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Complications and surgical results of stone-directed antegrade pyelography compared to the retrograde pyelographic access method in percutaneous nephrolithotomy using 'bull's eye' technique: A randomized clinical trial

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Abstract

Objectives: This study aimed to evaluate the differences in outcomes and complications in stone-directed antegrade pyelography using the 'bull's eye' technique in patients with renal stones versus the conventional method of percutaneous nephrolithotomy (PCNL). Although conventional PCNL access using retrograde pyelography is useful, it is time-consuming and may cause postoperative discomfort. Herein, we report our experience in the application of this new technique.

Methods: Between January 2017 and June 2018, 100 patients participated in this randomized clinical trial. Stone-directed antegrade pyelography using the 'bull's eye' technique under fluoroscopic guidance was used for percutaneous access in the intervention group. The second group, consisting of those who had undergone conventional PCNL using retrograde pyelography and 'bull's eye' technique in the same period, were considered as the controls. Pre- and postoperative laboratory examinations, surgical results and complications were recorded and compared between the two groups.

Results: A single calyceal puncture in partial staghorn and staghorn stone patients was sufficient in 72.2% of the antegrade group and in 78.9% of the retrograde group (p=0.69). The double-puncture technique was necessary for 71.9% of renal pelvis stones in the antegrade group and for 9.4% in the retrograde group ($p<0.001$). The antegrade approach reduced the mean operative time and analgesic requirement significantly ($p<0.001$). No statistically significant difference, however, was found between the two groups regarding stone migration to the ureter, radiation time and postoperative complications.

Conclusions: The stone-directed antegrade approach using the 'bull's eye' technique is a safe and accurate method in PCNL access in patients with radiopaque and semi-opaque renal stones.

Keywords

Stone-directed, antegrade access, PCNL

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Introduction

Percutaneous nephrolithotomy (PCNL) is the gold-standard procedure for the extraction of large renal stones, as it is associated with low morbidity and acceptable stone clearance. A ureteric catheter is inserted retrogradely using the conventional method to infuse the contrast media needed for the visualization of the renal collecting system under fluoroscopic guidance.[1] Although the insertion of a ureteral catheter is recommended in many studies, others have suggested that using a ureteric catheter is not always necessary, mainly in uncomplicated cases, as its use may cause catheter-related complications and can have adverse effects on quality of life.[2]

An antegrade percutaneous approach without retrograde catheter insertion for the treatment of upper urinary tract stones has been reported for many years. In 1978, Arthur Smith described the first antegrade stent placement when he introduced a Gibbons stent through a percutaneous nephrostomy.[3] To date, various antegrade techniques for the removal of renal stones and retrieval of ureteral stents using ultrasound (B-mode, Doppler) or C-armed fluoroscopy without retrograde pyelography have been reported.[4–8] Armas-Phan et al. reported a successful PCNL with an antegrade approach to the renal collecting system under ultrasound guidance in their patients.[9] It has also been shown that surgical outcomes, postoperative complications and radiation exposure are comparable between catheterized and non-catheterized patients who have undergone PCNL.[10]

This study was conducted to evaluate the efficacy of a novel percutaneous access method using stone-directed antegrade pyelography with the 'bull's eye' technique in removing stones occupying the renal collecting system without the need to insert a ureteral catheter.

Methods

This clinical trial was carried out from January 2017 to June 2018, and 100 adult patients (57 men, 43 women) who were referred to the stone clinic of Shahid Faghihi Hospital of Shiraz University of Medical Sciences were enrolled (Figure 1). To determine the minimum required sample size, based on the study of Somani et al.,[11] we estimated a total required sample size of 80 (40 in each group). Given a 25% attrition rate, the final sample size was determined as 100 (50 in each group). Patients with a lower-pole renal stone >15 mm, non-lower-pole renal stone >20 mm, calyceal diverticular stone, staghorn or partial staghorn stone and those who failed to respond to shock-wave lithotripsy (SWL) who had radiopaque or semi-opaque renal stones on plain abdominal radiography were included in the study. Those with a solitary kidney or abnormal renal function were excluded. The protocol was in accordance with the Declaration of Helsinki and the local committee (ethical code: IR.SUMS.REC.1396.167). The study was conducted after obtaining Institutional Review Board approval and was registered at the clinical trial registration centre (registration code: IRCT20171126037628N2). After providing the patients with adequate information, they were all asked to sign an informed written consent. In order to allocation the patients randomly into either the retrograde ureteral catheter or the stone-directed group, we implemented block randomization using 25 blocks (with a size of four) with random allocation software.

All procedures were performed by a single surgeon (D.I.) who had equal experience in both techniques. Preoperative laboratory tests, including urine analysis, urine culture, complete blood count, coagulation profiles and renal function tests, were recorded. Patients with a urinary tract infection (UTI) were treated with appropriate antibiotics preoperatively.

All patients underwent an intravenous pyelogram or a spiral computed tomography scan of the abdomen before the operation. All procedures were performed in the prone position after appropriate padding.

The stone size was considered as the sum of the longest axis of the stone if patients had multiple calculi. The patients were given 1 g ceftriaxone (Ceftrax®; Jaber Ebne Hayyan, Tehran, Iran) preoperatively.

Surgical procedure

C-arm fluoroscopy was used to detect the location of the target stone. A 17 cm 18-gauge Chiba needle using the 'bull's eye' technique under fluoroscopic guidance was used to reach the targeted stone or a branch of the stone (in staghorn or partial staghorn stones). The C-arm was rotated 30° toward the surgeon and 30° caudally to help the needle advance appropriately towards the targeted stone or a branch of the stone after creating a 'bull's eye' sign on the fluoroscopy screen (Figure 2). The C-arm has then rotated back to 30° away from the surgeon and 30° cranially to monitor the depth of the puncture. With this approach, the needle tip was moved forward until the stone was reached. After that, the internal obturator of the needle was removed, and antegrade injection of the diluted iodinated contrast media was performed to enhance the renal collecting system (Figure 3). In cases where the needle was inserted through the appropriate calyx in the very first puncture, the procedure was continued as described in the next section. Otherwise, a second puncture was performed under fluoroscopic guidance to insert the needle into the desired calyx. For patients with a renal pelvis stone, first we approached the stone using a 23-gauge Chiba needle, and after that, a 18-gauge Chiba needle was used for the second puncture.

In the retrograde pyelography access group, after performing cystoscopy and insertion of a ureteral catheter (5 or 6 Fr), retrograde pyelography was done. Access to the desired calyx was achieved using the 'bull's eye'

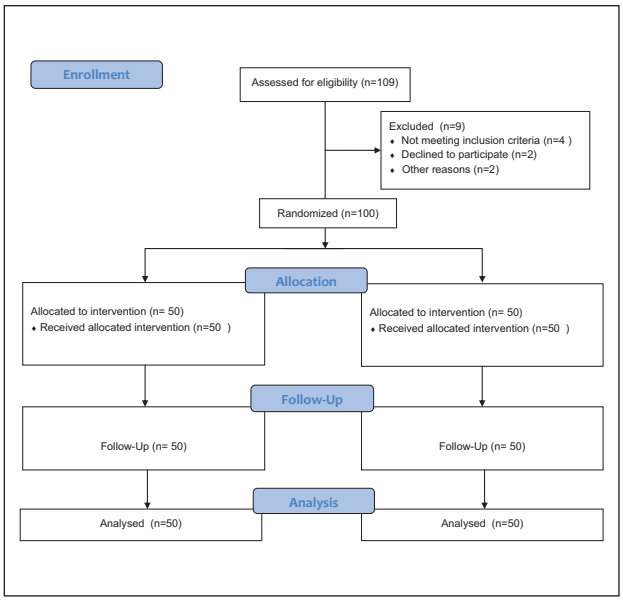

Figure 1. Consort diagram for our study.

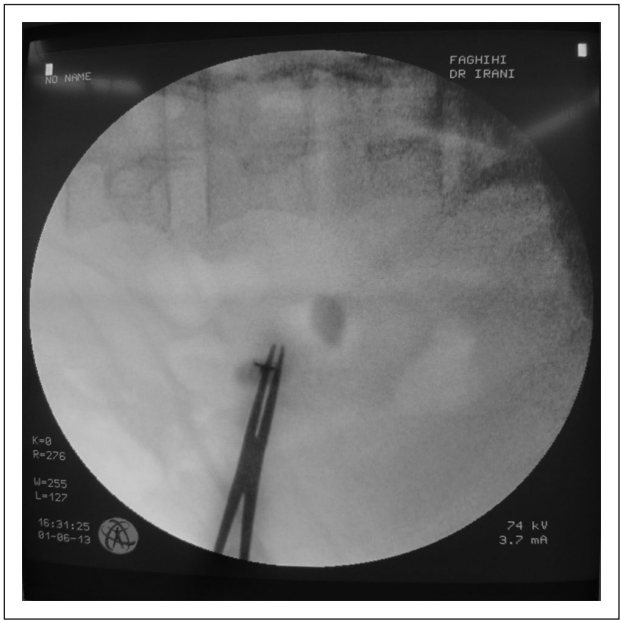

Figure 2. Creation of 'bull's eye' sign for appropriate needle advancement.

technique. Once the appropriate calyx was accessed, a 0.035-inch J-tip guide wire was passed through the ureter. If unsuccessful, it was allowed to be coiled in the opposite calyx or renal pelvis. A second (working) wire was also placed alongside the wire.

Afterward, a metallic cone-tip 26 Fr dilator designed by the author, as a one-shot dilator was used to dilate the tract under fluoroscopic guidance. A 24 Fr rigid nephroscope (Richard Wolf, Knittlingen, Germany) through a 28 Fr

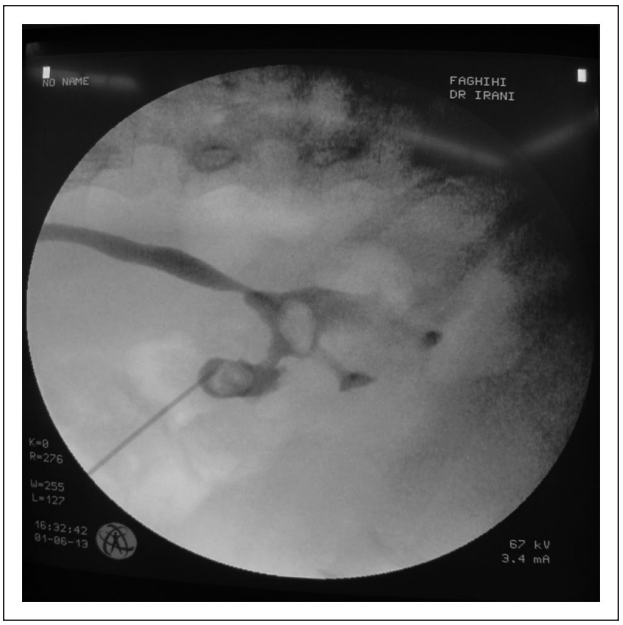

Figure 3. Antegrade injection of the contrast media.

Amplatz sheath (Cook Urological, Spencer, IN) was used for this procedure. Stones were fragmented using a ballistic lithotripter (Swiss Lithoclast, EMS Corp., Dallas, TX), and the particles were removed using a stone grasper. The removal of all the stones and particles was confirmed both endoscopically and fluoroscopically upon the completion of the procedure. Finally, an 18 Fr Foley catheter was placed as a nephrostomy tube.

In patients with impacted ureteropelvic junction stone and those with postoperative small scattered stone particles, a 4.8 Fr JJ stent was inserted antegradely under fluoroscopic guidance. For uncomplicated patients who had a single stone or lower stone burden preoperatively or those with complete stone clearance and minimal bleeding, however, no nephrostomy tube was inserted (totally tubeless procedure). As an alternative, in patients with failed antegrade access, the use of a fluoroscopically antegrade approach by an interventional radiologist under ultrasound scan or switching to the conventional retrograde method was considered.

Parenteral antibiotic (ceftriaxone 1 g b.i.d.) was used for 48 hours postoperatively. Pain relief was achieved through the administration of pethidine hydrochloride (50 mg/mL), 0.5–2 mg/kg body weight intramuscularly every three to four hours.

Statistical analysis

Data analysis was performed using SPSS v17 (SPSS, Inc., Chicago, IL). The comparison between quantitative variables was performed using an independent *t*-test. The chi-square test was used to compare qualitative variables between the two groups. *p*-Values of <0.05 were considered statistically significant.

Table 1. Stone characteristics and recurrence rate between the antegrade and retrograde groups.

Variables	Groups		*p*-Value
	Antegrade *N*=50	Retrograde *N*=50	
Operation side, left/right	24/26	22/28	0.69
History of previous ipsilateral renal surgery, positive/negative	5/45	4/46	0.99
Stone size, *M*±*SD*	26.3±8.2	26.7±8.2	0.82
Renal pelvis stones, *n* (%)	14 (28.0%)	15 (30.0%)	0.72
Lower calyseal stones,[a] *n* (%)	18 (36.0%)	19 (38.0%)	0.91
Others,[a] *n* (%)	18 (36.0%)	16 (32.0%)	0.65

[a]Diverticular stones are categorized in the calyceal stone category.
SD: standard deviation.

Table 2. Surgical outcome in the antegrade and retrograde groups.

Variables	Groups		*p*-Value
	Antegrade *N*=50	Retrograde *N*=50	
Operation time (minutes), *M*±*SD*	49.8±10.4	63±12.2	<0.001
Radiation time (seconds), *M*±*SD*	104.4±42.6	101.5±41.5	0.73
Single session stone, free rate, *n* (%)	48 (96.0)	46 (92.0)	0. 68
Stone migration, to ureter, *n* (%)	3 (6.0)	2 (4.0)	0.99
Ancillary procedures, *n* (%)	5 (10.0)	4 (8.0)	0.99
Need for blood transfusion, *n* (%)	2 (4.0)	3 (6.0)	0.99
Postoperative haemoglobin drop (g/dL), *M*±*SD*	0.9±0.5	1.0±0.6	0.71
Postoperative creatinine change (mg/dL), *M*±*SD*	0.3±0.2	0.3±0.2	0.57

Results

The two groups were similar regarding sex (p=0.84) and age (p=0.65). The mean age of the patients recruited in the study was 42.9±13.5 years in the stone-directed group and 44.1±13.3 years in the retrograde group (p=0.65). The mean stone size was 26.3±8.2 mm in the antegrade group versus 26.7±8.2 mm in the retrograde group (p=0.82), and the two groups were the same in terms of stone location (p=0.91). Patient information and the characteristics of their stones are outlined in Table 1.

Table 2 shows a summary of the surgical outcome and the complications reported in each group. There was no statistically significant difference between the two groups (stone-directed vs. retrograde) concerning postoperative haemoglobin drop (0.9±0.5 g/dL vs. 1.0±0.6 g/dL; p=0.71), creatinine levels (0.3±0.2 mg/dL vs. 0.3±0.2 mg/dL; p=0.57), the need for blood transfusion (2 vs. 3 cases; p=0.99) and pyelonephritis (1 vs. 2 cases; p=0.99). Moreover, radiation time during access (104.4±42.6 seconds vs. 101.5±41.5 seconds; p=0.73), stone-free rate and stone migration to the ureter (3 versus 2 cases; p=0.99) were not statistically different between the two groups.

Ancillary procedures included three ureteroscopy (URS), two SWL in the antegrade group and two URS and two SWL in the retrograde group without a statistically significant difference between the two groups (p=0.99). A single puncture was achieved to remove the calyceal, diverticular, partial staghorn and staghorn stones in 72.2% of the antegrade and 78.9% of the retrograde group. The difference was not statistically significant (p=0.69). A double puncture was required in 71.9% of the antegrade and 9.4% of the retrograde group to remove the renal pelvis stones (p<0.001).

A JJ stent was inserted in13 (26.0%) patients in the antegrade group and in 10 (20%) patients in the retrograde group (p=0.634). Totally tubeless PCNL was seen in 14 (28.0%) patients in the antegrade group and in one (2.0%) patient in the retrograde one (p=0.0008).

Mean operation time was significantly shorter in the antegrade group (49.8±10.4 minutes vs. 63.0±12.2 minutes; $p<0.001$). There was also a considerable difference in the analgesic requirement (pethidine hydrochloride 0.6±.02 mg/kg in antegrade vs. 1.2±.04 mg/kg in retrograde; $p<0.001$), but there were no differences between the two groups with regard to length of hospital stay (2.6 days vs. 2.6 days; $p=0.91$).

Discussion

One of the most critical parts of PCNL is access to the collecting system. However, in recent studies, Kallidonis et al. concluded that infundibular (non-papillary) puncture was as safe as papillary puncture in PCNL.[12,13] The antegrade approach under fluoroscopic or ultrasonic guide for the management of renal stones and retrieval of ureteral stents has been reported in many studies. Tzeng et al.[7] introduced Doppler ultrasound-guided PCNL as a safe and effective technique with minimal blood loss, especially for patients at higher risk of bleeding and associated complications.

Aravantinos et al.[14] reported their experience in antegrade retrieval of renal pelvis stones >2 cm under assisted local anaesthesia using a 24 Fr rigid nephroscope and a ballistic lithotripter without retrograde pyelography. Moreover, Fernandez et al.[15] performed antegrade PCNL in patients with urinary diversions and showed that intraoperative percutaneous renal access was facilitated by retrograde pyelography in only 12.1% of patients.

Along with these studies, our stone-directed antegrade technique showed several advantages over the conventional retrograde pyelography method in PCNL access. The operation time reduced considerably using this surgical approach, and there was no need to use a ureteral catheter. This result comes while many studies have linked longer operative time with a higher rate of postoperative complications.[16–19] In their study, Reich et al.[20] also found that a longer operative time was associated with a negative surgical outcome in major non-cardiac surgery. We did not find these complications in our study. Shortening the operative time in our study explains this.

Tubeless PCNL has been the subject of some studies. In tubeless PCNL, a nephrostomy tube is not inserted, but in the totally tubeless procedure, neither a nephrostomy tube nor a ureteral stent is used.[21] Zhong et al.[2] performed a meta-analysis to evaluate the efficacy and safety of totally tubeless PCNL. They found a significantly reduced hospital stay and analgesic requirement as well as absence of complications in this group. Aghamir et al.[22] and Chien-Hsing Chang et al.[23] found the same result when performed studies on totally tubeless PCNL. Similar to these results, as the totally tubeless procedure was done significantly more in the antegrade group, it may explain a statistically significant difference in analgesic requirement between the two groups.

On the other hand, Minamia et al.[24] compared tubeless and totally tubeless PCNL with conventional PCNL in terms of postoperative hospital stay, duration of analgesic use, UTI and blood transfusion. They concluded that tubeless PCNL was superior only in terms of length of hospital stay.

Single puncture adequacy was comparable in both groups in calyceal, diverticular and staghorn stones. This can be explained by the use of the 'bull'seye' technique in the antegrade group, which allowed us to reach the stone in the appropriate calyx in just one puncture. In the antegrade group, the rate of double puncture was significantly higher compared to the retrograde group. This was because in the antegrade technique, we approached the renal pelvis stones in the first puncture, and after performing antegrade pyelography, we entered the desired calyx in the second puncture. Opacification of the pyelocalyceal system due to retrograde injection of contrast media to improve the targeting of the appropriate calyx before needle insertion can explain the difference.

Furthermore, in order to minimize the risk of vascular injury in cases of renal pelvis stone, we used a 23-gauge Chiba needle instead of 18-gauge needle for the first puncture. It is well known that certain complications of PCNL, such as intrarenal vascular injuries and arteriovenous fistula formation, which may cause severe bleeding, are associated with more needle punctures.[25,26] However, we did not find any statistically significant difference in the risk of haemoglobin drop and need for blood transfusion between the two groups.

While a large number of stones were expected to migrate to the ureter after the application of the antegrade technique, no significant difference was noted between the two groups in this regard. We also expected to find a significantly increased radiation time during access in the antegrade group using the same technique (the 'bull's eye' technique) during access in both groups, which guaranteed the entrance to the collecting system in the very first needle insertion, and which can explain this insignificant difference. A statistically insignificant risk of postoperative pyelonephritis was reported in the retrograde group. This could be due to the introduction of bacteria from the lower urinary tract into the upper tract during ureteral catheter insertion.

The present study has some limitations. The stone-directed antegrade technique is not suitable for all patients, particularly those with complete radiolucent renal stones. Also, in patients with renal pelvis stones, at least two punctures are needed to enter the desired calyx using the stone-directed method. This act may increase the risk of intrarenal vascular injury and postoperative bleeding. While we did not find these complications in our study, renal access with retrograde pyelography is more advisable in these patients. Alternatively, access under ultrasonographic guidance or intraoperative intravenous pyelography under fluoroscopic guidance can be used to perform the antegrade method in these cases.

Finally, although it is well advised that performing PCNL with retrograde ureteral catheter insertion and

pyelography[27,28] is safe and successful in PCNL, in particular situations in which ureteral catheter insertion is difficult or impossible, such as patients with urinary diversion, ureteral reimplantation, angulated ureter and bladder neck elevation,[29–31] the stone-directed antegrade method of access can help in performing PCNL as a problem-solving and effective procedure in these patients.

In addition, in selected patients with a small stone burden, no residual stone and minimal bleeding, this procedure can be done without nephrostomy tube insertion (totally tubeless PCNL), which significantly reduces the length of hospital stay and analgesic requirements without increasing the complications.[32]

Conclusion

The stone-directed antegrade approach using the 'bull's eye' technique is a safe and accurate method of access in PCNL, particularly in special situations such as patients with urinary diversion and ureteral obstruction and in those who have opaque or semi-opaque stones. The technique not only obviates the need for retrograde catheter insertion, but also reduces the operative time and is more convenient form the patients' point of view. Multi-centre studies on a larger group of patients are needed to support the results of this study.

Conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Ethical approval

The protocol was in accordance with the Declaration of Helsinki and the local committee (ethical code: IR.SUMS.REC.1396.167).

Informed consent

Written informed consent was obtained from all subjects before the study.

Guarantor

A.H.

Contributorship

D.I. contributed to the design and did the surgery, drafted the manuscript, obtained the final approval and accepts accountability for the overall work. M.M.H. and A.H. contributed to the design, did the surgery, revised the manuscript, obtained the final approval and accept accountability for the overall work. L.M. and M.A.A. contributed to data collection and data analysis, revised the manuscript, obtained the final approval and accept accountability for the overall work. H.R.S. contributed to data collection, revised the manuscript, obtained the final approval and accepts accountability for the overall work.

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Supplemental material

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