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PRE-OPERATIVE AND INTRA-OPERATIVE FACTORS THAT INFLUENCE DEVELOPMENT OF SYSTEMIC INFLAMMATORY RESPONSE SYNDROME (SIRS) FOLLOWING PERCUTANEOUS NEPHROLITHOTOMY (PCNL)

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ABSTRACT

Background: Percutaneous nephrolithotomy (PCNL) is the preferred surgical treatment for large renal calculi but carries a risk of post-operative Systemic Inflammatory Response Syndrome (SIRS), which may lead to sepsis. Identifying pre-operative and intra-operative factors that predispose patients to SIRS can aid in risk reduction and improve surgical outcomes.

Method: A prospective observational study was conducted on 120 patients undergoing PCNL between January and December 2024 in a rural South Indian hospital. Patients aged 21–60 years with renal stones >2 cm were included. Preoperative urine cultures, inflammatory markers (CRP, NLR), HbA1c, serum creatinine, and intra-operative variables such as operative time and irrigation were recorded. Postoperative monitoring included vital signs and laboratory markers. SIRS was diagnosed based on established clinical criteria.

Result: The incidence of SIRS was 5% (6/120). SIRS patients had significantly elevated heart rate, respiratory rate, temperature, WBC count, and lower blood pressure ($p<0.05$). Risk factors included prolonged operative time (90 vs 83 minutes, $p=0.03$), larger stone size (29.6 mm vs 22.3 mm, $p=0.003$), elevated HbA1c (7.8% vs 5.6%, $p=0.002$), and serum creatinine (1.4 vs 1.1 mg/dL, $p=0.015$). E. coli was the most commonly isolated organism. Vancomycin and higher antibiotics were required in the SIRS group compared to the non-SIRS group, which responded well to ceftriaxone.

Conclusion: SIRS following PCNL can be minimized with proper preoperative optimization, infection control, and surgical technique. Key risk factors include diabetes, larger stone burden, prolonged surgery, and positive stone cultures. Focused perioperative strategies can reduce infectious complications post-PCNL.

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) is the ideal surgery of choice for large renal stones (>2 cm), staghorn calculi or stones refractory to other minimally invasive approaches. It was first introduced as a therapeutic option for renal stones in 1976 by Johansson and Fernström [1]. Despite its effectiveness, PCNL carries a risk of serious complications, notably **Systemic Inflammatory Response Syndrome (SIRS)**, a clinical condition characterized by fever or

hypothermia, tachycardia, tachypnea, and leukocytosis or leukopenia. Postoperative SIRS can evolve into sepsis and is associated with increased morbidity, prolonged hospitalization, and even mortality. It's incidence is reported to range from 9.8 to 37% [2]. Although rare, about 0.25–4.7% of the post-PCNL patients further progress into severe sepsis and uroseptic shock [3]. It is thus highly essential to identify high risk patients both during and before surgery. The **etiopathogenesis of SIRS** post-PCNL is complex and multifactorial. **Pre-operative factors** such as advanced age, female sex, poor glycemic control, chronic kidney disease, and immunosuppressed states predispose patients to infectious complication. Elevated preoperative neutrophil-to-lymphocyte ratio (NLR) and C-reactive protein (CRP) have been recognized as reliable predictors of SIRS, reflecting systemic inflammation even before surgery [4]. **Stone-related variables**, including larger stone burden, staghorn calculi, and presence of infection stones, pose a higher risk due to the bacterial biofilms harbored within the stone matrix, which can be disrupted during surgery, releasing endotoxins. Urinary tract infection or colonized stones with urease-producing organisms like *Proteus mirabilis* and *Klebsiella* are strong risk contributors [5].

Intra-operative factors play a significant role in triggering SIRS. Prolonged operative time leads to extended renal pelvic pressure and increases the risk of pyelovenous or pyelolymphatic backflow**,** facilitating systemic absorption of bacteria and endotoxins [6]. Use of multiple access tracts or excessive irrigation further exacerbates this risk. Given the potential severity of SIRS and its progression to life-threatening conditions like septic shock, early identification of modifiable risk factors and targeted perioperative strategies are essential. These include preoperative urine sterilization, limiting operative time, minimizing tract numbers, controlled irrigation pressures, and prompt postoperative monitoring. A clearer understanding of the interplay between preoperative and intra-operative variables can lead to better risk stratification models and evidence-based protocols to mitigate infectious morbidity following PCNL.This study aimed to understand the incidence of SIRS post PCNL and categorize risk factors so as to minimize the occurrence.

MATERIALS and METHODS

Study Design and Source of Data: This prospective observational study was conducted in the Department of Urology at a Rural Hospital in South India between January 2024 and December 2024 over a period of 12 months. After obtaining Institutional Ethics Committee approval and informed consent, a total of 120 patients undergoing **P**ercutaneous Nephrolithotomy were enrolled.

Inclusion Criteria:

- Adult patients aged 21–60 years.
- Radiologically confirmed renal calculi >2 cm or staghorn calculi.
- Normal coagulation profile and fitness for General Anaesthesia.

Exclusion Criteria:

- Patients with known immunosuppression or chronic steroid use
- Co-existing malignancy, pregnancy, or congenital renal anomalies
- Patients undergoing combined endoscopic procedures or with incomplete data
- Pregnancy

All patients underwent PCNL under **General Anaesthesia** in the prone position. After initial cystoscopy and insertion of a 5 Fr ureteral catheter, contrast pyelography was performed to delineate the pelvicalyceal system. Percutaneous access was achieved under fluoroscopic guidance, targeting the posterior lower calyx. The tract was dilated using Alken metal dilators up to 24 Fr, and a 24 Fr Amplatz sheath was placed. Nephroscopy was performed using a rigid 20.8 Fr nephroscope. Stone fragmentation was achieved using either pneumatic or ultrasonic lithotripsy. Stone fragments were retrieved using graspers. Complete clearance was confirmed by nephroscopic and fluoroscopic evaluation. A 16 Fr nephrostomy tube was placed postoperatively in all patients. In selected cases, a double-J stent was also inserted based on surgeon discretion. Patients were monitored in the postoperative unit with regular recording of vital signs and urine output. Complete blood counts, serum creatinine, and inflammatory markers (CRP, NLR) were measured on

postoperative day 1. Nephrostomy output was monitored and removed once urine was clear and afebrile. Ultrasound KUB was done on day 2 or 3 to assess for residual fragments or complications. Criteria for SIRS:SIRS was defined based on **Standard Clinical Criteria**:

- Body temperature >38°C or <36°C
- Heart rate >90 beats/min
- Respiratory rate >20 breaths/min or $PaCO_2$ <32 mmHg
- White blood cell count >12,000/mm³, <4,000/mm³, or >10% immature (band) forms
- Presence of any two or more of the above within 48 hours postoperatively was diagnostic of SIRS.

Statistical Analysis: Data were analyzed using **SPSS software version 26**. Quantitative variables were expressed as mean ± standard deviation and analyzed using **unpaired Student's t-test**. Categorical variables were compared using the **Chi-square test or Fisher's exact test**. A p-value of **<0.05** was considered statistically significant.

OBSERVATIONS AND RESULTS

Table 1 - Distribution based on Gender

Gender	Number of Patients (n)	Percentage (%)
Male	101	84.2%
Female	19	15.8%
Total	120	100%

As seen in Table 1, 101 patients were male and 19 were female.

Table 2 - Distribution based on Age

Age Group (Years)	Number of Patients (n)	Percentage (%)
21–30	17	14.2%
31–40	34	28.3%
41–50	38	31.7%
51–60	31	25.8%
Total	120	100%

As seen in Table 2, 31.7% patients belonged to the age group of 41-60 which was the highest in the study population

Table 3 - Diagnostic Parameters in the first 48 hours post surgery

Parameter	SIRS Group (n=6)	Non-SIRS Group (n=114)	p-value
Heart Rate (bpm)	102.5 ± 7.8	84.3 ± 8.6	<0.001
Respiratory Rate (/min)	23.8 ± 2.1	17.5 ± 2.3	<0.001
Temperature (°C)	38.7 ± 0.5	36.8 ± 0.6	<0.001
WBC (×10³/µL)	15.1 ± 2.2	8.4 ± 1.9	<0.001
Systolic BP (mmHg)	102.2 ± 9.3	121.4 ± 11.6	0.002
Diastolic BP (mmHg)	64.5 ± 6.1	78.6 ± 8.4	0.001
Operative Time (min)	90 ± 14	83 ± 7	0.03
Stone Size (mm)	29.6 ± 5.4	22.3 ± 4.9	0.003
HbA1c (%)	7.8 ± 1.2	5.6 ± 0.9	0.002
Serum Creatinine (mg/dL)	1.4 ± 0.3	1.1 ± 0.2	0.015

As seen in Table 3, the Heart Rate/Respiratory Rate/Temperature/White Cell counts and Blood Pressure were higher in the patients who developed SIRS (5%) as compared to the ones who did not develop SIRS (95%). The p-value was significant in the Paired Student t-test for the presence of SIRS and also for the various parameters ($p<0.05$).The operative time, a major detrimental factor was also high in the SIRS group as compared to the non-SIRS group ($p<0.05$).The bigger the size of stone, the higher is the perative time and that poses for higher chance of SIRS ($p<0.05$). It was also seen that higher Serum Creatinine and HbA1c predisposed to more complications ($p<0.05$). As seen in Table 4, Escherichia coli is the most common organism isolated. Among the 6 patients, 4 patients (66.67%) had a positive culture of the same organism prior to the surgery which makes it a compelling evidence. Among the 6 patients who developed SIRS, 4 were female and 2 were male ($p<0.05$). As seen in Table 5, Cephalosporins were used in 90 patients (75%) proving that it is an ideal fist list drug in the post-operative period of PCNL. Vancomycin was needed in the treatment of 1 patient who developed SIRS.

Table 4 - Various bacteria isolated in individuals developing SIRS

Pre-op Urine Culture	Intra-op Urine Culture	Stone Culture	Organism Identified
Positive	Positive	Positive	Escherichia coli
Negative	Negative	Positive	Klebsiella pneumoniae
Positive	Positive	Positive	Proteus mirabilis
Negative	Negative	Positive	Pseudomonas aeruginosa
Positive	Negative	Positive	Enterococcus faecalis
Positive	Positive	Positive	E. coli (ESBL-producing)

Table 5 - Various Antibiotics used in the post-operative period

Antibiotic Used	SIRS Group (n=6)	Non-SIRS Group (n=114)
Ceftriaxone	2	88
Piperacillin-Tazobactam	1	16
Meropenem	1	1
Amikacin (adjunctive)	1	9
Vancomycin	1	0

DISCUSSION

In this prospective study, the **incidence of SIRS was 5% (6/120)**, which is much lower than many previously reported rates (10–35%) but aligns well with more contemporary data reflecting improved peri-operative and post-operative protocols. In a study conducted in 2024, Lan et al. observed 17.2% SIRS among 303 patients who underwent mini-PCNL with controlled irrigation pressure [7]. In contrast, lower rate in this study may reflect tight intraoperative irrigation control and strict antibiotic protocols. Ideal aseptic measures and proper use of antibiotic regimes can help in decreasing the development of SIRS. This study correlates well with the fact that females are more prone for the development of SIRS post PCNL as reported by Aghdas et al in 2006 [8]. It does not correlate well with the study done in 2019 by Kamal et al where the males had more incidence [9]. Such discrepancies can be attributed to the immunity of each individual and does not pose great value to the surgery. As per a study in 2025 conducted by Fang et al, prolonged operation time ($p = 0.040$; OR, 1.054; 95% CI, 1.005–1.107) and high white blood cell count ($p = 0.041$; OR, 1.004; 95% CI, 1.000-1.008)predisopsed to higher incidence of SIRS [10]. This aligns well with the findings presented here. All six SIRS patients in this study had positive stone cultures, with organisms ranging from *E. coli*, *Klebsiella*, *Proteus*, *Pseudomonas*, to *Enterococcus*—mirroring findings from Xu et al in 2022 [11], where *E. coli* and *Proteus mirabilis* comprised 53.6% and 10% of isolates respectively. They also concluded that antibiotic therapy exceeding seven days should be appropriate before PCNL in patients with positive urine cultures. In 2025, Zheng et al showed no significant difference in SIRS between pre-op sterilized versus non-sterile urine cultures after ≥5 days of antibiotics [12]. They also concluded that achieving a negative UC before PCNL is not a necessary condition. Patients with positive urine cultures can safely undergo surgery after 5 days or more of sensitive antibiotic treatment without the need for a negative result. This aligns well with findings presented here wherein 66.67% of affected patients had a positive urine culture before surgery. This study prioritized controlled irrigation pressure (<30 mmHg) and single-tract dilation. Lan et al [7] found multi-tract procedures as an independent risk factor in the development of SIRS. As reported by Mishra et al in 2023, renal pelvic urine culture intra-operatively helps in identifying an active ongoing infection and saving time with regard to the correct antibiotic to be used for treatment [13]. This policy has been used in this study and thus the outcomes are better than previous literature. The antibiotic usage differed notably between our groups: SIRS patients more often required

Piperacillin-Tazobactam (66%), **Meropenem (33%)**, and adjunctive **Amikacin (50%)**, versus prophylactic **Ceftriaxone** in 77% of non-SIRS cases. A study performed in 2015 by Wei et al concluded that the comorbidity of diabetes was significantly associated with an increasing incidence of both infectious and major postoperative complications after PCNL [14]. This correlated well with our study wherein the affected individuals had a higher HbA1c. This can be attricuted to the resistance created to the functioning of antibiotics by the high sugar levels.

CONCLUSION

This study reinforces that the incidence of post-PCNL SIRS can be minimized (~5%) in patients with the use of controlled operative techniques and appropriate perioperative antibiotics. Key risk factors include positive stone cultures, uncontrolled irrigation and extended operative times. Integrating intraoperative culturesand evidence-based antibiotic regimens is paramount. The main high risk factors identified included longer surgical time, excessive use of irrigation, Diabetes Mellitus and size of the Renal Stone.

LIMITATIONS

As this was a single-center study, modest cohort design limits statistical power, particularly for low-incidence events. Also, culture-based antibiotic sensitivity may not identify fastidious or anaerobic pathogens. Future multi-centric trials can evaluate tailored irrigation pressure and optimized antibiotic durations in high-risk populations.

CONFLICT OF INTEREST

The authors report no Conflict of Interest of any kind.

DECLARATIONS

The study protocol for medical research involving human subjects was approved by the local ethics committee under the latest Declaration of Helsinki. This article does not contain any studies with animals performed by any of the authors.

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