)	41 (36.6)	
Partial or complete staghorn	49 (68.1)	71 (63.4)	
Largest stone diameter (mm)	28.2±11.9	31.7±13.0	0.491
Hydronephrosis			0.774
None	16 (22.2)	26 (23.2)	
Mild	32 (44.4)	42 (37.5)	
Moderate	13 (18.1)	26 (23.2)	
Severe	11 (15.3)	18 (16.1)	
Grade of surgeon			0.135
Associate consultant	2 (2.8)	12 (10.7)	
Consultant	37 (51.4)	55 (49.1)	
Senior consultant	33 (45.8)	45 (40.2)	

Values are presented as mean±standard deviation or number (%).
USGA-PCNL, ultrasound-guided access percutaneous nephrolithotomy; FGA-PCNL, fluoroscopy-guided access percutaneous nephrolithotomy; ASA PS, American Society of Anesthesiologists physical status.

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Table 2. Comparison of operative outcome of USGA-PCNL vs. FGA-PCNL

Variable	USGA-PCNL (n=72)	FGA-PCNL (n=112)	p-value
Site of puncture			
Upper pole	4 (5.6)	4 (3.6)	0.027
Mid pole	6 (8.3)	3 (2.7)	
Lower pole	59 (81.9)	105 (93.8)	
Multiple	3 (4.2)	0 (0)	
Duration of surgery (min)	169±62.6	169±60.7	0.997
Size of Jacques catheter used (French)	17.6±4.2	22.0±3.4	0.053
Type of ureteric stenting			
None	2 (2.8)	4 (3.6)	0.559
Pollack	25 (34.7)	47 (42.0)	
DJ stent	45 (62.5)	61 (54.5)	

Values are presented as number (%) or mean±standard deviation.
USGA-PCNL, ultrasound-guided access percutaneous nephrolithotomy; FGA-PCNL, fluoroscopy-guided access percutaneous nephrolithotomy; DJ, double J.

Table 3. Comparison of stone outcome of USGA-PCNL vs. FGA-PCNL

Variable	USGA-PCNL (n=72)	FGA-PCNL (n=112)	p-value	
			Univariate analysis	Multivariate analysis
Stone free status				
Yes	48 (66.7)	49 (43.7)	0.159	-
No	24 (33.3)	63 (56.3)		
Need for second-look procedure				
Yes	12 (16.7)	35 (31.2)	0.027	0.090*
Size of residual stone (mm)	10.5±3.0	10.7±4.6		
No	60 (83.3)	77 (68.8)		
Size of residual stone (mm)	4.7±3.2	4.9±3.8		
Types of additional procedure				
ESWL	9/12 (75.0)	32/35 (91.4)	0.047	-
URS and laser lithotripsy	3/12 (25.0)	1/35 (2.9)		
PCNL	0 (0)	2/35 (5.7)		
Duration of Jacques catheter (d)	3.9±6.1	3.7±3.8	0.823	-
Length of hospital stay (d)	2.9±2.8	4.6±5.7	0.008	0.024**

Values are presented as number (%) or mean±standard deviation.
USGA-PCNL, ultrasound-guided access percutaneous nephrolithotomy; FGA-PCNL, fluoroscopy-guided access percutaneous nephrolithotomy; ESWL, extracorporeal shockwave lithotripsy; URS, ureterorenoscopy.
*Multivariate analysis (logistic regression) was performed with the following as variables: age, sex, race, American Society of Anesthesiologists physical status classification, largest stone diameter, staghorn or nonstaghorn stones, severity of hydronephrosis, number of puncture, duration of surgery, percentage of postoperative hemoglobin change, presence of intraoperative/postoperative complication and USGA or FGA.
**Multivariate analysis (linear regression) was performed with the following as variables: age, gender, race, ASA score, largest stone diameter, staghorn or non-staghorn stones, postoperative fever, presence of intraoperative/postoperative complication, percentage of postoperative hemoglobin change, transfusion or not, USGA vs. FGA, and size of Jacques catheter <16Fr or >16Fr.

USGA-PCNL group required subsequent ureteroscopy and laser lithotripsy, 9 ESWL and none repeat PCNL (p=0.047). The mean duration of Jacques catheter was 3.9±6.1 days in USGA-PCNL and 3.7±3.8 in FGA-PCNL (p=0.823). The mean length of hospitalization was 2.9±2.8 days in USGA-PCNL vs. 4.6±5.7 days in FGA-PCNL on univariate analysis (p=0.008). Multivariate analysis also showed statistical significant reduction of hospital stay with p=0.024.

The complication rates of the 2 approaches were shown in Table 4. There were no statistical differences in blood loss, postoperative acute renal impairment (defined as serum creatinine increased by 50% from baseline) as well as other complications according to Clavien-Dindo classifications. There was one patient who suffered a pleural injury requiring chest tube insertion and another patient had renal pelvis stenosis requiring open pyeloplasty in the FGA-PCNL group (Table 5). No patient in the USGA-PCNL group had accidental injury to the adjacent organs.

Table 4. Comparison of complications of USGA-PCNL vs. FGA-PCNL

Variable	USGA-PCNL (n=72)	FGA-PCNL (n=112)	p-value
Complication			
No	40 (55.6)	72 (64.3)	0.236
Yes	32 (44.4)	40 (35.7)	
Clavien-Dindo classification			
Grade 0	41 (56.9)	69 (61.6)	0.594
Grade I	13 (18.1)	19 (17.0)	
Grade II	13 (18.1)	13 (11.6)	
Grade III	5 (6.9)	11 (9.8)	
Blood transfusion			
No	60 (83.3)	99 (88.4)	0.328
Yes	12 (16.7)	13 (11.6)	
Postoperative % hemoglobin drop	12.7±13.2	9.2±12.7	0.089
Postoperative acute renal Impairment			
No	65 (90.3)	100 (89.3)	0.829
Yes	7 (9.7)	12 (10.7)	
Fever			0.558
No	56 (77.8)	89 (79.5)	
Yes	16 (22.2)	23 (20.5)	

Values are presented as number (%) or mean±standard deviation.
USGA-PCNL, ultrasound-guided access percutaneous nephrolithotomy; FGA-PCNL, fluoroscopy-guided access percutaneous nephrolithotomy.

Table 5. Detailed Clavien-Dindo classification grade III complications of USGA-PCNL vs. FGA-PCNL

USGA-PCNL	FGA-PCNL
Two patients had postoperative bleeding that required renal angioembolisation	Four patients had postoperative bleeding that required renal angioembolisation
One patient had ureteric obstruction secondary to edema that required adjustment of nephrostomy tube by interventional radiologist	One patient had postoperative severe hematuria requiring cystoscopy and evacuation of clots
One patient had infected perinephric hematoma requiring percutaneous drainage	One patient had significant amount of residual stone fragment requiring relook PCNL
One patient had nephrocutaneous fistula secondary to distal ureteric edema and ureteric stones requiring ureteroscopy and laser lithotripsy and insertion of DJ stent	One patient had distal migration of DJ stent requiring change of DJ stent
	One patient had PUJ stenosis requiring open pyeloplasty
	One patient had infundibular stenosis, diagnosed from second PCNL due to stone recurrence, requiring dilatation
	One patient had blocked nephrostomy tube requiring adjustment under anesthesia
	One patient had hydrothorax requiring urgent insertion of chest tube

USGA-PCNL, ultrasound-guided access percutaneous nephrolithotomy; FGA-PCNL, fluoroscopy-guided access percutaneous nephrolithotomy; DJ, double J; PUJ, pelvi-ureteric junction.

DISCUSSION

Puncture during PCNL is traditionally carried out under the guidance of fluoroscopy. Exposure to radiation is an ongoing concern for the urologists, surgical assistants, nurses and patients [1,16,17]. The application of an alternative imaging technique is the best way to solve this problem. Basiri et al. [8] reported a mean duration of access of 11 minutes in a group of 50 patients undergoing USGA-PCNL whereas Agarwal et al. [9] quoted 1.8 minutes in his study involving 112 cases of USGA-PCNL. Both acknowledged that USGA-PCNL was highly accurate and duration of radiation exposure was significantly reduced. However, data comparing the outcomes and complications in both groups of USGA-PCNL and FGA-PCNL remains scarce and needs to be addressed. Our present study is one of the few designed to address this gap. We showed that USGA-PCNL was as safe as FGA-PCNL and with real-time ultrasound guidance during access puncture. Moreover, the risk of accidental puncture injury to adjacent organs like pleura or colon was eliminated.

Majority of our PCNL were performed by a lower pole

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puncture, i.e., 81.9% in USGA-PCNL and 93.7% in FGA-PCNL. The main reasons are surgeons' preference and to avoid entering the pleura. Wong and Leveillee [11] and Raza et al. [12] reported 2.8% and 3% rate of hydrothorax respectively with upper pole puncture under standard FGA-PCNL. The magnitude of the concern of thoracic injury is evident with Finelli and Honey [18] describing thoracoscopy-assisted PCNL for upper pole puncture. When upper pole, mid pole puncture and multiple pole puncture were deemed necessary in our study, USGA-PCNL was favoured. Despite more upper pole punctures performed using USGA-PCNL, there was no lung or pleural injury reported in our study compared to one in FGA-PCNL. We believe that this was due to the improved visibility of renal calyces and surrounding anatomy by ultrasound. Positional changes of bowel in supine (during CT scan) and prone (on table) positions were well reported [19,20]. With ultrasound guidance during access puncture, one will be able to more confidently avoid the bowel, thereby improving the accuracy of puncturing the desired calyx. In addition, fluoroscopic puncture via the triangulation method required a more lateral point of entry as opposed to ultrasound-guided puncture, increasing the risk of colonic injury [21].

Kalogeropoulou et al. [22] and Gamal et al. [23] revealed some difficulty in ultrasound-guided PCNL with a nondistended collecting system. Gamal et al. [23] reported 25 cases of moderate hydronephrosis and 9 cases of severe hydronephrosis, all with single stone. They concluded that USGA-PCNL can be performed safely by an experienced urologist for patients with a single stone at the renal pelvis in a moderately to markedly dilated pelvicalyceal system [23]. Li et al. [24] presented a series of successful ultrasound puncture in 132 cases after artificial retrograde dilatation of the collecting system. In our study, we did not find any statistical significance in the degree of hydronephrosis between the two arms. 66.6% of the USGA-PCNL arm had no or mild hydronephrosis compared to 60.7% of the FGA-PCNL arm (p=0.774). This showed that USGA-PCNL is safe and reproducible in general urology units. There was also no statistical significance in terms of the grades of surgeon performing the surgery (p=0.135). This further reinforces that USGA-PCNL is not difficult to learn. We think that with proper training, as well as the advancement in the technology of ultrasound providing sharp images, the lack of a moderate or severe hydronephrosis should not be a limiting factor to shy away from ultrasound-guided PCNL. The use of ultrasound puncture guide as suggested by Desai can be considered as a start to increase the surgeon's confidence [25].

A recent 7-year single center study by Chi et al. [7] reported a high stone free rate of 90.5% in a group of 562 patients and 9.5% required auxiliary measures after one PCNL. Agarwal et al. [9] also claimed that all patients achieved stone free in his randomized trial. Basiri et al. [26] randomised 92 patients into 46 USGA-PCNL and 46 FGA-PCNL and found no difference in the stone free rate, with 79.0% and 65.2% in the USGA-PCNL and FGA-PCNL respectively, after one session of PCNL (p=0.485). In this study, we reported a statistically insignificant difference in the stone free rate with USGA-PCNL (49.1%) compared to FGA-PCNL (36.9%) (p=0.159). We also did not find any difference in the need for second-look procedure in these groups. As this is a retrospective study, the need for second-look procedure was not clear but likely to be influenced by the surgeons' and the patients' preference. A longer follow-up and a prospective study are needed to study the true impact of USGA-PCNL in the stone free rate.

In this study, we also found that smaller nephrostomy tube was needed in the USGA-PCNL. We postulate that this may be due to the intra-operative use of color Doppler ultrasound to demonstrate a path of needle puncture to circumvent areas with dense vasculatures. As a result, this led to a less bloody intraoperative field observed by the surgeon, leading to the decision of placement of a smaller tube.

Our study did not show a shorter total duration of operation for USGA-PCNL over FGA-PCNL as total operative duration was dependent on a multitude of factors. The overall duration of operation was influenced by the grades of surgeon, the size and composition of stones, the locations of stone fragments and the physical build of the patients among others. A separate timing taken for puncture would be ideal in demonstrating the benefit of USGA-PCNL over FGA-PCNL in this aspect. As this was a retrospective study, we did not routinely record the duration required for puncture separately from the total operative timings. There was indeed no study that showed a difference in the overall duration of USGA-PCNL and FGA-PCNL.

There are several limitations in our study. As this is a retrospective study, the use of ultrasound in each PCNL was mainly dependent on the surgeon's training and preference. This was a heterogenous group of surgeons with varying level of expertise. There was scarce data regarding the stone composition and analysis. However, one of the strength of this study is that the definition of stone free status was clearly stated, i.e., <4 mm [15]. These could be the reasons for the relatively low stone free rate compared to other studies.

CONCLUSIONS

The use of ultrasonography to guide access puncture during PCNL eliminates the risk of inadvertent organ injuries. Similar operative and stone outcomes show that the learning curve for USGA is minimal compared to conventional FGA.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

REFERENCES

1. Rao PN, Faulkner K, Sweeney JK, Asbury DL, Sambrook P, Blacklock NJ. Radiation dose to patient and staff during percutaneous nephrostolithotomy. Br J Urol 1987;59:508-12.
2. Bowsher WG, Blott P, Whitfield HN. Radiation protection in percutaneous renal surgery. Br J Urol 1992;69:231-3.
3. Karamcheti A, O'Donnell WF. Percutaneous nephrolithotomy: an innovative extraction technique. J Urol 1977;118:671-2.
4. Zhou X, Gao X, Wen J, Xiao C. Clinical value of minimally invasive percutaneous nephrolithotomy in the supine position under the guidance of real-time ultrasound: report of 92 cases. Urol Res 2008;36:111-4.
5. Hosseini MM, Hassanpour A, Farzan R, Yousefi A, Afrasiabi MA. Ultrasonography-guided percutaneous nephrolithotomy. J Endourol 2009;23:603-7.
6. Yan S, Xiang F, Yongsheng S. Percutaneous nephrolithotomy guided solely by ultrasonography: a 5-year study of >700 cases. BJU Int 2013;112:965-71.
7. Chi Q, Wang Y, Lu J, Wang X, Hao Y, Lu Z, et al. Ultrasonography combined with fluoroscopy for percutaneous nephrolithotomy: an analysis based on seven years single center experiences. Urol J 2014;11:1216-21.
8. Basiri A, Ziaee AM, Kianian HR, Mehrabi S, Karami H, Moghaddam SM. Ultrasonographic versus fluoroscopic access for percutaneous nephrolithotomy: a randomized clinical trial. J Endourol 2008;22:281-4.
9. Agarwal M, Agrawal MS, Jaiswal A, Kumar D, Yadav H, Lavania P. Safety and efficacy of ultrasonography as an adjunct to fluoroscopy for renal access in percutaneous nephrolithotomy (PCNL). BJU Int 2011;108:1346-9.
10. El-Nahas AR, Shokeir AA, El-Assmy AM, Shoma AM, Eraky I, El-Kenawy MR, et al. Colonic perforation during percutaneous nephrolithotomy: study of risk factors. Urology 2006;67:937-41.
11. Wong C, Leveillee RJ. Single upper-pole percutaneous access for treatment of > or = 5-cm complex branched staghorn calculi: is shockwave lithotripsy necessary? J Endourol 2002;16:477-81.
12. Raza A, Moussa S, Smith G, Tolley DA. Upper-pole puncture in percutaneous nephrolithotomy: a retrospective review of treatment safety and efficacy. BJU Int 2008;101:599-602.
13. Osman M, Wendt-Nordahl G, Heger K, Michel MS, Alken P, Knoll T. Percutaneous nephrolithotomy with ultrasonography-guided renal access: experience from over 300 cases. BJU Int 2005;96:875-8.
14. Andonian S, Scoffone CM, Louie MK, Gross AJ, Grabe M, Daels FP, et al. Does imaging modality used for percutaneous renal access make a difference? A matched case analysis. J Endourol 2013;27:24-8.
15. Somani BK, Desai M, Traxer O, Lahme S. Stone-free rate (SFR): a new proposal for defining levels of SFR. Urolithiasis 2014;42:95.
16. Majidpour HS. Risk of radiation exposure during PCNL. Urol J 2010;7:87-9.
17. Hellawell GO, Mutch SJ, Thevendran G, Wells E, Morgan RJ. Radiation exposure and the urologist: what are the risks? J Urol 2005;174:948-52.
18. Finelli A, Honey RJ. Thoracoscopy-assisted high intercostal percutaneous renal access. J Endourol 2001;15:581-4.
19. Chalasani V, Bissoon D, Bhuvanagir AK, Mizzi A, Dunn IB. Should PCNL patients have a CT in the prone position preoperatively? Can J Urol 2010;17:5082-6.
20. Punwani S, Halligan S, Tolan D, Taylor SA, Hawkes D. Quantitative assessment of colonic movement between prone and supine patient positions during CT colonography. Br J Radiol 2009;82:475-81.
21. Vallancien G, Capdeville R, Veillon B, Charton M, Brisset JM. Colonic perforation during percutaneous nephrolithotomy. J Urol 1985;134:1185-7.
22. Kalogeropoulou C, Kallidonis P, Liatsikos EN. Imaging in percutaneous nephrolithotomy. J Endourol 2009;23:1571-7.
23. 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;25:593-6.
24. Li JX, Tian XQ, Niu YN, Zhang X, Kang N. Percutaneous nephrolithotripsy with pneumatic and ultrasonic power under B-type ultrasound guidance for treatment of renal calculi in non-dilated collecting system. Zhonghua Wai Ke Za Zhi 2006;44:386-8.
25. Desai M. Ultrasonography-guided punctures-with and without puncture guide. J Endourol 2009;23:1641-3.
26. Basiri A, Mirjalili MA, Kardoust Parizi M, Moosa Nejad NA. Supplementary X-ray for ultrasound-guided percutaneous nephrolithotomy in supine position versus standard technique: a randomized controlled trial. Urol Int 2013;90:399-404.

https://doi.org/10.4111/icu.2017.58.5.346