Safety and efficacy of ultrasonography as an adjunct to fluoroscopy for renal access in percutaneous nephrolithotomy (PCNL)

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Study Type – Therapy (case series)
Level of Evidence 4

OBJECTIVE

- To evaluate the safety and efficacy of ultrasonography (US)-guided renal access in percutaneous nephrolithotomy (PCNL), as compared with conventional fluoroscopy-guided renal access in a prospective randomized trial.

PATIENTS AND METHODS

- From January 2008 to October 2009, 224 patients with renal calculi undergoing PCNL were randomized into two groups.
- Group 1 (112 patients) underwent PCNL using only fluoroscopy-guided renal access; while in group 2 (112 patients), US guidance for puncture was used in addition to fluoroscopy.
- The inclusion criteria were: normal renal functions, American Society of Anesthesiology scores 1 or 2, absence of congenital abnormalities, aged 15–70 years, and anticipated single-tract procedure. The patients in both groups were matched for age, sex, and stone characteristics.
- The Student *t*-test was used for statistical analysis with an allowable error of 5%.

RESULTS

- The mean time to successful puncture was 3.2 min and 1.8 min in group 1 and group 2, respectively ($P < 0.01$).
- The mean duration of radiation exposure to successful puncture was 28.6 s in group 1 and 14.4 s in group 2 ($P < 0.01$).
- The mean numbers of attempts for successful puncture in the desired calyx was 3.3 in group 1 as compared with 1.5 in group 2 ($P < 0.01$).
- The meantime taken for tract formation in group 1 was 7.4 min with radiation exposure of 82 s, while in group 2 it took 4.8 min with radiation exposure of 58 s ($P < 0.01$).
- Successful access was achieved in all patients. All patients were stone-free at the end of the operation. The hospital stay (2–3 days) was same in both groups. There was no incidence of significant bleeding requiring transfusion during or after surgery. All the patients were followed-up for a ≥6 months.

CONCLUSION

- US-guided puncture in PCNL helps in increasing accuracy of puncture and decreasing radiation exposure for the surgical team and the patients.

KEYWORDS

percutaneous nephrolithotomy (PCNL), kidney stone, ultrasonography, flouroscopy

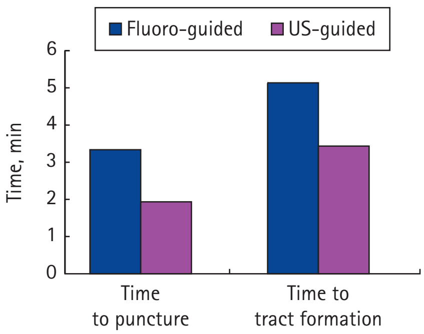
INTRODUCTION

The important milestones in the history of percutaneous renal surgery include the description of Goodwin *et al.* [1] of percutaneous nephrostomy in 1955 and the first publication by Fernstrom and Johannson[2] of percutaneous nephrolithotomy (PCNL) in 1976. The technique we use today is a modification of the method that Wickham and his contemporaries designed and revised [3,4]. Wickham described the staged approach starting with a percutaneous nephrostomy under local anaesthesia, followed by the dilatation of the tract serially over the next few days, with subsequent stone removal under general anaesthesia using a rigid 30° cystoscope. Today of course, PCNL is widely used as the most popular choice to treat patients with all types of renal stones, especially the larger ones [5–7].

To date, fluoroscopy has been the main tool to achieve renal access in PCNL, notwithstanding its inherent hazard of exposing the patient, surgeon and participating staff to the risk of ionizing radiation. The surgeon, in particular, is likely to be exposed to radiation on a regular and cumulative basis. Similarly, certain patients who have recurrent stones may be subjected to repeated radiation exposure during fluoroscopy-based procedures. Thus, radiation dose is an extremely important issue, especially in a young child, who is significantly more radiosensitive and more likely to manifest radiation-induced changes over his or her lifetime [8].

Puncture for renal access can also be achieved using ultrasonography (US) guidance as an alternative to fluoroscopy. The US approach has the advantages of minimizing radiation exposure and also allows imaging of intervening structures between the skin and kidney. US also allows evaluation of the pelvi-calyceal system of kidney in three-dimensional (3D) orientation and helps to

FIG. 1. Time to puncture and tract formation.



distinguish between anterior and posterior calyces with great accuracy. It also allows localization of the exact position of stone in relation to the pelvi-calyceal system [9].

The present prospective randomized trial was conducted to evaluate if the use of US for puncture in PCNL improved accuracy and reduced duration of radiation exposure and operative duration as compared with the standard fluoroscopy-guided renal access.

PATIENTS AND METHODS

From January 2008 to October 2009, 224 patients with renal calculi who underwent PCNL were enrolled in this prospective randomized study. The study was conducted after obtaining Institute Review Board approval. The methodology followed was as per the Consolidated Standards of Reporting Trials (CONSORT) statement. The inclusion criteria were normal renal function, American Society of Anesthesiology (ASA) score 1 and 2, absence of congenital abnormalities, aged 15–70 years, and an anticipated single-tract procedure. Patients with congenital anomalies, e.g. ectopic kidney, polycystic, horseshoe, or malrotated kidney; and patients who underwent transplant or urinary diversion, were excluded from the study. The degree of hydronephrosis was not considered in the selection criteria. No patients had an indwelling stent before the study.

All patients were treated for urinary infection preoperatively with appropriate antibiotics after urine culture and sensitivity test. The patients were randomized before PCNL by a simple random sampling technique. The two groups were similar in terms of age and sex, metabolic and anatomical features. The mean (range) age of patients in group 1 was 35 (22–55) years and in group 2 was 31 (18–59) years. The male : female ratio in both groups was ≈ 3 : 1. The mean (range) serum creatinine in group 1 was 1.2 (0.9–1.6) mg/dL and in group 2 was 1.3 (0.9–1.7) mg/dL. The mean (range) stone size in group 1 was 2.3 (1.1–3.1) cm^2 and in group 2 was 2.8 (0.9–3.5) cm^2.

Group 1 (112 patients) had the standard fluoroscopy-guided renal access before PCNL, while patients in group 2 (112 patients) had US-guided renal access. US-guided puncture was done using GE Logic 5000 machine with 3.5 MHz sector probe with a puncture-guide. On US, the puncture pathway is represented by an electronic dotted line on the scanner screen, which facilitates exact placement of the needle.

All procedures were performed prone after retrograde ureteric catheterization, under spinal or epidural anaesthesia, by one surgeon experienced in endourological procedures. A retrograde catheter was used for injecting saline to distend the pelvi-calyceal system, and for fluoroscopically confirming the accuracy of puncture by injecting a combination of contrast and a small amount of air, to delineate the posterior calyx accurately.

Before starting the procedure, an i.v. bolus injection of a diuretic (furosemide, 10 mg) was given to every patient to distend the pelvi-calyceal system. In our experience, furosemide helps in sustained and uniform distension of pelvi-calyceal system throughout the procedure, and acts as a useful supplement to intermittent instillation of saline through the retrograde catheter.

Biplanar C-arm fluoroscopy (Group 1) or US (Group 2) was used to make the initial puncture. The posterior calyx was chosen for puncture in most instances, except when the stone was directly present in the anterior calyx and was deemed to be unapproachable through the adjoining posterior calyx. The posterior calyx can be easily identified by US while it can be recognised fluoroscopically by using a combination of contrast and air, as air is light and collects in the posterior calyx.

A 0.97 mm Terumo J-tip nitinol guidewire was used, which due to its soft distal tip and firm proximal shaft, did not require to be exchanged at a later stage. An attempt was made to pass the guidewire down the ureter whenever possible, if unsuccessful, it was allowed to be coiled in the opposite calyx or pelvis. If multiple tracts were anticipated, a guidewire was placed for each tract at the outset, before starting dilatation. A safety guidewire was placed using an Alken cannula in all cases at the beginning of dilatation for tract formation.

For tract dilatation fascial dilators (Cook surgical) were used under fluoroscopic guidance in both groups. For stone removal a 21 F sheathless nephroscope (Wolf) was used through a 26/28 F Amplatz sheath in both groups. Stones were fragmented and cleared using a combination of ultrasonic and pneumatic lithotripsy (EMS Swiss lithoclast). Complete stone clearance was achieved in all cases meticulously, and was confirmed both endoscopically and fluoroscopically at completion of the procedure. At the end of the procedure a single nephrostomy tube was placed in both groups.

The factors evaluated included operative duration, including time to successful puncture and tract formation, duration of radiation exposure for puncture and tract formation, and the number of attempts for successful puncture. Patients were discharged from hospital when there was no pain and the urine was clear. Patients were followed at 1 week, 1 month and then 3 monthly, with a minimum follow-up of 6 months. All patients underwent plain X-ray and non-contrast CT at 1 month after PCNL for confirmation of complete stone clearance.

The Student *t*-test was used for statistical analysis with an allowable error taken to be 5%.

RESULTS

The mean (SD) time to successful puncture was significantly higher in group 1 at 3.2 (1.2) min than group 2 at 1.8 (0.7) min ($P < 0.01$; Fig. 1). The mean (SD) duration of radiation exposure in group 1 was 28.6 (8.4) s and in group 2 was 14.4 (6.5) s, significantly lower in group 2 than in group 1 ($P < 0.01$; Fig. 2). The mean (SD) number of trials given for successful puncture in the desired calyx was significantly higher in group 1 at 3.3 (1.0) than in group 2 at 1.5 (0.6) ($P < 0.01$). The mean time taken for tract formation in group 1 was 7.4 min with radiation exposure of 82 s while in group 2 it took 4.8 min with radiation exposure of 58 s ($P < 0.01$).

Successful access was achieved in all patients. All patients were stone-free at the end of the operation. The hospital stay (2–3 days) was same in both groups. There was no incidence of significant bleeding requiring transfusion. In both groups, none of the patients had any pleural or visceral injury at the time of achieving renal access.

Patients in both groups were stone free on non-contrast CT at 1 month. None of the patients showed any significant perinephric fluid collection. Two patients in each group had an episode of secondary haemorrhage in the second postoperative week, which was managed conservatively in each case. All the patients were followed-up for ≥6 months. There were no long-term sequelae in any patient and none required re-admission for pain, infection or obstruction.

DISCUSSION

The key requisite for PCNL is access to the collecting system. Percutaneous renal access can be achieved under fluoroscopic control or using US-guided puncture. Given the high degree of vascularity of the kidney, the ideal percutaneous tract should lead straight from the skin through the papilla of the target calyx into the renal pelvis. Vascular injury of renal parenchyma is minimised when puncture is through the posterior calyx.

US has the great advantage of helping the surgeon in posterior calyceal puncture by delineating 3D anatomy of the kidney. Use of a diuretic to transiently dilate calyces is very helpful to facilitate US-guided puncture without complications [10].US-guided puncture is also preferred for patients in whom retrograde ureteric catheterization is unsuccessful and for percutaneous nephrostomy in pregnant women [11–13].

Excessive use of fluoroscopy leads to increase radiation exposure to all persons present in operating theatre. It is well known that radiation hazard is directly proportional to cumulative radiation exposure time [14,15]. In males, the spermatogonia in the testis are the most radiosensitive cells of the reproductive system. Radiation doses as low as 0.15 Gyresult in oligozoospermia after a latent period of ≈ 6 weeks. Doses > 0.5 Gy result in temporary azoospermia. Recovery begins >1 year after doses of <1 Gy but requires 2–3 years after doses of 2 Gy. However, permanent sterility can be induced by doses of 5–6 Gy. In females germ cells are non-proliferative, so they suffer from permanent sterility or ovarian failure at doses of 12 Gy in prepubertal and 2 Gy in premenopausal women [16].

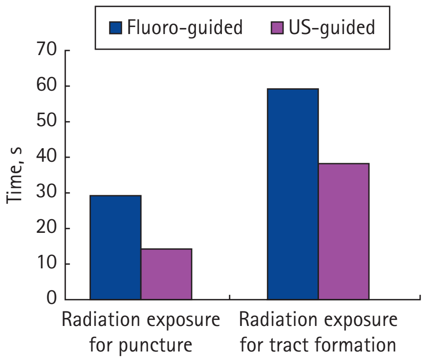
Thus it is very important to reduce exposure time in high-volume centres by following the principle of 'ALARA' (as-low-as-reasonably-achievable) [17]. However, fluoroscopy-guided puncture continues to be the preferred approach for PCNL in many parts of the world, especially where the puncture is made by the urologist himself in the operating theatre. For this reason, US-guided access needs to be popularised among surgeons, through structured training and orientation in US for surgeons.

Desai [18] reported the advantages of US needle guidance in pelvi-calyceal puncture. It helps in avoiding radiation, avoiding visceral injury and, most importantly, intra-renal vascular injury. US allows a straight and the shortest access to the collecting system with minimal morbidity. US-guided access is of particular importance in the paediatric population and in special situations, e.g. where the procedure is performed with the patient supine.

There appear to be only a few published studies on US-guided puncture in PCNL, and even fewer that have compared it with fluoroscopically-guided puncture in a prospective randomized fashion. Hosseini *et al.* [19] evaluated the safety and efficacy of US-guided PCNL in 47 patients. In all, 39 patients were stone free the day after the operation, and five patients had fragments which passed in 4 weeks (total stone-free rate 93.61%). They concluded PCNL using US is a good alternative to the fluoroscopic method.

Basiri *et al.* [20] reported on US-guided PCNL in 30 patients in the flank position. The stone-free rate was 88.9% in the patients with a single calculus and 75.0% in the patients with staghorn or multiple calculi. They concluded US-guided PCNL has satisfactory outcomes compared with the standard technique of PCNL, without any major complications and with the advantage of preventing radiation hazards and damage to the adjacent organs.

FIG. 2. Radiation exposure for puncture and tract formation.



In another study, Basiri *et al.* [21] compared US-guided access for PCNL with conventional fluoroscopy-guided access in a clinical trial of 100 patients with no abnormalities of the upper urinary tract. The duration of access and radiation exposure was significantly less in the group of patients who underwent US-guided puncture.

Karami *et al.* [22] evaluated the safety and efficacy of PCNL with US-guided renal access in the lateral decubitus flank position in a prospective randomized trial of 40 patients. In that study successful access was achieved in all patients. The complete stone clearance rate was 85%. They concluded PCNL with US-guided renal access in the lateral decubitus flank position is safe and convenient, and prevents harmful effects of radiation for the surgeon, surgical team, and patient.

In the present study, complete stone clearance was achieved in all cases with no significant morbidity. The mean time to successful puncture and mean duration of radiation exposure was significantly lower in the group which underwent US-guided puncture. Similarly the time taken and radiation exposure in tract formation was also shorter with US-guided puncture. The mean number of trials required for successful puncture in the desired calyx was also significantly lower with US-guided puncture, attesting to improved accuracy of puncture under US-guidance.

We found that US with a needle-guide helps in assessing the accurate depth and plane of the puncture. Real-time US shows 3D anatomy as well as the relationship of the kidney to intervening structures and surrounding viscera. In addition, US-guidance allowed a more direct and precise trajectory to be chosen, resulting in greater ease of dilatation. There were also fewer instances of dilator slippage and guidewire kinking during serial dilatation, resulting in a saving of time as well as radiation exposure. If multiple tracts are likely to be required for stone clearance, US helps in placing multiple guidewires in desired calyces at the outset of the procedure.

Another technique that we have learnt is that the desired posterior calyceal puncture can be facilitated by opacification with a small amount of air during US-guided puncture as well. We inject 2–3 mL air from the ureteric catheter and, being lighter, air collects in the non-dependent posterior calyx in the prone position. On US air can be seen as echogenic shadow in posterior calyx, which can then be targeted for puncture.

In conclusion, addition of US-guided puncture in PCNL helps in increasing accuracy of puncture and decreasing radiation hazards for the surgeon, surgical team and patient.

CONFLICT OF INTEREST

None declared.

REFERENCES

1 **Goodwin WE, Casey WC, Woolf W.** Percutaneous trocar (needle) nephrostomy in hydronephrosis. *J Am Med Assoc* 1955; **157**: 891–4
2 **Fernstrom I, Johansson B.** Percutaneous pyelolithotomy. A new extraction technique. *Scand J Urol Nephrol* 1976; **10**: 257–9
3 **Wickham JE, Kellett MJ.** Percutaneous nephrolithotomy. *Br J Urol* 1981; **53**: 297–9
4 **Wickham JE, Kellet MJ.** Percutaneous nephrolithotomy. *Br Med J (Clin Res Ed)* 1981; **283**: 1571–2
5 **Alken P, Hutschenreiter G, Günther R, Marberger M.** Percutaneous stone manipulation. *J Urol* 1981; **125**: 463–6
6 **Segura JW, Patterson DE, LeRoy AJ, McGough PF, Barrett DM.** Percutaneous removal of kidney stones. Preliminary report. *Mayo Clin Proc* 1982; **57**: 615–9
7 **Clayman RV, Surya V, Miller RP *et al.*** Percutaneous nephrolithotomy: extraction of renal and ureteral calculi from 100 patients. *J Urol* 1984; **131**: 868–71
8 **Seibert JA.** Tradeoffs between image quality and dose. *Pediatr Radiol* 2004; **34** (Suppl. 3): S183–95
9 **Kumari-Subaiya S, Phillips G.** Ultrasound-guided access to the kidney. In Smith AD ed., *Controversies in Endourology*, Chapter 1. Philadelphia: WB Saunders, 1995: 1–9
10 **Gupta S, Gulati M, Suri S.** Ultrasound-guided percutaneous nephrostomy in non-dilated pelvicaliceal system. *J Clin Ultrasound* 1998; **26**: 177–9
11 **von der Recke P, Nielsen MB, Pedersen JF.** Complications of ultrasound-guided nephrostomy: a 5-year experience. *Acta Radiol* 1994; **35**: 452–4
12 **Gupta S, Gulati M, Uday Shankar K, Rungta U, Suri S.** Percutaneous nephrostomy with real-time sonographicguidance. *Acta Radiol* 1997; **38**: 454–7
13 **Khoo L, Anson K, Patel U.** Success and short-term complication rates of percutaneous nephrostomy during pregnancy. *J Vasc Interv Radiol* 2004; **15**: 1469–73
14 **Brateman L.** Radiation safety considerations for diagnostic radiology personnel. *Radiographics* 1999; **19**: 1037–55
15 **Castaneda WR, Espenan GD.** How to protect yourself and others from radiation. In Smith AD, Badlani G, Bagley D eds. *Smith's Textbook of Endourology*, 1st edn. Section 1, Chapter 3. St Louis: Quality Medical, 1996: 21–8
16 **Hall EJ, Giaccia AJ.** Hereditary effects of radiation. In McAllister L, Bierig L, Barrett K eds. *Radiobiology for the Radiologist*, 6th edn. Section 1, Chapter 11. Philadelphia: Lippincott Williams & Wilkins, 2006: 1156–7
17 **Giblin JG, Rubenstein J, Taylor A, Pahira J.** Radiation risk to the urologist during endourologic procedures, and a new shield that reduces exposure. *Urology* 1996; **48**: 624–7
18 **Desai M.** Ultrasonography-guided punctures – with and without puncture guide. *J Endourol* 2009; **23**: 1641–3
19 **Hosseini MM, Hassanpour A, Farzan R, Yousefi A, Afrasiabi MA.** Ultrasonography-guided percutaneous nephrolithotomy. *J Endourol* 2009; **23**: 603–7
20 **Basiri A, Ziaee SA, Nasseh H *et al.*** Totally Ultrasonography-guided percutaneous nephrolithotomy in the flank position. *J Endourol* 2008; **22**: 1453–7
21 **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
22 **Karami H, Arbab AH, Rezaei A, Mohammadhoseini M, Rezaei I.** Percutaneous nephrolithotomy with ultrasonography-guided renal access in the lateral decubitus flank position. *J Endourol* 2009; **23**: 33–5

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Abbreviations: **ASA**, American Society of Anesthesiology; **PCNL**, percutaneous nephrolithotomy; **US**, ultrasonography; **3D**, three-dimensional.