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Surgical Training in Percutaneous Nephrolithotomy: The Learning Curve

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Abstract

Objective: It is also well-known that percutaneous nephrolithotomy (PCNL) is a difficult surgical technique with reported long learning curves. To determine the number of percutaneous nephrolithotomy (PCNL) operations which are required to achieve competence or excellence.

Materials and Methods: Two hundred and ten consecutive PCNL operations performed by single surgeon, with no previous experience in performing solo PCNL, were studied. Operation duration, stone extraction percent, stone-free rate, number of access, tubeless cases, and complications were studied in sequential groups of 20 patients as the surgeon gained experience.

Results: Operation duration decreased from the mean of 84.67 ± 19.34 minutes in the first to 20th patients to 82.81 ± 11.47 minutes in the 21st to 40th patients, and then remained unchanged. Minor complications were only observed in the first to 40th patients. Stone extraction percent increase from the mean of 85.0% in the first to 20th patients to 95.29% in 91st to 105th patients. Percentage of patients with no residual fragments decreased from 85.0% in the first to 20th patients to 95.29% in the 91st to 105th patients. No statistically significant differences were observed in estimated blood loss or transfusion rate between sequential groups of subjects.

Conclusion: An improvement in operation duration was observed, and absence of complications was achieved after 40 cases. The improvement in stone clearance was observed up to the last subjects. Competence and excellence were achieved after 45th and 105th operations, respectively.

Keywords: Training; Percutaneous nephrolithotomy; Urolithiasis.

Introduction

Since introduction in 1976, percutaneous nephrolithotomy (PCNL) has revolutionized the stone surgery and has widely practiced all over the world, especially for large urinary stones (>2 cm) or stones for which other less invasive therapy (such as ESWL) has failed. Many modifications in this technique were later introduced that have made its learning process rather complicated and difficult [1]. However, despite more than 30 years of development, it remains a difficult procedure to learn. Moreover, despite being a very effective procedure for removing stones, the complication rate is higher than for other endoscopic procedures for managing stones, particularly in less experienced hands [2]. Therefore, there is a need to improve the training for PCNL, to maintain it as a safe and effective treatment for patients. Because it is a complicated procedure, urologist will need to perform a certain number of PCNLs to gain the necessary experience and skills to conduct the surgery competently. Knowing the mean number of cases needed to achieve surgical competence is important for planning surgical training. There are many variables used as markers to assess surgical competence, and hence for evaluating the surgical learning curve. Percutaneous Nephrostomy tube insertion for the drainage of an obstructed hydronephrotic kidney was first described in 1955 [3]. The elective dilation of a nephrostomy tract for the specific purpose of stone removal was not, however, introduced until 1976 by Fernstrom and Johansson [4]. Percutaneous stone extraction had been previously described in 1941 after a nephrostomy tube was created during open surgery [5]. The modern day technique of percutaneous nephrolithotomy (PCNL) was quickly adopted and by the early to mid-1980s, it had a more widespread use [6,7]. Initially used for smaller stones, fragmentation of large stones and their subsequent extraction was described later [8]. Few studies have been performed to investigate PCNL learning curve in which operation duration and radiology screening time were employed to determine the curve [9,10]. As suggested before, these markers are not the best indicators of clinical performance and there is still no consensus regarding the best practical clinical surrogate markers of performance in PCNL operations.

Materials and Methods

Two hundred and ten consecutive PCNL operations for removal of large renal stones performed by a single surgeon between March 2013 to December 2014 were studied prospectively. All patients signed a written informed consent, and we discussed with them in detail the potential side effects and complications prior to treatment. The study was approved by the local ethics committee. The surgeon was a graduated urologist who was trained for fellowship in endourology and had no previous experience of performing solo PCNL. He had experience in performing other endourology procedures like ureteroscopy, transureteral lithotripsy, and percutaneous ultrasound-guided nephrostomy. In our department, urology fellows first observe 30 operations, then, scrub as first aid in another 30 operations with a senior fellow, and thereafter, they perform PCNL while the senior fellow is scrubbed as first aid and interferes in case of any problem for another 30 operations. After the previous three steps, the fellow is allowed to perform solo PCNL unsupervised and asks for help if required. The studied PCNL operations were this latter group of unsupervised operations. Patients with body mass index (BMI) ≥ 30, patients with abnormal renal anatomy such as ectopic or horse shoe kidneys and a stone burden of more than 700 mm^2 were excluded from the study. The stone burden was measured as the product of the two dimensions on plain radiographs. All patients were evaluated with renal function test, hemogram, coagulation profile, urine routine, urine culture sensitivity and ultrasonography. An intravenous urography (IVU) was carried out in all to assess function and plan the puncture. Urinary tract infections detected preoperatively were treated according to antibiotic sensitivity. Computed tomography (CT) scan was performed in patients with history of open surgery. Patients with retrorenal colon in CT scan were candidate for open stone surgery. After general anesthesia, a 5 or 6 French (F) ureteral catheter was inserted and fixed to a Foley catheter. Patients were then turned into a prone position with special care for the pressure points. Transpapillary puncture was made preferably away from the previous incision site if any, using a three part needle (Angiomed 1.3mm (17.5G)) under fluoroscopy control after retrograde opacification of the pelvicaliceal system via ureteral catheter. An angle tip terumo wire was then positioned in the upper ureter. The tract was then dilated initially using serial Teflon dilators up to 10 Fr, followed by placement of Alken's rod. The subsequent tract dilation was performed by serial metallic or Teflon dilators. After Amplatz sheath insertion, nephroscopy was performed and stones were fragmented by a pneumatic lithotripter and removed. Normal saline was used for continuous irrigation. If there was a more than 2 cm residual stone that could not be accessed from the first tract, a second access was established. The fragmented calculi were removed using forceps or suction. On the table, complete clearance was ensured on fluoroscopy and direct nephroscopy. An adequate size nephrostomy was placed at the end of the procedure. Nephrostomy was removed on the second post-operative day after the check X-ray KUB and abdominal ultrasonography or CT scan (for radiolucent stones) were performed to determine the residual stones. The nephrostomy tract site was the dressed with sterile dressing. Patient was then discharged with the instructions to remove the dressing after 72 hours and follow-up after one week if asymptomatic. Patient's age, sex, body mass index (BMI), stone burden, laterality, operative duration, length of hospital stay, number of attempts before successful entry into collecting system, stone free rate (SFR) and intra-operative and post-operative complications rate were compared between three groups.

Results

All the patients were divided into three groups. First 20 patients were included in Group-1. 21 to 40^{th} patients were included in Group-2 and 41^{st} (n=170) patients onwards were included in Group-3. All the 3 groups were comparable in terms of Body mass index (BMI), stone laterality, number of stones, opacity, stone burden and the preoperative hydronephrosis, which is shown in Table 1. Mean operative time for Group 1 was longer (84.67 ± 19.34 min) as compared to Group- 2 (82.81 ± 11.47 min) and Group 3 (78.83 ± 9.62 mints), which was statistically significant. The Attempts to access the pelvi-calyceal system (PCS) in Group-1 patients was higher and was 3.72 ± 1.43 compared to and 2.48 ± 0.91 in Group 2 and 2.14 ± 1.26 in Group-3 respectively, and this was statistically significant (P< 0.0001), which is shown in Figure 1. Table 2 also compares the complications within the three groups. Overall intraoperative bleeding was encountered in 15% (3/20) in Group-1, 10.00% (2/20) in Group-2, and 3.53% (6/170) in Group-3 patients requiring blood transfusion. Bleeding responded to conservative measures. Injury to adjoining organ colon on the right side was noted in one (6.6%) in Group-2, who developed severe sepsis and died on fifth post-operative day. None of our patients developed pseudo aneurysms, However, 3(15.00%) patients in Group 1, 2 (10.00%) in Group-2, and 6 (3.53%) in Group-3 developed Pneumothorax and who required chest drain placement. All these patients had upper calyeal second puncture for stone clearance. 5 (20.0%) of Group-1, 3 (15.0%) in Group-2, and 6 (3.53%) in Group-3 patients developed postoperative fever and that was attributed to pyelonephritis. These patients were treated conservatively with injectable antibiotics (first-generation cephalosporin and aminoglycoside) until they were afebrile and then switched over to oral therapy (oral quinolone) to complete two weeks of medication. Auxillary procedures such as second look PCNL and SWL were performed in 1.72 ± 1.53 in Group-1, 1.61 ± 0.76 in Group-2, and 1.24 ± 0.71 in Group-3 patients. Stone extraction percent increase from the mean of 85.0% in the first to 15^{th} patients to 95.29% in 91^{st} to 105^{th} patients. Percentage of patients with no residual fragments decreased from 85.0% in the first to15^{th} patients to 95.29% in the 91^{st} to 105th patients, which is shown in Figure-2. No statistically significant differences were observed in estimated blood loss or transfusion rate between sequential groups of subjects.

Table 1: Demographic profile of patients in all the three groups.

Parameters	**Group 1** (n = 20)	**Group 2** (n = 20)	**Group 3** (n = 170)	***Total*** *(n = 210)*	**p value**
Mean Age *(years)*	36.57 ± 12.46	41.48 ± 13.78	38.74 ± 12.28	38.79 ± 12.84	0.457
SEX					
Males	13 (10.0%)	12 (9.23%)	105 (80.77%)	130 (61.9%)	0.945
Females	7 (8.75%)	8 (10.0%)	65 (81.25%)	80 (38.1%)	
BMI *(kg/m²)*	26.7 ± 3.65	28.9 ± 7.64	27.2 ± 6.31	27.31 ± 5.87	0.465
Stone size *(cm)*	2.93 ± 1.53	3.41 ± 2.83	2.97 ± 1.61	3.01 ± 1.98	0.557
Stone Side					
Right	9 (9.28%)	7 (7.22%)	81 (83.51%)	97 (46.19%)	0.559
Left	11 (9.73%)	13 (11.50%)	89 (78.76%)	113 (53.81%)	
Location of Stone					
	4 (6.67%)	6 (10.0%)	50 (83.33%)	60 (29.13%)	
CalycealPyelocalyceal	8 (8.89%)	9 (10.0%)	73 (81.11%)	90 (43.69%)	0.986
Pelvic	4 (7.14%)	5 (8.93%)	47 (83.93%)	47 (27.18%)	
Number of Stones					
Single	15 (9.55%)	16 (10.19%)	126 (80.25)	157 (74.76%)	0.848
Multiple	5 (9.43%)	4 (7.55%)	44 (83.02%)	53 (25.24%)	
Opacity					
Radioopaque	15 (9.38%)	16 (10.00%)	129 (80.63%)	160 (76.19%)	0.912
Radiolucent	5 (9.43%)	4 (8.00%)	41 (82.00%)	50 (23.81%)	

Preoperative hydronephrosis					
None	5 (10.87%)	5 (10.87%)	36 (78.26%)	46 (21.90%)	
Mild	5 (10.87%)	5 (10.87%)	47 (82.46%)	57 (27.14%)	0.994
Moderate	5 (10.87%)	5 (10.87%)	45 (81.82%)	55 (26.19%)	
Severe	5 (10.87%)	5 (10.87%)	42 (80.77%)	52 (24.76%)	

Table 2: Results and complications in all the three groups

Parameters	**Group1 (n = 20)**	**Group 2 (n = 20)**	**Group-3 (n= 170)**	***Total (n = 210)***	**pvalue**
Mean Operative Time *(minutes)*	84.67 ± 19.34	82.81 ± 11.47	78.83 ± 9.62	79.77 ± 13.67	*0.037**
Fluoroscopic screening times	6.14 ± 2.57	5.73 ± 2.69	4.81 ± 1.83	5.02 ± 2.37	0.006*
Access attempts	3.72 ± 1.43	2.48 ± 0.91	2.14 ± 1.26	2.32 ± 1.20	< 0.0001*
Secondary tract	3.37 ± 1.22	2.23 ± 0.87	1.98 ± 0.55	2.14 ± 0.87	< 0.0001*
Auxiliary procedures	1.72 ± 1.53	1.61 ± 0.76	1.24 ± 0.71	1.32 ± 0.98	0.014*
Average Drop in Hb(*gm%*)	1.28 ± 0.51	1.16 ± 0.35	0.98 ± 0.71	1.03 ± 0.52	0.108
Bleeding(Intra-op)	3(15.00%)	2 (10.00%)	6 (3.53%)	11 (5.24%)	0.056
Blood Transfusion	2 (10.0%)	1 (5.00%)	8 (4.71%)	11 (5.24%)	0.603
Pseudoanurysm	0(0%)	0(0%)	0(0%)	0(0%)	---
Pneumothorax	3(15.00%)	2 (10.00)%	6 (3.53%)	11 (5.24%)	0.056
Renal pelvic injury	1 (5.0%)	0	0	1 (0.48%)	0.008*
Damage to adjoining colon	0	1 (5.0%)	0	1 (0.48%)	0.008*
Post-Operative Fever	5 (20.0%)	3 (15.0%)	6 (3.53%)	13 (6.19%)	0.003*
Stone Clearance	17 (85.0%)	18 (90.0%)	162 (95.29%)	197 (93.81%)	0.148
Hospital stay *(days)*	3.34 ± 1.09	3.23 ± 1.21	2.96 ± 0.87	3.02 ± 1.07	0.131

** Significant*

Figure 1: Comparison of fluoroscopic screening times, access attemptsand auxiliary procedures in all three groups.

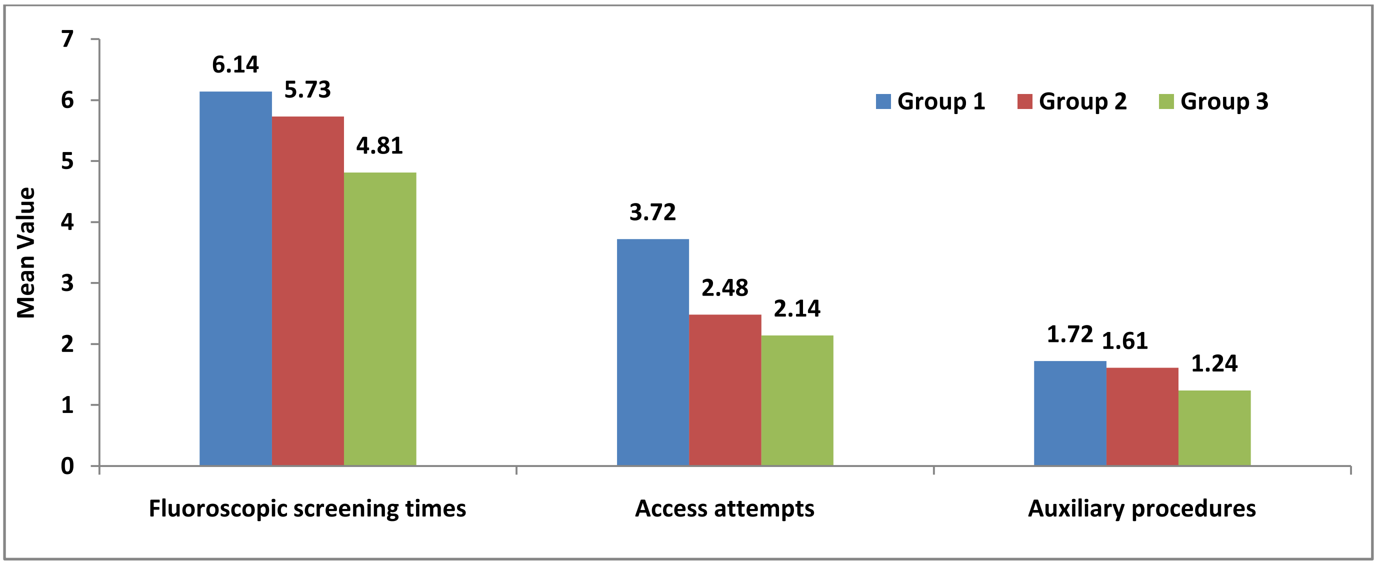
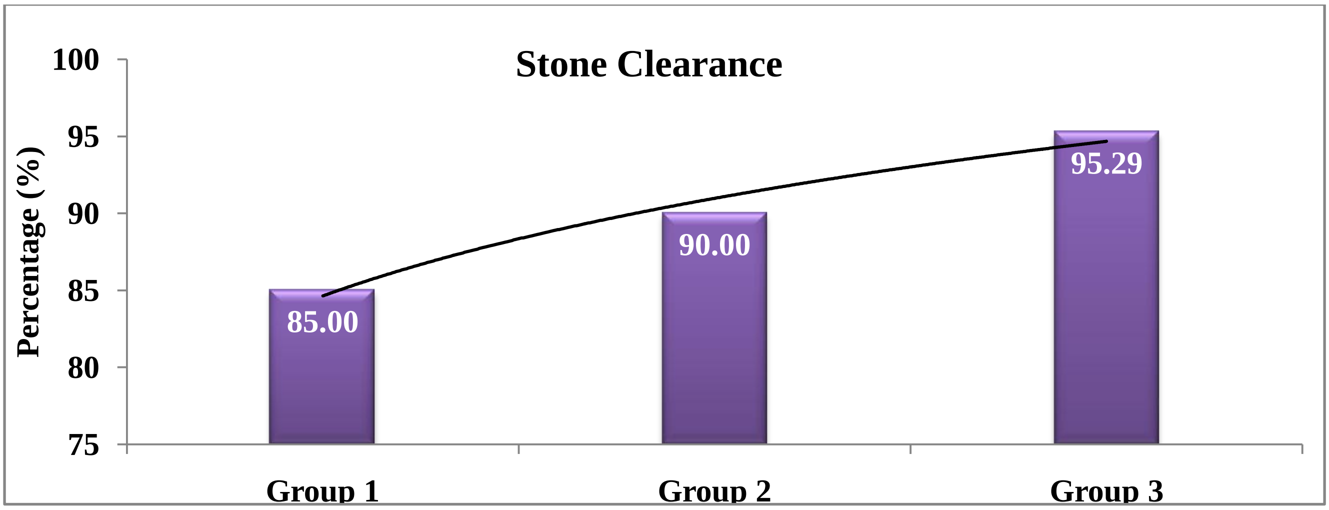


Figure 2: Comparison of stone clearance in all three groups



Discussion

PCNL is the preferred choice of treatment for large (>2 cm) renal or staghorn renal stones [11]. The planning and successful execution of the initial access into the kidney is crucial to the outcome of PCNL. In many institutions (especially in western hemisphere), the kidney is accessed by an interventional radiologist in the radiology department, requiring PCNL to be astaged procedure. A recent American survey revealed that only 11% of urologists performing PCNL routinely obtained percutaneous access by themselves [12]. Although a large proportion of urologists have the capability to acquire access tracts for these procedures,very commonly accessing the tract for PCNL is delegated to interventional radiologists, either separately or as a combined procedure. The reasons are mainly due to the steep learning curve to acquire the necessary skills for obtaining the PCNL tract [13]. The urologist's ability to access the kidney in the operating room, permitting PCNL to be carried out in one stage, is advantageous for several reasons. The urologist's selection of the optimum tract based on the intrarenal anatomy and the ability to make secondary tracts as required, and permits more effective stone removal [14]. Wattersonet al. also found access-related complications were fewer and stone-free rates improved when the urologist made the percutaneous access [12].

The PCNL procedure has a steep learning curve and if not performed properly, can be associated with a high complication rate in the beginning of the experience [15]. Adequate training during residency or fellowship is paramount to increasing the number of urologists obtaining their own access for PCNL [16]. Lee and colleagues examined the effect of residency training in percutaneous access on clinical practice [17]. Not surprisingly, urologists trained in percutaneous access during residency were significantly more likely to perform percutaneous procedures in clinical practice compared to untrained urologists. Thus, increasing residency training in percutaneous access should increase the number of urologists obtaining their own percutaneous access. To define the learning curve for PCNL there are some potential surrogate markers which include stone clearance rate, complication rate, operation time, fluoroscopic screening time, and radiation dose. Using these markers, it has been suggested that competence at performing PCNL is reached after 60 cases and excellence is obtained after 115 cases [10].

Tanriverdi et al. have studied the learning curve of one surgeon prospectively, using many parameters, including stone-free rate and complication rate [9]. The two markers showing improvement were the operation time and the fluoroscopic screening times. No further decrease in the operation time was observed after case number 60. A drop in the mean fluoroscopy screening time was observed from a peak of 17.5 ± 3.2 min in the first 15 cases to 8.9 ± 4.3 min for cases 46 through 60. This decline continued in cases 61-104 but was not significant. These authors suggested that competence in PCNL is obtained after 60 cases. A survey in the United States showed that residents were comfortable with percutaneous access after an average of 21.2 ± 4.5 access procedures [17]. A minimum of 20-25 cases of PCNL need to be performed by the resident under structured apprenticeship to make the resident competent and confident. Several models have been developed to train urologists in the art of PCNL [16]. Our study shows that competence in PCNL was achieved by the residents after a minimum of 30 cases. We used many parameters, including stone-free rate, complication rate, the OT time and fluoroscopy time to assess the learning curves. Several models have been developed to train urologists in the art of PCNL [18]. Surgical stimulation is being increasingly considered for training and testing. Presently two types of surgical stimulators exist, inanimate and VR virtual stimulators [19]. Several groups have described an ex-vivo model for percutaneous procedures using porcine kidneys preimplanted with makeshift calculi and surrounded by chicken carcasses.

Using these methods, the porcine ureter can be cannulated and air pyelogram or contrast media can be infused in a retrograde fashion to facilitate percutaneous access, stone manipulation/removal, and endopyelotomy [20-22]. Though the model is inexpensive, introducing animal organs in an operating room and the lack of kidney motion will limit application of this bench model. Since 1995, manually positioned and fully automated robots were introduced to assist in providing renal access for PCNL procedure; however, the size and complexity precluded their use in routine clinical practice [23]. Recently, a new technique using a portable mechanical gantry with a needle guiding device, C-arm fluoroscopy, and a laptop computer containing the software and graphic user interface for selecting the targeted calyx has been established [24]. Although the last technique is portable, light-weight, and simple to set up and operate, providing accuracy in gaining calyceal access, the cost of manufacturing is very high and, most importantly; it was tested on synthetic and animal models only. The ability to secure a safe and precise percutaneous access is an essential step in performing PCNL, and many techniques to establish renal access have been described in the literature[25]. Shergill et al., identified an easy technique to establish the correct depth of initial percutaneous needle insertion which they have labelled it as ‘‘the 3-Finger Technique.’’ They have successfully used this technique to demonstrate and teach PCNL access [26]. The trainees were able to achieve percutaneous access without immediate or late complications. Despite the fact that several devices have evolved as educational tools, it needs to be determined whether these tools can be used for validation of surgeon’s skills.

Conclusion

PCNL is an effective but complicated procedure, with a difficult learning curve. To perform the procedure with competence, an urologist must have a good understanding of the surgical anatomy and the principles of the instruments, through a structured programme, workshops and master classes. Facing the challenge of restricted working hours during surgical training, a new training approach is needed to maintain the standard of surgical skills training. While the traditional apprenticeship approach is still the key for establishing experience in the procedure, the use of various models and stimulators can help to shorten the learning curve for PCNL. Continuous medical education and training will also be essential to practising urologists, to improve the standard of their practice.

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