Predictors of success and complications of monoplanar renal access for conventional prone percutaneous nephrolithotomy

Analysis of 662 cases

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ABSTRACT

INTRODUCTION: Our aim was to assess how monoplanar fluoroscopy-guided access affects the outcomes of percutaneous nephrolithotomy (PCNL).

METHODS: This retrospective study included all patients who had renal stones and underwent prone PCNL using monoplanar fluoroscopy-guided access in a single tertiary care center between January 2015 and January 2024. Preoperative and postoperative patient- and procedure-related variables, such as operative time, intraoperative blood loss, number of tracts, complications, stone-free rate (SFR), and hospital stay, were assessed. Multivariable analysis was performed to detect predictors of residual stones and complications.

RESULTS: A total of 662 patients with an average age of 47±12 years were included. Comorbidities were reported in 26.1%. American Society of Anesthesiologists (ASA) score was I in 64.8%. The mean stone diameter was 2.8±0.9 cm. Only 6% had positive preoperative urine culture. The mean stone Hounsfield unit (HU) was 1054±304 with a mean operative time of 94±31 minutes. Most cases (74.9%) required only one tract. Postoperative fever was reported in 22.4%. The median estimated blood loss (EBL) was 160 mL. The complications included urine leak (4.1%), blood transfusion (1.5%), sepsis (1.5%), renal pelvic perforation (0.8%), superselective angio-embolization (0.6%), pleural injury (0.6%), and colonic injury (0.2%). The median hospital stay was three days. Approximately 73% were stone-free. The only predictor of residual stone was higher stone diameter (odds ratio [OR] 1.536, p=0.001). Predictors of complications were three tracts (OR 4.501, p=0.033) and higher EBL (OR 1.003, p<0.001).

CONCLUSIONS: The monoplanar fluoroscopy-guided approach has demonstrated a noteworthy success rate, rendering it a safe modality for prone conventional PCNL.

INTRODUCTION

The American and Canadian guidelines recommended percutaneous nephrolithotomy (PCNL) as the first-line therapy option for kidney stones with a diameter >2 cm and resistance to extracorporeal shockwave lithotripsy (ESWL) due to its higher stone-free rate (SFR) and minimally invasive nature compared to open, laparoscopic, or robotic approaches. Additionally, it is considered a viable alternative for calyceal diverticular stones.[1,2]

The most crucial stage in PCNL is creating percutaneous renal access. The sufficiency of the access directly affects the success and complication rates of this procedure.[3] Fluoroscopy, computed tomography (CT), and ultrasonography (US) have all been used to guide entry into the collection system; however, fluoroscopy is the most frequently employed method.[4]

A fluoroscopic machine offers good-quality images, and urologists are familiar with it from the various diagnostic and therapeutic endourologic procedures for which it is used; thus, it is preferred for percutaneous renal access, especially in the operating room. Fluoroscopic monitoring is crucial for the entire operation, including renal access, guidewire manipulation, tract dilatation, residual stone evaluation, and post-procedural nephrostogram.[5]

Few studies evaluated the effectiveness and safety of monoplanar fluoroscopy-guided renal access for

KEY MESSAGES

- The monoplanar fluoroscopy-guided approach for obtaining percutaneous access during PCNL provided high success rates while maintaining safety and facilitating the puncture process.
- Higher stone diameter is a predictor of residual stones during monoplannar fluoroscopy-guided conventional prone PCNL.
- Higher intraoperative blood loss and creation of three tracts were predictors of complications during monoplanar fluoroscopy-guided conventional prone PCNL.

conventional prone PCNL.[6-8] Therefore, this study assessed how the monoplanar fluoroscopic-guided access affected PCNL outcomes and assessed the predictors of residual stones and complications.

METHODS

This retrospective study on prospectively collected data was performed on patients with renal stones who underwent PCNL in a single tertiary care stone center from January 2015 to January 2024, after obtaining local ethics approval (#RC-13-2-2023). A total of four surgeons with PCNL experience of >100 cases performed these surgeries; however, most of the cases were assisted by our trainees, as we are a tertiary care center and we have a residency training program recruiting two residents each year. Factors related to the patients and procedures were observed, in addition to pre- and postoperative variables, such as operative time, intraoperative blood loss, number of tracts, complications, SFR, and duration of hospitalization.

Bilateral renal stones and renal abnormalities were exclusion criteria. All patients underwent preoperative complete blood counts (CBC), serum creatinine, coagulation profile, and urine cultures. Radiographic studies included pelvi-abdominal US and either intravenous urography (IVU) or CT scan. Cases with postoperative clinically insignificant residual fragments <4 mm were considered stone-free. The modified Clavien grading system, described by Tefekli et al,[9] was employed to categorize complications.

PCNL technique

All patients received an intravenous infusion of 1 g of ceftriaxone as a preoperative preventive antibiotic regimen. All procedures were conducted under general anesthesia. The patients were tilted to a prone posture following ureteral catheter insertion in the lithotomy position. Under fluoroscopic guidance at 0 degrees (vertical plane) (Figure 1A), the site of the stone(s) was marked with needle mark (s) (needle tip of 3 mL syringe) (Figure 1B) before the retrograde urography being done. These needle marks help select the most appropriate calyx to gain access to extract the targeted stone, which is established by orientation of the puncture needle outside the body on the skin surface towards the target calyx.

The skin was punctured at the posterior axillary line at a 30-degree angle from the coronal plane of the patient by an 18-gauge Chiba puncture needle, which was advanced toward the chosen calyx. Two good signs for proper puncture are the following: 1) medial movement of the kidney while approaching the curved renal appearance (shadow of the kidney under fluoroscopy) during entry of the puncture needle in the renal capsule; and 2) a slight jiggle of the needle is performed during the trajectory of the puncture needle towards the center of target calyx (fornix) that causes what appears as a "fovea sign" when the tip of the needle indent and penetrate the cup of the target calyx.

Figure 1A. Fluoroscopy set up for the standard monoplanar prone percutaneous nephrolithotomy.

Correct needle placement within the calyx was confirmed by observing a free fluid flow or by aspirating urine. In case of unsuccessful puncture, the tip of the needle was not completely withdrawn from the skin but retracted approximately 1–2 cm from the calyx intracorporeally to be outside the kidney curvature line (renal shadow) to avoid parenchymal injuries, then the entry angle was adjusted more superficial or deeper on the same vertical plane and reinserted. Successful puncture was followed by introduction of a curved guidewire (0.038 inches) into the collecting system toward the renal pelvis, upper calyx, upper ureter, or sometimes in the targeted calyx only to act as a guide over which the tract was dilated (Figures 1C–F).

The guidewire was left in place after the needle was carefully removed, a 1 cm skin incision was made, and the lumbodorsal fascia was opened using a straight artery forceps. Then, a safety guidewire was introduced using the 8/10 F Teflon dilators. Dilation was done using renal Amplatz dilators up to 30 F, and a 30 F Amplatz sheath was inserted over under fluoroscopic guidance to enable the insertion of a 26 F nephroscope.

All stones were disintegrated using pneumatic lithotripsy into small fragments to be extracted by the forceps. Fluoroscopic screening, endoscopic imaging, and antegrade nephrography were used intraoperatively to confirm the absence of stones and the proper integrity of the collecting system. A 24 F nephrostomy tube was inserted into the renal pelvis at the end of the procedure. A silk suture was used to fix the nephrostomy at the skin surface, and the incision was then cleansed, sutured, and bandaged.

Patients with confirmed intraoperative stone-free status and without intraoperative complications were eligible for a tubeless procedure, depending on the surgeon's preference. On the day of surgery, the nephrostomy tube was clamped to provide tamponade and was later unclamped 4–6 hours from the procedure. The ureteral catheter was routinely maintained in place following PCNL or replaced by a JJ stent according to the situation of every case.

On the first postoperative day, X-ray of the bladder, ureter, and kidney (KUB) was done for radiopaque stones and a renal US for radiolucent stones. On the second postoperative day, stone-free patients and those with clinically negligible residual pieces had their ureteric catheters removed and nephrostomy tubes clamped for two hours and then removed if there was no development of fever or significant urinary leakage. JJ stents were removed after two weeks in stone-free patients; however, the patients were scheduled for auxiliary treatment in case of residual stones.

Statistical analysis

Data management and statistical analysis were performed using SPSS version 28 (IBM, Armonk, NY, U.S.). Quantitative data were checked for normality using the direct data visualization methods and the Kolmogorov-Smirnov test. Numerical data were summarized using medians and ranges or means and standard deviations following normality tests.

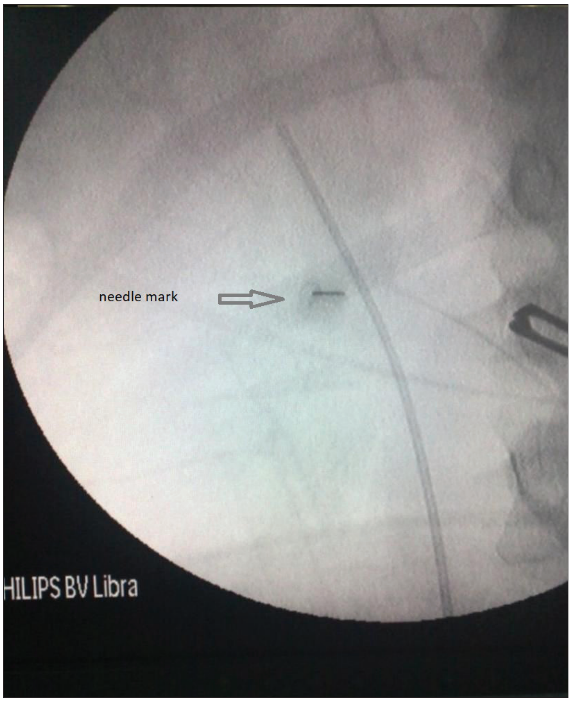

Figure 1B. Needle mark over the skin under fluoroscopic guidance.

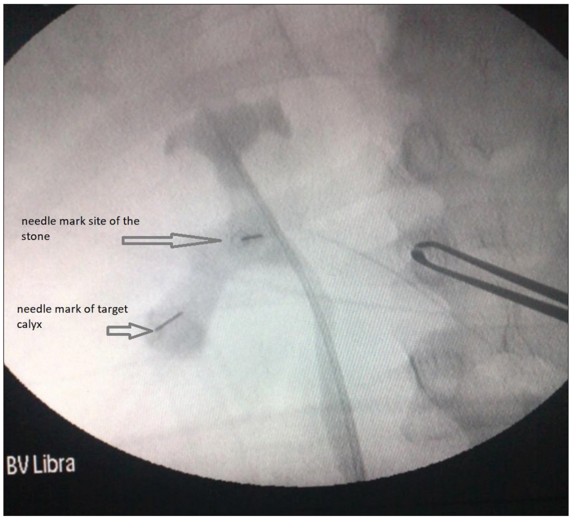

Figure 1C. Retrograde urography with selection of the proper access and proper calyx.

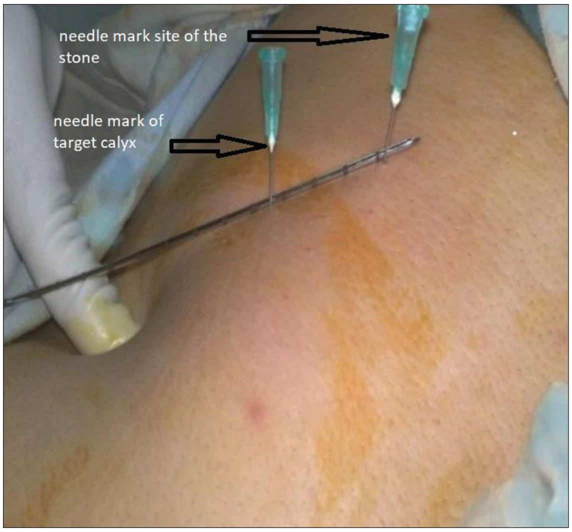

Figure 1D. Choosing the direction of the puncture needle using the marking needles over the skin under fluoroscopic guidance.

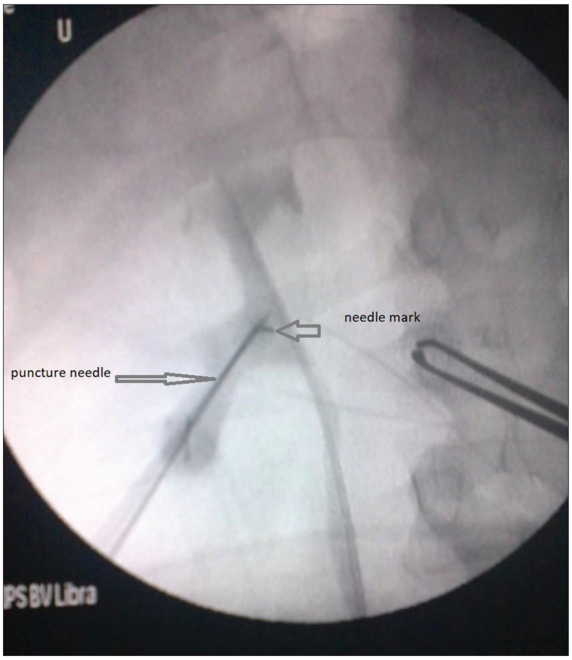

Figure 1E. The puncture needle into the correct direction and the desired calyx under fluoroscopic guidance.

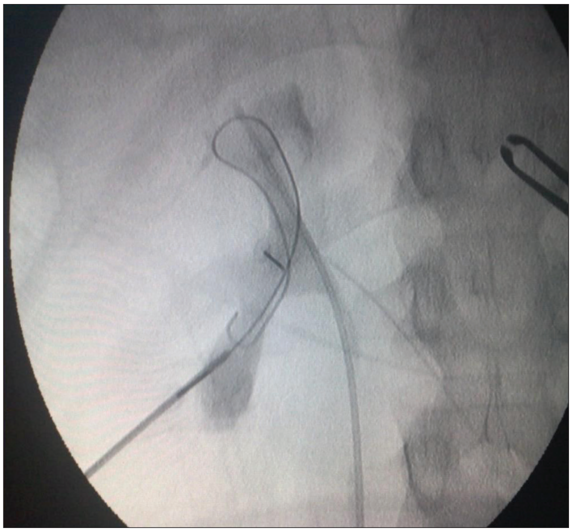

Figure 1F. Introduction of the curved tip 0.038 guidewire into the kidney through the trocar of the puncture needle under fluoroscopic guidance following successful puncture.

Numbers and percentages served as a summary of categorical data. Using independent t-tests or Mann-Whitney U tests for quantitative variables with normal and non-normal distributions, respectively, quantitative data were compared according to the presence or absence of stones. The Chi-squared test was used to compare categorical data.

The occurrence of complications and residual stones was predicted using multivariate logistic regression analyses. The odds ratios (OR) were calculated along with 95% confidence intervals (CI). There were two sides to each statistical test. Significant p-values were considered at <0.05.

The sample size was calculated using Epi-info software version 7.2.5.0 based on a previous study, which reported a stone-free rate of the monoplanar access technique for PCNL of 80%.[6] The minimum sample size calculated was 470 patients. Confidence level and margin of error were adjusted at 97% and 4%, respectively.

RESULTS

General characteristics

A total of 662 patients were included. As shown in Table 1, the mean age of the studied patients was 47±12 years. There was a male predominance (66.9%). The mean body mass index (BMI) was 34.8±6.6. About one-third had recurrent stones (29.6%). One-quarter had previous renal surgery (25.1%). Comorbidities were reported in 26.1%. The most frequent American Society of Anesthesiologists (ASA) score was I (64.8%). The mean stone diameter was 2.8±0.9 cm. Only 6% had a positive preoperative urine culture and received the appropriate antibiotic before surgery. Most patients (86.3%) showed calyceal involvement. The mean stone Hounsfield unit (HU) was 1054±304. Only 14.8% demonstrated perirenal stranding.

Operative and postoperative findings

The mean operative time was 94±31 minutes. The most frequent number of tracts was one (74.9%). The

Table 1. General characteristics, operative and postoperative criteria of patients

Variable (662 patients)		
Age (years)		47±12
Female gender		219 (33.1)
BMI		34.8±6.6
Recurrent stone		196 (29.6)
Previous renal surgery (same kidney)		166 (25.1)
Comorbidities		173 (26.1)
ASA score	ASA I	429 (64.8)
	ASA II	156 (23.6)
	ASA III	77 (11.6)
Stone diameter (cm)		2.8 ±0.9
Calyx involvement		571 (86.3)
Stone HU		1054±304
Perirenal stranding		98 (14.8)
Positive preoperative urine culture		40 (6.0)
Operative time (minutes)		94±31
Number of tracts	One	496 (74.9)
	Two	134 (20.2)
	Three	32 (4.8)
Intraoperative blood loss (mL)		220 (40–1500)
Postoperative fever		148 (22.4)
Positive postoperative urine culture		162 (24.5)
Exit strategy	Nephrostomy tube	149 (22.5)
	Nephrostomy with JJ	300 (45.3)
	Nephrostomy with ureteric catheter	164 (24.8)
	Tubeless	49 (7.4)
Postoperative blood loss (ml)		160 (60–850)
Complications (61 patients; 9.2%)	Urine leak	27 (4.1)
	Blood transfusion	10 (1.5)
	Renal pelvic perforation	5 (0.8)
	Arterial embolization	4 (0.6)
	Sepsis	10 (1.5)
	Pleural injury	4 (0.6)
	Colonic injury	1 (0.2)
Hospital stay (days)		3 (2–15)
Stone-free		483 (73)
Residual fragments number	One	104 (58.1)
	Two	69 (38.5)
	Three	6 (3.4)
Residual fragments size (cm)		1 (0.5–2.2)
Residual fragments management	ESWL	100 (55.9)
	Second look	52 (29.0)
	URS	27 (15.1)

Data are shown as mean ± standard deviation or number (percentage). ASA: American Society of Anesthesiologists; BMI: body mass index; ESWL: extracorporeal shockwave lithotripsy; HU: Hounsfield unit; URS: ureteroscopy.

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median intraoperative blood loss was 220 mL, ranging from 40–1500 mL. Fever was reported in 22.4%. About one-quarter showed positive postoperative urine culture (25.5%). The most frequent exit strategy was nephrostomy with JJ (45.3%). The median postoperative blood loss was 160 mL, ranging from 60–850 mL. Postoperative complications included urine leak (4.1%), blood transfusion (1.5%), sepsis (1.5%), renal pelvic perforation (0.8%), arterial embolization (0.6%), pleural injury (0.6%), and colonic injury (0.2%).

The median hospital stay was three days, ranging from 2–15 days. Approximately three-quarters of the patients (73%) showed a stone-free outcome. The most frequent procedure with residuals was ESWL (55.9%). The median residual fragment size was 1 cm, ranging from 0.5–2.2 cm. The most frequent residual fragment number was one (58.1%) (Table 1).

General characteristics, operative and postoperative findings according to stone-free status

ASA scores significantly differed between those with and without stone-free outcomes (p=0.022). ASA I was encountered in a higher number of patients with residuals compared with stone-free patients (73.2% vs. 61.7%), while ASA III was greater in stone-free patients (12.8% vs. 8.4%). Additionally, the stone diameter was significantly higher in patients with residuals than in stone-free patients (2.9±0.8 cm vs. 2.7 ±0.9, p=0.006) (Table 2).

Table 2. General characteristics, operative and postoperative outcomes according to stone-free status

Variable		Stone free		p
		Yes (n=483)	No (n=179)	
Age (years)		47±13	46±12	0.218
Females gender		159 (32.9)	60 (33.5)	0.884
BMI (kg/m²)		34.5±6.6	35.6±6.6	0.065
Recurrent stone		150 (31.1)	46 (25.7)	0.180
Previous renal surgery (same kidney)		130 (26.9)	36 (20.1)	0.073
Co-morbidities		136 (28.2)	37 (20.7)	0.051
ASA score	ASA I	298 (61.7)	131 (73.2)	**0.022**
	ASA II	123 (25.5)	33 (18.4)	
	ASA III	62 (12.8)	15 (8.4)	
Stone diameter (cm)		2.7±0.9	2.9±0.8	**0.006**
Preoperative urine culture		31 (6.4)	9 (5)	0.505
Calyx involvement		414 (85.7)	157 (87.7)	0.508
Stone HU		1041±313	1088±275	0.06
Operative time (minutes)		95±30	93±33	0.457
Number of tracts	One	371 (76.8)	125 (69.8)	0.104
	Two	88 (18.2)	46 (25.7)	
	Three	24 (5)	8 (4.5)	
Intraoperative blood loss (mL)		220 (40–1500)	250 (150–1200)	0.720
Postoperative fever	107 (22.2)	41 (22.9)	0.837	
Positive postoperative urine culture		120 (24.8)	42 (23.5)	0.714
Exit strategy	Nephrostomy tube	121 (25.1)	28 (15.6)	**<0.001**
	Nephrostomy with JJ	206 (42.7)	94 (52.5)	
	Nephrostomy with ureteric catheter	112 (23.2)	52 (29.1)	
	Tubeless	44 (9.1)	5 (2.8)	
Postoperative blood loss (mL)		160 (60–850)	160 (60–850)	0.579
Complications		43 (8.9)	17 (9.5)	0.813
Hospital stay (days)		3 (2–15)	3 (2–14)	0.864

Significant p-values are marked in bold. Data are shown as mean ± standard deviation or number (percentage). ASA: American Society of Anesthesiologists; BMI: body mass index; HU: Hounsfield unit.

Table 3. Multivariate logistic regression analysis to predict residual stone

Variable		OR (95% CI)	p
Age (years)		0.989 (0.974–1.003)	0.131
Gender		1.062 (0.72–1.567)	0.760
BMI		1.015 (0.986–1.045)	0.327
Recurrent stone		1.177 (0.518–2.675)	0.697
Previous renal surgery (same kid)		0.534 (0.176–1.626)	0.270
Comorbidities		1.327 (0.553–3.184)	0.527
ASA score	ASA I	R	R
	ASA II	0.536 (0.256–1.12)	0.097
	ASA III	0.521 (0.173–1.569)	0.246
Stone diameter (cm)		1.536 (1.187–1.988)	**0.001**
Preoperative urine culture		0.694 (0.31–1.555)	0.375
Clayx involvement		1.037 (0.603–1.785)	0.894
HU of stone		1 (1–1.001)	0.589
Perirenal stranding		1.322 (0.551–3.169)	0.532
Number of tracts	One	R	R
	Two	1.278 (0.813–2.008)	0.288
	Three	0.382 (0.124–1.178)	0.094
Intraoperative blood loss		1 (0.999–1.001)	0.646

Significant p-values are marked in bold. ASA: American Society of Anesthesiologists; CI: confidence interval; HU: Hounsfield unit; OR: odds ratio; R: reference category.

No significant differences were observed regarding age (p=0.218), gender (p= 0.884), BMI (p=0.065), recurrent stones (p=0.180), previous renal surgery (p=0.073), comorbidities (p=0.051), preoperative urine culture (p=0.505), calyx involvement (p=0.508), stone HU (p=0.06), and perirenal stranding (p=0.712) (Table 2).

The exit strategy significantly differed according to stone-free status (p<0.001). No significant differences were demonstrated regarding operative time (p=0.457), number of tracts (p=0.104), intraoperative blood loss (p=0.720), postoperative fever (p=0.837), postoperative urine culture (p=0.714), postoperative blood loss (p=0.579), complications (p=0.813), and hospital stay (p=0.864) (Table 2).

Multivariate analysis for prediction of residual stones and complications

On multivariate analysis, only increased stone diameter was associated with residual stones (OR 1.536, 95% CI 1.187–1.988, p=0.001) (Table 3). Predictors of complications were three tracts (OR 4.501, 95% CI 1.13–17.937, p=0.033) and higher intraoperative blood loss (OR 1.003, 95% CI 1.001–1.004, p<0.001) (Table 4).

Table 4. Multivariate logistic regression analysis to predict complications

Variable		OR (95% CI)	p
Age (years)		1.006 (0.982–1.031)	0.608
Gender		0.824 (0.43–1.581)	0.561
BMI		1.002 (0.954–1.052)	0.946
Recurrent stone		2.243 (0.748–6.72)	0.149
Previous renal surgery (same kid)		0.434 (0.092–2.054)	0.292
Comorbidities		1.11 (0.264–4.668)	0.887
ASA score	ASA I	R	R
	ASA II	0.811 (0.254–2.595)	0.725
	ASA III	1.18 (0.204–6.837)	0.853
Stone diameter (cm)		1.173 (0.78–1.766)	0.443
preoperative urine culture		0.347 (0.087–1.377)	0.132
Clayx involvement		1.228 (0.477–3.16)	0.671
HU of stone		1 (0.999–1.001)	0.744
Perirenal stranding		0.545 (0.123 –2.405)	0.423
Number of tracts	One	R	R
	Two	1.705 (0.842–3.45)	0.138
	Three	4.501 (1.13–17.937)	**0.033**
Intraoperative blood loss		1.003 (1.001–1.004)	**<0.001**

Significant p-values are marked in bold. ASA: American Society of Anesthesiologists; CI: confidence interval; HU: Hounsfield unit; OR: odds ratio; R: reference category.

DISCUSSION

Ensuring proper parenchymal access is crucial for successful PCNL, as it serves as the gateway for endoluminal procedures. Adequate access to the renal collecting system is imperative for the success of the procedure.[10] The construction of renal access entails choosing the ideal calyx, performing the initial puncture, dilating the tract, and inserting an access sheath. Failure or inefficiency in one of these processes could result in undesirable outcomes or compromise the success of the entire procedure.[11]

The most crucial element is that establishing secure transparenchymal and transpapillary access to the collecting system requires the surgeon to have a good understanding of renal anatomy. This knowledge lessens the chance of bleeding or harm to nearby organs. When performing a puncture to access the kidney, it is important to consider the orientation and depth of the selected calyx. Additionally, the calyx ability to spring and the medial movement of the kidney indicate that the surgeon is in the proper location. The capacity to create additional tracts as needed and choose the best tract based on the intrarenal anatomy allow for more efficient stone removal.[12] Watterson et al revealed that access-related problems are reduced when urologists create their own percutaneous access.[13]

In the current study, dilation was done using renal Amplatz dilators. According to one study, balloon vs. Amplatz dilatation caused less bleeding.[14] Another study reported that the type of dilation technique and anticipated blood loss or transfusion rates are unrelated.[15]

Regarding operative and postoperative findings, our findings are in line with those of Hatipoglu et al, who investigated 200 individuals with renal stones who underwent monoplanar PCNL. The age of the patients was 30.32 years at the time of the procedure. The average procedure time was 79.8 minutes. On the first postoperative day, 80.5% of patients were stone-free. In the third month, the final success rate, including patients with clinically insignificant residual fragments, was 98% after further procedures, such as ESWL, ureterorenoscopy, and re-PCNL. Aside from one patient with a nearby organ injury (colon), there were no serious complications.[6]

Dede et al concluded that using the biplanar approach resulted in shorter fluoroscopy and puncture times; however, there was significantly shorter operative time, less hematocrit drop, and auxiliary procedures in the monplanar access compared with the biplanar one.8 The hospital stay ranged from 1.3–3.4 days, while SFR and complications did not differ significantly.

Several studies have reported similar results. In one trial involving 25 patients who underwent standard fluoroscopically-guided procedures, the mean operative time was 79.58 minutes, with a SFR of 75.5% and a mean hospital stay of 61.79 hours.[16]

Another study reported a mean operative time of 88.93±33.29 minutes and a SFR of 78.6%. The mean hospital stay was 85.88±17.25 hours. One patient needed a transfusion, and fever was reported in two patients.[17] Two randomized studies by Basiri et al and Agarwal et al compared the US with fluoroscopic-guided PCNL. They revealed a significant decline in fluoroscopy time during access (41.4 vs. 57 seconds, $p=0.0001$, and 14.4 vs. 28.6 seconds, $p<0.01$, respectively).[18,19]

PCNL has gained scientific interest as a promising alternative method due to its high success rate; however, it is important to remember that this procedure has life-threatening complications. Our findings regarding bleeding, fever, renal pelvic perforation, arterial embolization, pleural injury, colonic injury, and urinary infection in PCNL cases involving the use of the monoplanar access approach were consistent with those reported in the literature.[20-22]

In the current study, intraoperative blood loss was a major factor that might contribute to complications. Although bleeding frequently results from percutaneous renal access, it can also occur due to parenchymal damage during various procedure steps, such as tract dilation, stone fragmentation, and stone removal, or from vascular system lesions brought on by arteriovenous fistulae or pseudoaneurysms. Renal injury and bleeding may also result from excessive torque on a rigid nephroscope.[6,23]

Another patient-related factor that influenced the procedure is the BMI. Due to the restricted renal access, limited fluoroscopic visibility, and muddled anatomic landmarks, PCNL surgery in obese patients is more difficult than in non-obese patients.[24,25] Since there were no patients who were morbidly obese in this study, the body size likely had no impact on the operational parameters.

Finally, the success of renal access, the frequency of complications, the length of the procedure, and hospital stay are all components of the cascade. Among these factors, successful renal access is of utmost importance. Operative time is a metric that affects perioperative and postoperative complications and is regulated by patient-, stone-, and procedure-related factors. The high percentage of postoperative positive urine culture and postoperative fever could be related to the presence of struvite stones with a large stone burden and long operative time.

In some patients who presented with obstructive back pressure, the preoperative urine culture might be sterile, while in fact, the kidney contains infective urine proximal to the site of obstruction. Another reason for fever might have been the potential rise in intrarenal pressure due to the prone position with the use of pneumatic lithotripsy, which does not offer simultaneous suction, as in the case of utrasounic lithotripsy.

Limitations

The present study has some limitations because patients were not chosen randomly, and it was not a prospective study. Furthermore, we did not evaluate the radiation intensity, and the SFR was assessed using postoperative US and KUB X-ray, which are inferior to the non-contrast CT in terms of the accuracy; however, we did include a large number of patients from a single tertiary care stone center over 12 years.

Future controlled prospective studies should be considered.

CONCLUSIONS

The monoplanar fluoroscopic-guided approach for obtaining percutaneous access during PCNL provided high success rates while maintaining safety and facilitating the puncture process. Higher stone diameter is a predictor of residual stones, and higher intraoperative blood loss and creation of three tracts were predictors of complications.

COMPETING INTERESTS: The authors do not report any competing personal or financial interests related to this work.

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