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The Influence of Access on the Efficacy and Complications in PCNL for Renal Calculi

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Abstract: *PCNL has remained standard procedure for renal calculi patients. Over the years, improvements in techniques, instruments and better understanding of anatomy has led diminished complications rate. However significant complications still occurs. Here we tried to determine the effects of percutaneous access point, number and location on success as well as complication rates during PCNL. This was a prospective study of patients who underwent PCNL between august 2012 to November 2013.Total 166 patients were studied. Stone was categorized as simple in 75 (45.2%) and complex in 91 (54.2%). Out of 91 renal units with complex stones, in 56 complete clearance could achieve in first setting. Among the rest 35 renal units, 19 underwent relook PCNL. Out of 75 cases with simple calculi 63 achieved complete clearance in first setting, 12 had residual calculi. It is evident from the study that clearance rates were not dependent on the site and number of access.*
Keywords*: complex calculi., intercostal chest drain, PCNL, supracostal,*

I. Introduction

The first description of percutaneous stone removal was that of Rupel and Brown [1] of Indianapolis, who removed a stone through a previously established surgical nephrostomy track. It was not until 1955, however, that Goodwin described the first placement of a percutaneous nephrostomy tube to drain a grossly hydronephrotic kidney [2], however he did it without imaging. In 1976, Fernstrom and Johannson first reported the establishment of percutaneous access with the specific intention of removing a renal stone. Subsequent advances in endoscopes, imaging equipment, and intracorporeal lithotripters allowed urologists and radiologists to refine these percutaneous techniques through the late 1970s and early 1980s into well-established methods for removal of upper urinary tract calculi. As the percutaneous approach to stone removal is superior to the open approach in terms of morbidity, convalescence, and cost, Percutaneous Nephrolithotomy (PNL) has replaced open surgical removal of large or complex calculi at most institutions

Percutaneous nephrolithotomy maintains its position as the most effective treatment option for patients with large stone burdens, in situations associated with complex renal anatomy, and when attempting to achieve an immediate state is a high priority. Improvements in technique and instruments have diminished complication rates associated with this procedure. However, significant complications, such as hemorrhage, encountered in 1–23% of cases, intrathoracic complications, observed in 2–12.5%, and other organ injuries, observed in <1%, are being reported with percutaneous renal surgery [3-12]. The necessity for supracostal access, multiple tract procedures, prolonged operation time, occurrence of intraoperative complications and method of percutaneous tract dilation are major outstanding risk factors associated with increased morbidity and complication rates [7, 11].

The literature is replete with studies that have assessed the complications of PCNL. But studies that have documented the effect of site of access, total number of tracts dilated on the clearance of stones and occurrence of complications are very few [2, 13]. Herein, we assess our experience in order to determine the effects of percutaneous access point, number and location on success as well as complication rates during PNL at our Centre.

II. Material And Methods

This study was conducted in the department of urology, NIMS medical college, Jaipur, between August 2012 to November 2013. All patients undergoing PCNL for renal calculi were included in the study. A written informed consent was taken from the patients before enrolling them for the study. Routine investigations were done, along with IVP, postop stone clearance monitored with x ray. The stone burden was determined by radiographic studies, and stones were basically classified as simple (isolated renal pelvis, or isolated caliceal stones) or complex (partial or complete staghorn stones, renal pelvis stones with caliceal stones), regardless of their size. Anemia was treated pre- operatively; prophylactic antibiotics were given to all patients. PCNL was done as a single stage procedure under general or regional anesthesia. Ureteric catheter was used in all patients to delineate the system. Access usually achieved through bulls eye technique. For a supracostal access, the needle puncture was placed immediately above the upper border of lower rib to avoid damage to the intercostal

vessels. Once the PCS was entered a guide wire was manipulated down the ureter if possible, or coiled in calyx as much as possible. Subsequently tract was dilated with alken sequential metal dilators to accept 24-30- French Amplatz sheath.

The stones were fragmented with pneumatic lithotripter through 26 french nephroscope. Smaller fragments and debris were evacuated under direct vision using a wide bore suction cannula (14-french) through the working channel of nephroscope. A double j stent was used almost in all patients were the pelviureteric junction was entered with the nephroscope. The procedure was terminated by placement of 20-french nephrostomy tube into the tract(s). If on table fluoroscopy revealed complete clearance, only a single nephrostomy tube was placed regardless the number of tracts. If there was doubt about complete clearance or there was bleeding from other tracts, additional nephrostomy tubes were placed in those tracts also. For patients with supracostal access, chest x-ray was done selectively if there was decreased air entry on the side of PCNL, or a fall in oxygen saturation or if patient developed dyspnea, tachypnea, or chest pain postoperatively. On suspicion of chest complication, a thoracic surgeon was consulted, and chest tube was placed if indicated. Stone clearance was documented on plain x- ray the next morning, and a second look procedure was planned if there was any residual stone. In patients with complete stone clearance the nephrostomy tube was removed the next day. Successful stone removal was defined as complete clearance of the stone. Insignificant residue was defined as a residual fragment of <2mm. The need for blood transfusion was decided on the clinical assessment and postoperative hemoglobin. Detailed records of intra and post-operative events were maintained. Statistical analysis- all data were prospectively entered in MS office Excel sheet and results were analyzed by SPSS software.

III. Results

A total of 166 renal units were included in the final analysis. The mean age was 37.39 ± 14.13yrs.', (Range 5 – 70 yrs).There were 17 patients under the age of 18 out of which 5 were under the age of 12.There were 113(68.07%) male and 53(31.93%) female subjects. Male: female ratio was 2.13: 1.The Mean stone size was 3.83 ± 1.23 cm. The median stone size was 3.65 cm. Stone sizes ranged from 1.8 cm to 8 cm. It was the largest measured dimension of the stone on plain X-ray KUB.

Stones were categorized as 'simple' in 75(45.2%) and 'complex' in 91(54.2%) patients. The mean size of simple and complex stones was 2.85 ± 0.51 cm and 4.64 ± 1.05 cm respectively. Among the 75 "Simple stones", there were 65 isolated pelvic calculi, 2 isolated superior caliceal calculi and 8 isolated inferior calyceal calculi. Among 91 renal units with complex calculi the distribution of the location of calculi was as follows:

Location of calculi	**No of renal units**
Calyceal diverticulum	1
Multicalyceal	2
Partial staghorn	11
Pelvic + inf. calyceal	21
Pelvic + mid calyceal	4
Pelvic + multicalyceal	10
Pelvic + sup calyceal	4
1. Staghorn	30
Staghorn + multialyceal	4
Staghorn + sup calyceal	1
Upper ureteric + Calyceal	3

PCNL was done on the right side in 99 patients out of which one underwent an endopyelotomy along with PCNL and rest 67 renal units underwent left PCNL. Most of our patients underwent the procedure under Spinal anesthesia (112), 40 under combined spinal and epidural anesthesia and 12 under General anesthesia.

Calyx punctured during PCNL:

Though multiple calyces were punctured in some patients, when the primary calices that were punctured were taken into account, the following were the results:

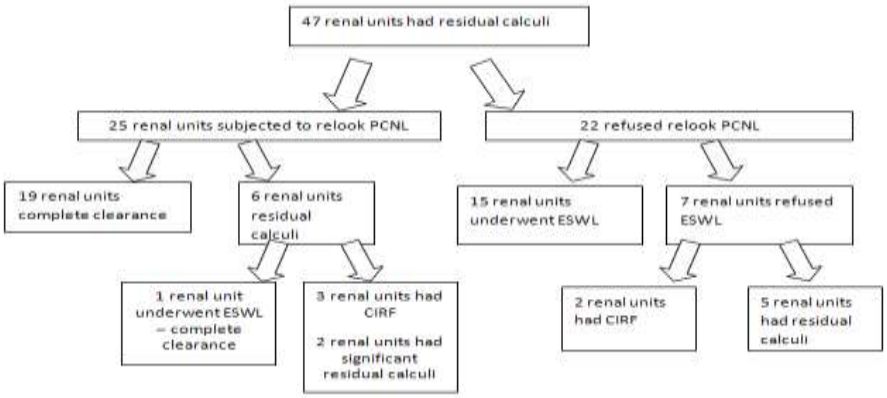
Calyx Punctured	**No of renal units**
Inferior	14
Middle	61
Middle + Inferior	9
Superior	55
Superior + Inferior	10
Superior + Middle	15
Superior + Middle + Inferior	2

The site of puncture was subcostal in 103 patients, between 12th and 11th rib in 62 patients and between 11th and 10th rib in one patient.

Residual calculi: After the first PCNL out of 166 renal units 119 renal units were fully cleared of stones. The reasons for terminating the procedure in the remaining 47 renal units were as follows:

Reason for termination of PCNL	No of renal units
Prolonged operative time	**14**
loss of access	**6**
Intra-op BP fluctuation	**1**
Improper angulation	**5**
Difficult access	**1**
Blocked Superior Calyx	**1**
Bleeding	**19**

Fate of the renal units with residual calculi:



In conclusion out of 166 PCNL, 7 renal units had significant residual calculi. This success rate was after multiple attempts at stone removal using both PCNL and ESWL sequentially. Hence the final success rate was 95.78%.

Clearance after PCNL assessed by type of calculi:

	Success	
Type of stone	**Yes**	**No**
Simple(n= 75)	**74(98.6%)**	**1(1.4%)**
Complex(n = 91)	**85(93.4%)**	**6(6.6%)**
Total	**159(95.8%)**	**7(4.2%)**

P: 0.12931045 by fisher's exact test

There was no statistically significant difference between the Success rates after multiple interventions depending upon whether the stone was simple or complex.

calculi and their clearance after PCNL based on the calyx of access:
There were totally 46 renal units with staghorn calculi. 37 of them underwent superior calyceal puncture. The clearance rates are as follows:

Calyx of access	Complete clearance	Residual calculi
Superior	19	18
Other calyces	4	5

P:0.5 not significant

Staghorn calculi and their clearance after PCNL based on the number of access points:
Among the 46 renal units with staghorn calculi there was single access in 29 renal units whereas 17 renal units underwent multiple access. The clearance rates are as follows:

No of access points	**Complete clearance**	**Residual calculi**
Single	15	14
Multiple	8	9

P:0.76 not significant.

It is evident from the above observations that the clearance rates after PCNL for staghorn calculi were not dependent on the calyx of access and on the no of access points.
Success rates after multiple interventions in staghorn calculi: After sequential PCNL followed by ESWL in appropriate patients of staghorn calculi the final clearance rates were 93.5% in a group of 46 patients with staghorn calculi. The 93.5% includes three patients with CIRF also.

Complications after PCNL:
Pleural complications:

Among 63 renal units with supracostal punctures there were 2 cases of hemopneumothorax that required Intercostal drainage (ICD) tube placement. One of these 2 required immediate post op ICD placement. Another patient developed hydropneumothrax after nephrostomy removal on POD 3, which was managed conservatively and patients repeat chest X-ray after 2 weeks showed complete resolution. Another patient developed hemothorax with breathlessness in the immediate post-operative period and an ICD which drained 600 ml of blood relieved the patient of his symptoms. ICD was removed after 2days. Of the three patients with pneumothorax, two required ICD in the immediate post-op period whereas one patient developed chest symptoms after nephrostomy tube removal. She was managed conservatively for three days, when the repeat chest X-ray showed hydropneumothorax and she required ICD placement after which she improved.
The incidence of pleural complications was 7 among 63 patients with supracostal puncture which gives an incidence of 11.11%. There was only one patient who did not require intervention and was managed successfully conservatively. 9.52% of the patients with supracostal puncture required ICD drainage for incidence of pleural complications. The only patient with supra 11^{th} rib puncture did not develop any pleural complications.

Infectious complications:

All patients were preoperatively given intravenous third generation cephalosporins or culture specific antibiotics prior to surgery. Three patients developed fever and urine culture showed pseudomonas aureginosa growth which was treated with appropriate antibiotics and patients improved. Eight patients developed sepsis and were treated with inotrope support and broad spectrum antibiotics.

Other complications:

Three patients had a prolonged leak from the nephrostomy site and they were managed with DJ stenting. There were no deaths in the immediate postoperative period (within four weeks).One patient developed Superior calyceal infundibular stenosis after superior calyceal access for partial staghorn with multiple secondary calculi and subsequently patient underwent infundubulotomy. One patient with chronic renal failure underwent PCNL with a creatinine of 5.8mg/dl and was discharged after successful PCNL. After 4 months, he developed perinephric abscess on the opposite side died due to worsening of renal failure and sepsis.

Relationship between blood transfusion and size of stone:

Blood transfusion was required in 36 (21.7%) patients. The mean size of stone in patients with blood transfusion was 4.65 cm whereas the mean for all calculi was 3.83 cm. The median size of stone in patients with blood transfusion was 4.85 cm whereas the median for all calculi was 3.65 cm. The stone size was evaluated with respect to the chance of blood transfusion and it was found that stones larger than 4 cm were found to have a significantly more chance of blood transfusion than stones smaller than 4cm.

Blood transfusion	**Stone Size <4 cm**	**Stone Size ≥4 cm**	**Total**
No	82	48	
Yes	10	26	36
Total	92	74	166

P Value: 0.000 highly significant

There was a significantly greater chance of blood transfusion in patients with calculi ≥ 4cm.
Relationship between blood transfusion and type of stone:

The relationship between blood transfusion and type of stone was evaluated and results tabulated as follows:

Blood transfusion	**Complex calculi**	**Simple calculi**	**Total**
No	63	67	
Yes	28	8	36
Total	91	75	166

P Value: 0.002 significant

There was a significantly greater chance of blood transfusion in patients with complex calculi as opposed to simple calculi.

Relationship between blood transfusion and no of access points:

The relationship between blood transfusion and no of access points was evaluated and results tabulated as follows:

Blood transfusion	Single access	Multiple access	Total
No	112	18	130
Yes	20	16	36
Total	132	34	166

P Value: 0.000 highly significant

There was a significantly greater chance of blood transfusion in patients with multiple access points when compared with single access in PCNL.

Logistic regression Analysis:

Due to the fact that all these factors affecting blood transfusion are interrelated, the multimodal logistic regression was used. The results are as follows:

Parameter Estimates

Blood_transfusion[a]		B	Std. Error	Wald	df	Sig.	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
No	Intercept	-.280	.962	.085	1	.771			
	Typeof stone-complex	.147	.820	.032	1	.858	1.158	.232	5.784
	Typeofstone-simple	0[b]	.	.	0	.	.	.	.
	Stone size < 4 cm	1.214	.730	2.764	1	.096	3.365	.805	14.071
	Stone size ≥4 cm	0[b]	.	.	0	.	.	.	.
	Calyx_punctured=Inf	.129	.467	.076	1	.783	1.138	.455	2.842
	Calyx_punctured=Sup	0[b]	.	.	0	.	.	.	.
	Single access	1.188	.460	6.660	1	.010	3.281	1.331	8.091
	Multiple access	0[b]	.	.	0	.	.	.	.

a. The reference category is: yes.

b. This parameter is set to zero because it is redundant.

By this analysis, only number of access points was significantly related to the occurrence of blood transfusion. The beta coefficient of regression analyses was greater than 1 if the stone size was lesser than 4cm and hence there was a trend towards no blood transfusion in patients with stones smaller than 4 cm. All other factors were not positively correlating to the chance of blood transfusion.

IV. Discussion

The intent of this study was to describe the exact calyx punctured, supra or infracostal puncture, no of access made and the clearance rates after PCNL. The occurrence of complications like pleural, bleeding, infection and any other significant complication were documented and intended to be described. Among the 166 PCNL carried out during the study period there were 82 superior calyceal approaches. There were 63 supracostal punctures which work out to 38% of all punctures. In a study by Yadav R et al Supracostal access was obtained in 332 (37.3%) out of 890 PCNL [14]. In a study by Sukumar S et al 565 patients underwent PCNL, of whom 110 (19.5%) had a supracostal access [15]. We did not have any hesitation in using the supracostal access for puncture of the appropriate calyx.

In our study population of 166 PCNL there were single access in 132 (79.5%) cases and multiple access in 34(20.5%) cases. In a study by Muslumanoglu AY et al, one single percutaneous access was sufficient in 210 (76.4%), while 2 accesses were utilized in 44 (16%), and 3 accesses in 21cases (7.6%)[16]. The intent in doing PCNL was complete clearance of all calculi and there was no hesitation in making multiple tracts during PCNL for maximizing clearance when the patient was stable.

With regard to the clearance rates out of 166 PCNL, 7 renal units had significant residual calculi. This success rate was after multiple attempts at stone removal using both PCNL and ESWL sequentially. Hence the final success rate was 95.78%. When the type of stone was factored into the analyses the clearance rates were 98.6% for simple calculi and 93.4% for complex calculi. An overall success rate of 94.9% was achieved and

when simple and complex calculi were analyzed separately the success rate was 99.3% and 90.2% respectively in a analysis of PCNL carried out by Muslumanoglu AY et al[16]. After sequential PCNL followed by ESWL in appropriate patients of staghorn calculi the final clearance rates were 93.5% in a group of 46 patients with staghorn calculi. The 93.5% includes three patients with CIRF also. When success rates after multiple interventions was analyzed by Aron et al in 2005 with combined approach a total success rate of 94% (including 4 renal units with insignificant residue) was achieved[17].

Clearance rates according to access points:

The clearance rates depend on the access points only in stones with large sizes. In the present study, an overall success rate of 95.8% was achieved during follow-up, and higher stone clearance was observed in patients with simple stones when compared to patients with complex stones (statistically not significant). The mean stone burden was greater, and the success rates were diminished in the complex stone group, in which multiple accesses were more commonly indicated. On the other hand, the need for supracostal access was not related with the complexity of the stones, and did not affect the success rates.

Limitations:

The study does not take into account the surgeons experience when they performed the PCNL. The surgeons group consisted of consultant urologists and resident trainees. The surgeons were at different levels of expertise and it is difficult to factor that variable when we assess the clearance rates after PCNL.

Complications:

Pleural complications:

In various studies, the risk of pleural violation during supracostal access for has been reported to be between 0% to 12.5%.[18-20].In our study, the incidence of pleural complications was 7 among 63 patients with supracostal puncture which gives an incidence of 11.11%. There was only one patient who did not require intervention and was managed successfully conservatively. 9.52% of the patients with supracostal puncture required ICD drainage for incidence of pleural complications. The only patient with supra 11^{th} rib puncture did not develop any pleural complications.

Bleeding complications:

The incidence of blood transfusion after percutaneous procedures has been 2% to 45% among different series. Multiple renal punctures and renal pelvic perforation are associated with twofold greater loss. Kukrejaet al.[11] in a prospective study, evaluated factors affecting blood loss during PCNL. They found that diabetes, multiple tract procedures, a prolonged operative time, and intraoperative complications were associated with significantly greater blood loss during PCNL. The most common major complication in this series was bleeding necessitating blood transfusion, observed in 27% of patients, and these results correlate with previously published series.

Although all patients experience some blood loss during tract dilation and nephroscope manipulations, this bleeding is generally tamponed by the Amplatz sheath and theoretically by the nephrostomy tube placed through the tract at the end of the operation, while the urine usually clears within 24–48 h after the procedure. However, hemorrhage is still the most common and worrisome complication of percutaneous renal surgery. The overall blood transfusion rate after PNL is reported to range between 6 and 23% [5, 8].

The bleeding usually arises from injury to the anterior or posterior segmental arteries rather than the smaller peripheral interlobular arteries, which are surrounded by dense parenchyma, and are therefore easier to tamponed with the Amplatz sheath or nephrostomy tube, although there is no study to our knowledge confirming the relationship of parenchymal thickness and degree of bleeding. The most common causes of bleeding in the late postoperative period are arteriovenous fistulas and pseudoaneurysms. Although no perioperative open surgical exploration due to bleeding was indicated in our series, the procedure had to be terminated in 19 patients because of hemorrhage disabling vision and deteriorating hemodynamics of the patient. All patients were successfully managed by conservative measures, and their stones were cleared in a second PNL session.

The relationship of hemorrhage during PNL and patient and procedural factors has been extensively investigated in the literature. Establishing optimal percutaneous access appears to be the key determinant of PNL-related blood loss [11]. There are also controversies regarding the method of initial puncture, which can be made by using either ultrasound or fluoroscopy guidance. Fascial, filiform dilators, Amplatz renal dilator set, Alken metal, co-axial dilators, a radially expanding single-step system and high-pressure balloon dilators are all alternatives for percutaneous tract formation. Studies further show that creating a smaller tract (i.e. mini-perc technique) may reduce bleeding.

We also advocate the role of the endourologist in performing percutaneous access, while preferring fluoroscopy-guided access in order to reach the desired calix by further planning the course of the operation under fluoroscopy. In addition, the same set of Alken dilator system was used in all cases, eliminating the impact of the method of percutaneous access formation in the present study.

In our study, by logistic regression analyses, only number of access points was significantly related to the occurrence of blood transfusion. The beta coefficient of regression analyses was greater than 1 if the stone size was lesser than 4cm and hence there was a trend towards no blood transfusion in patients with stones smaller than 4 cm. All other factors were not positively correlating to the chance of blood transfusion.

Other complications:

Though mortality after PCNL is an extremely rare occurrence, AhmetTefekli et al[21]have reported one death in their series of 811 cases and there were no deaths during the postoperative period in our study.PCNL in ADPKD and horseshoe kidneys have been found to have a satisfactorystone-free rate and acceptable morbidity[22,23]. Though in our study there were only 4 horseshoe kidneys and 4 cases of ADPKD all these patients did not experience any increase in morbidity.

V. Conclusions

5.1 Among the 166 PCNL that were performed during the study period, 7 renal units had significant residual calculi after multiple attempts at stone removal using both PCNL and ESWL sequentially. Hence the final success rate was 95.78%.

5.2 There were 75 simple renal calculi and 91 complex renal calculi and among the 91 complex renal calculi there were 46 staghorn calculi.

5.3 There were 63 supracostal punctures among the 166 renal units undergoing PCNL.

5.4 The stone clearance rates after PCNL for staghorn calculi were not dependent on the calyx of access, site of puncture and on the no of access points.

5.5 The incidence of pleural complications were 7(11.11%) among 63 patients with supracostal puncture out of which 6 required intercostal drainage (ICD) tube placement. All patients of pleural injury could be managed with ICD tube placement successfully and they recovered well.

5.6 Regarding blood transfusion, after using multimodal logistic regression analyses, there was a significantly increased chance of blood transfusion if more than one access was made during PCNL

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