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Study of Correlation between Intrarenal Pressure and Post-Operative Complications in Percutaneous Nephrolithotomy

Chitaranjan Shah[1*], Arbind Kumar Shah[1], Prabodh Regmi[1], Robin Bahadur Basnet[1], Anil Shrestha[1] and Parash Mani Shrestha[1]

[1]Department of Urology, National Academy for Medical Sciences, Bir Hospital, Kathmandu, Nepal.

Authors' contributions

This manuscript is the collaboration of all the authors. Author CS has designed the outline of the manuscript and the production of the first version. Authors RBB, PR, AKS, AS and PMS have helped to collect data and bibliographic research and have supervised the work. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: Even after constant advancement and miniaturization in percutaneous nephrolithotomy complications are evident. Stone burden, pre-operative microbiological status of urine, comorbidity, age, operative time, intra-operative level of sterility and antibiotic prophylaxis are commonly discussed risk factors for post-operative complications during percutaneous nephrolithotomy. Assessment of relationship between intra renal pelvic pressure and the complications was the aim of this study.

Materials and Methods: A prospective study was undertaken in patients undergoing percutaneous nephrolithotomy under fluoroscopic guidance during twelve months' duration. The demographic characteristics, body mass index, stone characteristics (burden, density and number), rise in intrarenal pressure in relation to position of surgery, different energy sources used and size of tract, duration of operation and perioperative complications during percutaneous nephrolithotomy were recorded and the findings and outcome analyzed.

**Corresponding author: Email: drchitaranjan@gmail.com;*

Results: Out of 125 patients, intrarenal pelvic pressure was found to be raised >30 mmHg in 72.8% (91 cases). Forty-one patients (32.8%), developed fever, found to be significantly associated with raised intrarenal pelvic pressure >30 mmHg, (P = 0.01). WBCs counts were significantly high among the raised intrarenal pelvic pressure group. Age of the patients, gender, body mass index and hospital stay were insignificant variables for development of fever in relation with rise in intrarenal pelvic pressure. Stone burden, prolonged duration of surgery, prone position of surgery and use of pneumatic lithotripsy were significant variables causing rise in intrarenal pelvic pressure.

Conclusion: Raised intrarenal pelvic pressure (> 30 mmHg) in association with increased stone burden, prolonged duration of surgery, prone position and pneumatic lithotripsy during percutaneous nephrolithotomy are significant risk factors for the development of post-operative complications mainly fever.

Keywords: Complications; fever; intra-renal pelvic pressure; renal stone; percutaneous nephrolithotomy.

1. INTRODUCTION

Percutaneous nephrolithotomy (PCNL) is the recommended treatment for renal stones more than 2 cm. Though the advancement and miniaturization of instruments of PCNL has significantly reduced the morbidity and mortality, infection and bleeding are still most common complications. PCNL is categorized as a clean-contaminated or contaminated surgery. Post-operative bacteriuria usually occurs in renal stone patients with pre-operative sterile urine [1].

During PCNL, the outflow is mainly through the interspace between the scope and the sheath and through the ureteral catheter. Reduction in outflow may lead to increased intra renal pelvic pressure. In the landmark canine study of Hinman and Redewill, pyelovenous backflow occurred at renal pressures above 30 to 35 mmHg [2]. Persistent high IRP can cause systemic fluid absorption through pyelovenous-lymphatic backflow, pyelotubular backflow, and forniceal rupture.

Absorption of infected stone debris and bacteria released from an infected stone upon disintegration may lead to bacteremia, postoperative fever and occasionally, septicemia [3]. The incidence of septic shock after PCNL is 1%, although this has a mortality rate as high as 66-80% [4]. In clinical practice, maintaining an IRP of less than 30mm Hg is recommended during percutaneous intrarenal procedures [5].

A significant number of PCNL is done in our institution and infective complication is the commonest. Therefore, we realized the necessity for this study at our center.

2. MATERIALS AND METHODS

A prospective study was conducted at the Department of Urology, Bir Hospital, from May 2019 to April 2020 (12 months) among patients with nephrolithiasis undergoing PCNL and who gave consent were included in the study. Patients who had bilateral procedures, operative time of more than 60 minutes and culture positive urine sample, those needing multiple tracts for puncture and age below 14 years were excluded from the study.

Ethical clearance was obtained from the Institution Review Board of National Academy of Medical Sciences, Bir Hospital, Kathmandu, Nepal. Pre-operatively, patients were assessed in the Department of Urology, Bir Hospital and demographic parameters of the patients, history, and physical examination were documented. CT KUB or CT IVU was obtained for all the patients. Stone burden was calculated (area) by multiplying the longest length with the perpendicular length in millimeter square unit (mm^2). For a patient with multiple stones, all stones were measured individually, and the sum was used as cumulative stone burden. Preoperative investigations were done including urine culture and sensitivity. Patients with growth in urine culture were prescribed 7 days of oral antibiotic according to sensitivity and urine cultures were repeated. Patients showing growth even after initial course of antibiotics were admitted and injectable antibiotic started 3 days prior to surgery. The variables were extracted from a study conducted at Department of Urology, Bir Hospital by Basnet RB (2018) [6].

2.1 Operative Technique

All the surgeries were performed by three experienced urologists. All the procedures were

done under spinal anesthesia. Prophylactic antibiotic (Ceftriaxone 1 gm) was given at the time of anesthesia. After spinal anesthesia, patient was placed in lithotomy position and an open tip ureteral catheter (6 French) was inserted in the ipsilateral renal pelvis under fluoroscopic guidance. Foley's urethral catheter was inserted, and ureteral catheter secured loosely to it. Patient was then positioned prone. Diluted contrast medium (Urograffin 76%, Bayer Zydus Pharma, India) was injected through the ureteral catheter to dilate and opacify the pelvicalyceal system. The transpapillary puncture was done under fluoroscopic guidance in two planes using two-part 18 G needle. After the confirmation of tip of the needle entry into the collecting system with free flow of clear saline, 0035" hydrophilic straight tip guide wire (Terumo) was inserted and negotiated down into the ureter and parked.

The tract dilatation was done by single step technique with the Amplatz system to the desired tract size. Rigid nephroscope (21 French, Richard Wolf) or rigid nephroscope (12 French, Karl Storz GmbH, Germany) was used.

Once the tract was established, the external open end of the ureteral catheter was connected to the IBP channel of IMEC-15 patient monitor (Mindray Medical Corporation, Shenzhen, China) with a baroceptor. The baroceptor was fixed at the horizontal plane of renal pelvis; after a zero adjustment, intra renal pelvic pressure was recorded each second, and the duration of raised IRP was obtained.

The stones were fragmented with pneumatic lithotripter (Nidhi Meditech Systems, India) and fragments removed by irrigation flow. Large fragments were grasped and extracted using forceps.
The free flow through the ureteral catheter was regularly checked. The exit strategies were total tubeless, tubeless or standard as per the decision of operating surgeon.

Postoperatively, patients were managed with IV fluids, antibiotic, analgesic and proton pump inhibitor (PPI). On the first post-operative day, change in hemoglobin level (gm %), total count and differential counts (TC/DC) and fever (Temperature >38^{0C} or >100.4^{0F}) were recorded. Patients were discharged after 48 hours or when they were clinically stable.

Patients were divided into 2 groups based on intraoperative rise in IRP and postoperative fever. Data analysis was done using the Statistical Packages for Social Sciences version 23 (IBM Corp., Armonk, NY, USA). Baseline characteristics were compared using the Chi-square test/Fisher's exact test for categorical variables and the Student's t-test/ Mann Whitney U test for continuous variables. A p-value less than 0.05 was considered statistically significant.

3. RESULTS

A total of 142 patients underwent PCNL during the study period. Seventeen patients were excluded due to operating time >60 minutes (n=10), requirement of multiple tracts (n=5) and age less than 14 years (n=2). Included in the final analysis were 125 patients.

Out of 125 patients, who qualified for the study, male to female ratio was 2.2:1. IRP elevated more than 30 mmHg was seen in 91 (72.8%) and 34 (27.2%) had less than 30 mmHg. Mean age and mean BMI were found statistically insignificant when both groups were compared, whereas stone areas were found to be significantly larger and duration of surgery significantly longer among the group with IRP more than 30 mmHg.

Table 1. Basic characteristics of patients

	IRP >30 mmHg group (N=91)	IRP < 30 mmHg group (N=34)	P-value
Male/Female	61/30	25/9	
Mean Age, Years (range)	40.13±13.75	36.56±12.66	0.190
Mean BMI Kg/m^2	23.45±3.8	23.32±2.18	0.854
Mean Stone Burden, mm^2 (range)	318.32±139.11	250.50± 87.28	0.002
Duration of Surgery	41.60±11.32	35.74±10.59	0.010

Table 2. Comparison of IRP in different tract sizes, energy sources used and position in PCNL

Variables	Mini-PCNL (n=113)	Standard PCNL (n=12)	P value	Pneumatic (n=116)	Shock pulse (n=9)	P value	Prone (n=100)	Supine (n=25)	P value
Cumulative duration of IRP >30 mmHg (seconds) <50 (n=31) >50 (n=60)	24 56	7 4	0.105 0.957	26 59	5 1	0.001	19 57	12 3	0.002
IRP < 30 mmHg group (n=34)	33	1		31	3		24	10	

Majority of the patients underwent Mini-PCNL (n=113) with no statistically significant difference among the two groups in relation to the duration of raised IRP duration. Twenty-four patients had IRP >30 mmHg for less than 50 seconds in mini PCNL and 7 out of 12 in standard group. However, 56 patients out of 91 had cumulative duration of IRP >30 mmHg of >50 seconds in Mini-PCNL and 4 out of 12 in standard PCNL group.

A total of 116 patients underwent PCNL by using pneumatic lithotripsy and the remaining 9 underwent PCNL using ultrasonic lithotripsy (shock pulse). A significant number of patients in shock pulse group had raised IRP duration for less than 50s.

One hundred patients underwent PCNL in prone position and 25 patients in supine position. A significantly high number of patients (n=57) patients in the prone position had raised IRP >30 mmHg for accumulated duration of more than 50s.

Forty-one patients developed post-operative fever out of 125 patients. In the raised IRP, >30 mmHg group, 36 out of 91 patients developed fever which was statistically significant compared to the IRP <30 mmHg group (P = 0.006).

Mean duration of hospital stay, white blood cell counts and change in hemoglobin level were found statistically insignificant, as illustrated in Table 3.

As depicted in Table 4, the complications, according to Clevien-Dindo classification were 41 (32.8%); out of which 65.9% were grade 1, mostly fever and had opioid analgesics, 22.0% were grade 2 and 12.2% % had grade 3.

Table 3. Post-operative variables in relation to IRP

	IRP >30 mmHg (N=91)	IRP <30 mmHg (N=34)	P value
Mean duration of hospital stay (days)	2.6±1.2	2.3±0.9	0.93
Total counts	9814±2539	9244±3260	0.305
Hemoglobin change (gram)	3.16±1.98	1.95±1.11	0.476

Table 4. Post-operative complications according to modified Clevien-Dindo classification

Complications	Elevated IRP group (n=91)	Normal IRP group (n=34)	p-value
Total	36	5	
Clavien grade 1	24	3	0.005
Clavien grade 2	8	1	
Clavien grade 3a	3	1	
Clavien grade 3b	1	0	
Clavien grade 4a	0	0	
Clavien grade 4b	0	0	

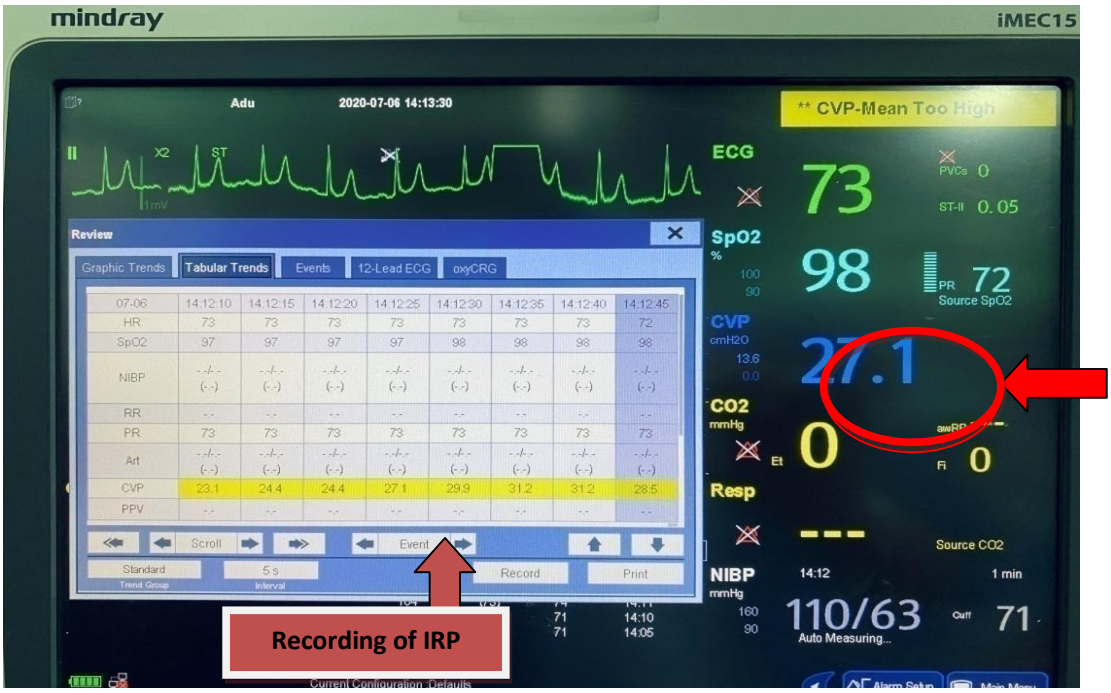

Image 1. IMEC-15 Mindray patient monitor showing IRP values and other recordings

4. DISCUSSION

With the dramatic increases in the incidence and prevalence of kidney stone disease , the use of PCNL to treat a large stone burden has continued to increase [7]. Success of stone removing surgery is measured by duration of surgery, stone free rate, complications, hospital stay, and cost.

Infectious complications after PCNL are common but in most of the cases no causative agent can be identified. Although serious infections resulting in severe sepsis and septic shock are rare, these complications may potentially result in life-threatening conditions [8].

During PCNL, a continuous pressurized irrigation is used to washout blood clots and debris to maintain clarity of vision and for active removal of the stone fragments after lithotripsy [9,10].

There are several studies reported on post PCNL fever, quoting different results with incidence ranging between 10%-32% [1,11]. In this study, a postoperative fever (>38.0°C) was recorded in 41 out of 125 cases. The occurrence of postoperative fever was 32.8% (41 out of 125 patients) which was similar to the rate of 39.8% reported by Gutierrez et al [4] and 26% that of Troxel and Low [12]. However, in our observation this rate fell to 19.2% (24 out of 125 patients) after 24 hours of PCNL.

In a randomized single-blind trial, Omar et al [13] randomized patients between low (80 mm Hg) and high (200 mm Hg) pressure irrigation during PCNL. They found that high pressure irrigation increased the risk of postoperative systemic inflammatory response syndrome. They did not directly measure IRP but instead relied on externally pressurized irrigation fluid.

Troxel and Low [12] directly measured IRP using a ureteral occlusion balloon catheter and a urodynamic system during PCNL. They demonstrated baseline and elevated pressures (26% greater than 30 mm Hg) like those obtained during their study (35% greater than 30 mm Hg). In contrast to the study by Omar et al, Troxel and Low did not find an association of IRP 30 mm Hg or greater with postoperative fevers [12,13]. In our study, IRP >30 mmHg was noted in 91/125, 72.8% (p=0.006), out of which 39% (36/91) developed fever. Cheng Wu et al [14] found significant association of higher IRP and increased incidence of postoperative fever where 43.83% (100 out of 228 patients) had IRP >30 mmHg and 28 patients developed fever. They asserted that the longer accumulated time of IRP

>30 mmHg for more than 60 seconds forecast postoperative fever.

The impact of stone burden as a risk factor for post PCNL fever is clear and confirmed by several studies [15–17] and in this study increase in stone burden showed significant rise in IRP (P = 0.002), a major risk factor facilitating the development of post PCNL fever.

In comparative studies of mini-PCNL and standard PCNL by Zhong wen et al [18] and Cheng Wu et al, [14] both showed that mini-PCNL was associated with higher IRP and significantly associated with postoperative fever. In this study, most of cases, 113/125 (90.4%) were mini-PCNL and we could not find statistical significance among them. Ninety two percent of postoperative fever was among mini-PCNL. Though only 10% of the tracts were of standard size, the IRP remained within the physiological range.

Liangren Liu and et al [17] in their systematic review and meta-analysis of two RCTs and two case control studies including 389 patients, it was found that PCNL in the supine position took a shorter operative time than the prone position, but both positions appeared to be equivalent with regard to the stone-free rate and over all complication rate, although fever occurred less commonly (OR: 0.39; 95% CI: 0.13-1.16; P = 0.09).

Falahatkar S and et al [19] mentioned in their prospective analytical cross sectional study of supine PCNL of 330 patients, fever occurred in 7.5 % (25 out of 330 patients) which was not found statistically significant. In this study, the IRP was found significantly lower among the supine group where 10/25 had no rise in IRP>20mmHg compared to 22/25 (P=0.000). In the patients in the supine position, the access sheath remains angled towards the horizontal in comparison with the prone position which reduces pressure in the collecting system and thus facilitating the stone fragments to wash out through the sheath.

Therefore, in this study, it was observed that in most of the patients with supine position, the IRP didn't rise above 30 mmHg and the rate of having fever was significantly lower among them, at 4/41, 9.7% (P=0.035).

In this study, the rise in IRP remained significantly lower (P=0.001) with accumulated time less than 50 seconds when Ultrasonic Lithotripsy (shock pulse) was used. Though there were relatively fewer number of cases in the shock pulse group, 9/125, only two among these patients developed fever, which didn't show statistical significance (P=0.483). Shock pulse fragments stones into small pieces and can aspirate these particles through the hollow bore of the transducer, which eliminates manual stone extraction. Due to the aspiration mechanism through the hollow probe of shockpulse, the IRP remained low [19].

Backflow may contribute to the postoperative fever. Systemic fluid absorption can occur through pyelovenous-lymphatic backflow, pyelotubular backflow, and forniceal rupture [20]. Dogan and et al [5] reported that 21% (17 out of 81 patients) had a postoperative fever, and the absorption of perfusion fluid was a high risk factor. In the landmark canine study of Hinman and colleagues, pyelovenous backflow occurred at renal pressures above 30 to 35 mmHg [2].

In our study, we did not directly measure pyelovenous backflow. However, the more accumulated time of raised IRP was observed among the group with increased duration of surgery. The duration of surgery was found significantly high among the IRP >30 mmHg group of patients which is 41.60 $\pm$ 11.32 vs 35.74 $\pm$ 10.59 minutes (P=0.010). Duration of surgery is a risk factor for post PCNL fever. So the prolonged rise in IRP enhances the systemic absorption of fluid and postoperative fever [21].

This study was conducted in a single center within a short period of time and with a relatively small number of patients are the limitations of this study. Further multi institutional study with larger cohort is recommended for better validation of results.

5. CONCLUSION

Raised intrarenal pressure (>30 mmHg) is significant risk factor for the development of post-operative complications of fever. Large stone burden, prolong duration of surgery, prone position and lithotripsy technique without suction like pneumatic lithotripsy may be associated with increased incidence of raised intrarenal pressure.

DISCLAIMER

The products used for this research are commonly and predominantly used products in our area of research and country. There is

absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

Informed written consent was obtained from all patients.

ETHICAL APPROVAL

The authors have obtained all necessary ethical approval from Institutional Review Board (IRB). This confirms either that this study is not against public interest, or that the release of information is allowed by legislation. All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. A copy of Institutional Ethical Approval letter has been submitted with the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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