Original article

Comparison of stone clearance rate based on upper, middle, or lower calyx puncture in Mini Percutaneous Nephrolithotomy (mPCNL)

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Abstract

Introduction: PCNL is the most common surgical technique used for the management of renal stones, particularly for those with more than 2 cm stones. The aim of this study is to identify which kidney calyx—upper, middle, or lower—when punctured achieves the highest stone clearance rate.

Methods: This was a prospective non-randomised study performed in department of urology, KIST medical college from September 1, 2021 to November 16, 2022. Patients who underwent PCNL were evaluated with detailed history, examination, and investigation. All the patients who fulfill the inclusion criteria during study period were included in the study. After preoperative investigation PCNL was done according to standard protocol. Perioperative complication recorded in Performa. Stone-free status was checked after 2 months of surgery with ultrasonography.

Results: 100 patients were included in this study among which 59 were male. The mean age of patients was 33.35 years [range 18-65 years]. Upper, middle and lower pole puncture was done in 23%, 33% and 44% patients respectively. The mean stone burden of the patient was 380.680 mm2. The average time for surgery according to access was 67.34 mins, 63.12mins, and 64.07 mins for the upper calyx, mid-calyx and for the lower calyx respectively. 84.33% of patients had complete stone clearance after 2 months in the USG examination. 91.3% [21] had stone clearance when approached through the upper calyx. It was 87.8%[29] by mid calyx and 75%[33] by lower calyx. Upper calyx puncture had statistical significance in stone clearance rate [P=0.43, P=0.021, P=0.002]. 11 had CRIF ≤4mm stone in PCS, and the remaining 6 had residual stone >4mm. In our study, thoracic complications were significantly higher in upper calyx puncture 8[30.4%, 8[24.24% in the middle calyx, and 3[6.8%] in lower calyx [P=0.02, P=0.98, P=0.03] respectively.

Conclusion: Upper calyceal puncture can produce the highest stone clearance rate, but it has been associated with significant postoperative morbidity, particularly in the chest. Lower calyx punctures have less intraoperative and postoperative morbidity, but their stone removal rates are lower than those of other procedures. Therefore, the balance between stone clearance rate and morbidity has been achieved using middle calyx puncture.

Keywords: PCNL; Puncture; Renal access.

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Introduction

Urolithiasis is one of the most common diseases. More than 70% of the patients in urology clinic are of urolithiasis.[1] Management of urolithiasis depends on the size, site, and consistency of the stone as well as evolving technology and expertise available. There are multiple options available for the management of renal stones, such as open surgery, endourology, laparoscopic surgery, etc. Percutaneous Nephrolithotomy (PCNL) is the most common surgical technique used for the management of renal stones, particularly for those with more than 2 cm stones.[2]

PCNL is commonly associated with significant morbidity. Because of the related morbidity, which can vary from hematuria to intestinal perforation, various innovations in technique and equipment have been made.[3] We do miniPCNL with 12Fr Nephroscope. Puncture of the kidney is one of the most important steps in PCNL. We puncture the upper, middle, or lower calyx of the kidney depending on the location of the stone.

Upper calyx puncture is extremely useful for the clearance of stone in the upper calyx, pelvis, and even lower calyx but it is associated with thoracic complications.[4,5] Middle calyx is less commonly used but provides the shortest track to the pelvis and can give access to the upper and lower calyx in favorable anatomy.[6] Lower calyx puncture is exclusively used for lower calyx stone but sometimes it is associated with colon perforation.[7]

Several studies compare the upper, middle, or lower calyx puncture, but very few compare all three calyces at once. In this study, we compared the miniPCNL's stone clearance rate based on access to the upper, middle, or lower kidney calyx.

Methods

This single center prospective non-randomized study was performed in department of urology, KIST medical college. 100 consecutive patients who fulfilled the inclusion criteria were included in study. Patients were recruited either from emergency or from outpatient department. Diagnosis was done by history, examination, ultrasonography of the abdomen and pelvis and CT Urogram. Perioperative management was done according to standard protocol. Permission was taken from the institutional review board. The study period was from September 1, 2021 to November 16, 2022.

A sample size of 87 was achieved with the website http://www.raosoft.com/samplesize.html. The margin of error is 5% and Confidence level is 95% Response distribution is 6%. The statistical analysis was carried out using Statistical Package for the Social Sciences for Windows software, version 21.0 (IBM, Chicago, IL). Descriptive statistics were used to analyze the data with the mean, the range for medians and the variance reported for continuous variables, and the proportions reported for categorical variables. Statistical significance was considered at 2-sided $p < 0.05$. Pearson's chi-square and Fisher's exact test were used for comparisons of percentages.

Table 1. Baseline characteristics

Parameters	Upper calyx [N=23]	Mid calyx [N=33]	Lower calyx [N=44]	Upper vs mid	Upper vs lower	Mid vs lower
				P value		
Age mean (years)± SD	38.2±12.4	38±13.2	39±12.8	0.37	0.51	0.12
Male: female n [%]	13:10	20:13	26:18	0.23	0.34	0.54
Left kidney: right kidney n [%]	9:14	18:15	24:20	0.29	0.42	0.41
Location of stone, n [%]						
Pelvis	9	14	12	0.54	0.32	0.64
Calyx	6	7	18	0.91	0.87	0.09
Pelvicalyx	5	4	14	0.65	0.77	0.61
Upper ureter	5	8	0	0.54	0.03	0.02
Stone burden ± SD [mm2]	392±165.5	369±110.2	381±187.3	0.43	0.31	0.78
Hounsfield unit stone	1005.33	1145.28	1054.73	0.37	0.65	0.29
Hydronephrosis, n [%]						
No HDN	6	7	11	0.18	0.25	0.23
Mild	8	11	14	0.54	0.92	0.28
Moderate	5	9	12	0.33	0.43	0.87
Severe	4	6	7	0.10	0.78	0.45
Preop UTI	3	6	5	0.23	0.45	0.52
Preop Hemoglobin	13.17	12.89	12.45	0.29	0.97	0.82
Preop Serum Creatinine	1.12	0.87	0.95	0.19	0.28	0.63

Table 2. Comparison of operative details and post-operative outcomes

Variables	Upper calyx [n=23]	Mid calyx [n=33]	Lower calyx [n=44]	Upper vs mid	Mid vs lower	Upper vs lower
				P value		
Duration of surgery in min ± SD	67±13.5	63±12.2	64±11.7	0.67	0.55	0.34
Skin Puncture site						
Subcoastal	2	17	44	0.02	0.54	0.003
Supracoastal	21	16	0	0.75	0.03	0.001
Postop fever	5	2	8	0.76	0.54	0.43
Hematuria	1	2	0	0.45	0.32	0.34
Hemoglobin drop	1.34	1.17	1.11	0.23	0.77	0.87
Chest complication	8[30.4%]	8[24.24%]	3[6.8%]	0.02	0.98	0.03
Stone free rate	21[91.3%]	29[87.8%]	33[75%]	0.43	0.021	0.002
CIRF rate	2	3	6	0.87	0.44	0.34
Mean hospital stay [day] ± SD[range]	4.12[3-9]	3.67[3-7]	3.12[3-8]	0.66	0.65	0.36

SD = Standard deviation HDN = Hydronephrosis UTI = Urinary Tract Infection

All the procedures were done by the first author himself. All the procedures were done under general anesthesia. 6Fr ureteric catheter was inserted in the lithotomy position. Then the patient was changed to the prone position. The puncture was done with an 18fr diamond tip needle. The decision to puncture the upper, middle or lower was taken after a retrograde pyelogram. The straight tract which was in the line of maximum bulk of stone was chosen as the best access. Tracts were dilated to 18Fr with the help of an alken dilator. 12Fr mini-nephroscope was used. Lithotripsy was done by pneumatic lithotripter. Renal drainage was done with a DJ stent and /or nephrostomy tube according to the surgeon's decision. Postoperatively nephrostomy tube was removed on day 1 and foley catheter was removed on day 2 and the patient was discharged as early as practicable. X-ray KUB was done in all patients on 2nd postop day. Stone-free status was confirmed after a USG examination of the kidney after 2 months of surgery. Stone of size ≤4mm was labeled as clinically insignificant residual fragment [CIRF] in sonography.[8]

Stone-free status was considered as the primary outcome and complications of PCNL (intraoperative, immediate postoperative, and late complications) was taken as a secondary outcome.

Results

100 patients were included in this study. 59 were male and 41 were female. In 23% of patients upper pole puncture was done, in 33% of patients middle pole puncture was done and in 44% of patients lower pole puncture was done. All the patients fulfilling the inclusion criteria completed the study. There was no difference in patients` demographic and clinical characteristics (**Table 1**). Average age of the patient was 33.35 years (Range 18-65 years). The mean stone burden of the patients was 380.680 mm2. The average brittleness of stone in the Hounsfield unit was 1056 [512-1504].

The average time for surgery was 75 min [range 42 min to 102min]. The average time for surgery according to access was 67.34 min for the upper calyx, 63.12min for the mid-calyx, and 64.07 min for the lower calyx. **Table 2** demonstrates details of intraoperative and postoperative events. Thirty-seven patients had supra-coastal entry points of the needle and the rest 63 had infra-coastal entry points. While breaking the stone with a pneumatic lithotripter 5 patients had renal pelvis perforation which was managed with DJ stenting. Urine leak from the nephrostomy tube was observed in 5 patients after removal of the tube but no such complication was seen in tubeless PCNL.

In the postoperative period, 20 patients developed fever, and urine leaks developed in 5 patients. Two patients were admitted within 2 weeks due to hematuria which was managed by bladder wash and irrigation. 84.33% of patients had complete stone clearance after 2 months in the USG examination. 91.3% [21] had stone clearance when approached through the upper calyx. It was 87.8%[29] by mid calyx and 75%[33] by lower calyx. In our study upper calyx puncture had statistical significance in stone clearance rate [P=0.43, P=0.021, P=0.002] (**Table 2**). Eleven had CRIF ≤4mm stone in PCS, and the remaining 6 had residual stone >4mm.

Complications that occurred in our study are demonstrated in **Table 3**. Complications were recorded as grade I, II, and IIIa according to the modified Clavien Dindo system. In our study, thoracic complications were significantly higher in upper calyx puncture 8[30.4%, 8[24.24% in the middle calyx, and 3[6.8%] in lower calyx [P=0.02, P=0.98, P=0.03] respectively.

Discussion

Numerous changes have been made to the PCNL procedure since it first began in 1976.[9] The PCNL track's dimensions have significantly shrunk. Although PCNL is

Table 3. Complication according to modified Clavien grading system [n=100]

Complications	Number
Grade I	
Fever	15
Decreased urine output requiring diuretics	3
Hydropneumothorax managed by watchful waiting	3
Bleeding that requires a single episode of nephrostomy clamping	0
Renal pelvic perforation managed by watchful waiting	5
Grade II	
Blood transfusion	2
Urine leakage	5
Wound infection	2
Febrile urinary tract infection	5
Postoperative ileus managed by nasogastric decompression	0
Hyposaturation requiring oxygen after surgery	10
Minor atelectasis requiring medical management	5
Grade IIIa	
Double J stent replacement for urine leakage >24 h	0
Bleeding requiring multiple bladder washouts/irrigations	2
Stent migration needed reposition	1
Urine leakage managed by ureteric stenting without GA	0
Hydropneumothorax needed chest tube	1
Grade IIIb	
Arteriovenous fistula requiring angioembolization	0
Perirenal abscess managed by open drainage	0
Grade IVa	
Bowel injury	0
Hyposaturation requiring ICU management	0
Grade IVb	
Urosepsis	0
Grade V	
Death	0

commonly used in the management of large-size stones it is not without significant morbidity. To decrease the morbidity different modifications in technique and the size of the tract have been tried.[10]

Because of the variability of shape, direction, and orientation of the infundibulum and calyces choice of puncture site has been key to the success of the procedure.[11] The basic principle has been to choose the tract which will provide access to the maximum bulk of the stone.[12]

In this study, we found stone clearance rate was 91.3% in the upper calyx, 75% in the lower calyx, and 87.8% in the middle calyx. A maximum stone-free rate has been found in the upper calyx. The reason for this may be the more favorable anatomy we find in the upper calyx. As we know kidney is oriented ventro-laterally and more inclined towards the midline.[13] If the PCNL track is from the upper calyx and it is more medial so we can have easy access to the upper calyx, pelvis, and lower calyx. It also prevents the migration of stone to another calyx because of the direction of flow of irrigational fluid and gravity.[14] Anatomy of the upper calyx makes the puncture relatively easy.[15] Arrangement of calyces is such that there is no anterior and posterior calyx.[16] So we have to choose medical vs lateral calyx. More proximity of the calyx toward the ventral side makes it easier to reach the kidney. But there are a few drawbacks to this technique. Most of the time, site of the upper pole puncture is above the 12th rib and sometimes it is even above the 10th rib.[16] As the site of puncture is higher it is associated with multiple complications such as postoperative pain, atelectasis, pleural effusion, injury to the liver and spleen, and sometimes even trauma to the lung parenchyma.[17] That is why it is not advisable to choose the puncture site above the 10th rib. During the procedure ergonomically it is comfortable for the right-handed person to procedure in the left kidney and vice versa.[17]

The middle calyx is chosen if the maximum bulk of the stone lies in the direction of the middle calyx or if the stone is in the renal pelvis or lower calyx and or pelvis. For the miniPCNL tract middle calyx seems to be a versatile track. Most of the time we were able to reach the stone from the top thus preventing the migration of stone to the upper calyx. Except in a few unfavorable pelvicalyceal systems, the mini nephroscope could reach the upper and lower calyx with a smaller Amplatz sheath [≤18Fr]. Another advantage of middle calyx puncture is that because of a favorable angle, the guidewire can reach the ureter most of the time making tract dilatation easy and reducing the chances of tract loss. As we see the distinct anterior and posterior division of the middle calyx so it is very important to enter the pelvicalyceal system from the posterior calyx. In the middle calyx puncture, very often puncture site is supracoastal but the calyx is entered from the lateral part of the ribs. So the chances of pleural violation are limited.[10]

Lower calyx access is considered the safest among all three calyces.[18] It is chosen if the bulk of the stone is in its direction. The compound calyx axis of the orientation of the minor calyx varies. So it is very important to find the posterior calyx for the entry to the pelvis. Sometimes if the location of the stone is in the anterior calyx then it is difficult to negotiate the guide from the calyx to the pelvis. Another disadvantage of lower calyx access is the migration of the stone to the upper calyx. In this scenario, if the nephroscope cannot be negotiated into the upper calyx then we have to either use a flexible nephroscope or make another track in the upper calyx.

In this study, we have found the maximum complication in upper calyx puncture. The reasons for this are during upper calyx puncture the tract goes between the ribs through the diaphragm and sometimes through the parietal pleura. Because of this patient complains of maximum pain. This pain will also compromise the expansion of basal areas of the lung leading to atelectasis and pneumonia. As mentioned by Ahmed et al upper pole puncture was significantly associated with intraoperative and postoperative bleeding. Even in the supracoastal puncture entry site of the calyx is above the entry site of the skin. We agree with the finding observed by Soares et al and El-Nahas that this makes the tract more oblique and longer subsequently causing bleeding during manipulation.[4,18]

Thoracic complications were significantly lesser in middle and lower calyx punctures [P=0.02, P=0.98, P=0.03]. Although 48.48% [16] of the puncture were supracoastal thoracic complications were significantly less in the middle calyx. This is because all the supracoastal punctures were at the lateral surface of the 11th Intracoastal space.

The stone clearance rate was maximum in the upper calyx. Because of anatomical orientation and easy access to another calyx, we can have better endoscopic clearance of the stone. The stone clearance rate is lowest in the lower calyx because of the migration of stone fragments. In lower calyx access need for another track if there is a stone that cannot be reached from the current track or the stone migrate to another track.

The upper pole of each kidney lies anterior to the posterior portion of the 11th and 12th ribs and during exhalation the lower limit of the parietal pleura crosses these ribs obliquely, such that the lateral portions of these ribs are inferior and lateral to the lower limit of the pleura.[20] The incidence of thoracic complications during supracostal punctures in various studies ranges between 3% and 16%.[20,21]

This study has some limitations. As a non-randomized study, it is important to acknowledge that there may be some inherent bias in the sample selection process. The anatomy of the pelvicalyceal system differs from person to person. The stone clearance rate is also determined by favorable anatomy. Another bias is during the choice of which calyx to puncture. There are no clear-cut criteria to choose the site of puncture. It is only a subjective judgment.

Conclusion

An upper calyceal puncture can produce the highest stone clearance rate, but it has been associated with significant postoperative morbidity, particularly in the chest. Lower calyx punctures have less intraoperative and postoperative morbidity, but their stone removal rates are lower than those of other procedures. Therefore, the balance between stone clearance rate and morbidity has been achieved using middle calyx puncture.

Reference

1. Trinchieri A. Epidemiology of urolithiasis: an update. Clin Cases Miner Bone Metab. 2008;5(2):101-6.
2. Sabler IM, Katafigiotis I, Gofrit ON, Duvdevani M. Present indications and techniques of percutaneous nephrolithotomy: What the future holds? Asian J Urol. 2018 Oct 1;5(4):287–94.
3. Gadzhiev NK, Obidnyak VM, Gorelov DS, Malkhasyan VA, Akopyan GN, Mazurenko DA, et al. Complications after PCNL: diagnosis and management. Urologiia. 2020 Nov:(5):139–48.
4. Soares RMO, Zhu A, Talati VM, Nadler RB. Upper Pole Access for Prone Percutaneous Nephrolithotomy: Advantage or Risk? Urology. 2019 Dec 1;134:66–71.
5. Aron M, Goel R, Kesarwani PK, Seth A, Gupta NP. Upper pole access for complex lower pole renal calculi. BJU Int. 2004 Oct;94(6):849–52.
6. Khadgi S, EL-Nahas AR, Darrad M, AL-Terki A. Safety and efficacy of a single middle calyx access (MCA) in mini-PCNL. Urolithiasis. 2019 Dec 10;48(6):541–6.
7. Rai A, Kozel Z, Hsieh A, Aro T, Smith A, Hoenig D, et al. Management of Colon Perforation During Percutaneous Nephrolithotomy in Patients with Complex Anatomy: A Case Series. J Endourol Case Reports. 2020;6(4):416.
8. Ermis O, Somani B, Reeves T, Guven S, Pes PL, Chawla A, et al. Definition, treatment and outcome of residual fragments in staghorn stones. Asian J Urol. 2020 Apr 1;7(2):116–21.
9. Lahme S. Miniaturisation of PCNL. Urolithiasis 2017;46(1):99–106.
10. Binbay M, Akman T, Ozgor F, Yazici O, Sari E, Erbin A, et al. Does Pelvicaliceal System Anatomy Affect Success of Percutaneous Nephrolithotomy? Urology. 2011 Oct 1;78(4):733–7.
11. Aron M, Yadav R, Goel R, Kolla SB, Gautam G, Hemal AK et al. Multi-Tract Percutaneous Nephrolithotomy for Large Complete Staghorn Calculi. Urol Int. 2005;75(4):327-32.
12. Turney BW. A New Model with an Anatomically Accurate Human Renal Collecting System for Training in Fluoroscopy-Guided Percutaneous Nephrolithotomy Access. J Endourol. 2014 Mar;28(3):360-3.
13. Singh V, Garg Y, Sharma K, Sinha RJ, Gupta S. Prospective randomized comparison between superior calyceal access versus inferior calyceal access in PCNL for inferior calyceal stones with or without pelvic stones. Urolithiasis. 2015;44(2):161–5.
14. Netto NR, Ikonomidis J, Ikari O, Claro JA. Comparative study of percutaneous access for

staghorn calculi. Urology. 2005;65(4):659–62.
15. Verma A, Tomar V, Yadav S. Complex multiple renal calculi: stone distribution, pelvicalyceal anatomy and site of puncture as predictors of PCNL outcome. Springerplus. 2016 Dec 1;5(1):1–6.
16. Singh R, Kankalia SP, Sabale V, Satav V, Mane D, Mulay A, et al. Comparative evaluation of upper versus lower calyceal approach in percutaneous nephrolithotomy for managing complex renal calculi. Urol Ann. 2015 Jan 1;7(1):31-5.
17. Gunawan S, Birowo P, Rasyid N, Atmoko W, Zeng G. Outcome and safety of upper pole versus non-upper pole single puncture PCNL for staghorn stones: a systematic review and meta-analysis [version 1; peer review: 2 approved with reservations]. F1000Research.2019;8:537.
18. El-Nahas AR, Shokeir AA, El-Assmy AM, Mohsen T, Shoma AM, Eraky I, et al. Post-Percutaneous Nephrolithotomy Extensive Hemorrhage: A Study of Risk Factors. J Urol. 2007 Feb;177(2):576–9.
19. Munver R, Delvecchio FC, Newman GE, Preminger GM. Critical analysis of supracostal access for percutaneous renal surgery. J Urol. 2001;166(4):1242-6.
20. Sukumar S, Nair B, Kumar PG, Sanjeevan K V, Bhat HS. Supracostal access for percutaneous nephrolithotomy: less morbid, more effective. Int Urol Nephrol. 2008 Jun;40(2):263–7.
21. Lojanapiwat B, Prasopsuk S. Upper-pole access for percutaneous nephrolithotomy: comparison of supracostal and infracostal approaches. J Endourol. 2006 Jul;20(7):491–4.