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Comparative Study of Hemodynamic Changes in Prone Position in Normal Versus Chronic Kidney Disease Patient in Percutaneous Nephrolithotomy Surgery

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ABSTRACT

Background: Percutaneous nephrolithotomy is commonly performed in the prone position, which can lead to significant hemodynamic alterations. Patients with chronic kidney disease may respond differently due to underlying cardiovascular and autonomic changes.
Objective: To compare hemodynamic changes in prone position between normal patients and chronic kidney disease patients undergoing percutaneous nephrolithotomy.
Methods: A prospective randomized study was conducted on 100 patients divided into two groups of 50 each: normal patients and chronic kidney disease patients. Hemodynamic parameters including heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure were recorded at baseline, after induction, immediately after prone positioning, and at regular intervals intraoperatively.
Results: Both groups showed a decline in hemodynamic parameters following prone positioning; however, the reduction was significantly greater in normal patients compared to chronic kidney disease patients. CKD patients demonstrated higher baseline values and relatively stable intraoperative parameters. The differences were statistically significant at multiple time intervals.
Conclusion: Prone positioning during percutaneous nephrolithotomy causes significant hemodynamic changes, with more pronounced effects observed in normal patients. Chronic kidney disease patients exhibit relative hemodynamic stability, likely due to compensatory physiological mechanisms. Careful monitoring is essential to ensure perioperative safety.

***Keywords**: Percutaneous nephrolithotomy, prone position, hemodynamic changes, chronic kidney disease.*

INTRODUCTION

Percutaneous nephrolithotomy (PCNL) has emerged as the gold standard surgical procedure for the management of large and complex renal calculi, offering high stone clearance rates with relatively minimal invasiveness compared to open surgery. Over the past decade, advancements in surgical techniques and anesthetic management have significantly improved patient outcomes; however, intraoperative physiological alterations, particularly hemodynamic changes, remain a critical concern during PCNL procedures, especially when performed in the prone position [1,2].

The prone position, traditionally preferred for PCNL due to improved access to the posterior calyces and enhanced surgical ergonomics, is associated with significant cardiovascular and respiratory alterations. Transition from supine to prone position leads to increased intra-abdominal and intrathoracic pressures, reduced venous return, decreased cardiac output, and potential alterations in systemic vascular resistance. These physiological changes may predispose patients to intraoperative hypotension, reduced organ perfusion, and hemodynamic instability, particularly under general anesthesia [3,4]. Furthermore, prone positioning may also influence pulmonary mechanics by reducing lung compliance and increasing airway pressures, thereby indirectly affecting cardiovascular performance [5].

Patients with chronic kidney disease (CKD) represent a particularly vulnerable population in the perioperative setting due to their impaired renal function and associated systemic comorbidities such as hypertension, anemia, electrolyte imbalance, and cardiovascular dysfunction. CKD is characterized by altered fluid homeostasis, endothelial dysfunction, and autonomic dysregulation, all of which can significantly impact hemodynamic stability during anesthesia and surgery [6,7]. Moreover, these patients often exhibit reduced physiological reserve, making them more susceptible to perioperative complications including hypotension, arrhythmias, and acute kidney injury [8].

In the context of PCNL, the interplay between surgical positioning and pre-existing renal impairment becomes clinically significant. While prone positioning itself may compromise hemodynamics, its effects may be further exaggerated in CKD patients due to their altered cardiovascular responsiveness and impaired compensatory mechanisms. Maintenance of stable hemodynamics is particularly crucial in these patients to prevent further deterioration of renal function and ensure adequate tissue perfusion [9].

Recent studies have highlighted the importance of careful intraoperative monitoring and individualized anesthetic management to mitigate the risks associated with prone positioning, especially in high-risk populations such as CKD patients. Comparative evaluations of hemodynamic responses between normal individuals and CKD patients undergoing PCNL remain limited but are essential for optimizing perioperative care and improving surgical outcomes [10].

Therefore, the present study was undertaken to compare the hemodynamic changes associated with prone positioning in normal patients versus those with chronic kidney disease undergoing percutaneous nephrolithotomy, with the aim of identifying clinically relevant differences that may guide anesthetic and perioperative management strategies.

MATERIAL AND METHODS

This study was conducted after obtaining approval from the Institutional Ethics Committee and was designed as a prospective randomized comparative study carried out over a period from January 2021 to January 2023. A total of 100 patients of either sex, aged between 18 to 60 years and belonging to American Society of Anesthesiologists (ASA) physical status I to III, scheduled for elective percutaneous nephrolithotomy (PCNL), were included in the study.

Patients were divided into two groups based on renal status. Group A consisted of normal patients, while Group B included patients diagnosed with chronic kidney disease (CKD). Patients aged between 18 to 60 years of either sex undergoing elective PCNL were included in the study. Patients with uncontrolled coagulopathy, pregnancy, immunodeficiency, ASA grade IV and V, cardiac disease, respiratory impairment with PaO_2 less than 60 mmHg on room air, and those below 18 years of age were excluded from the study.

All patients underwent thorough preoperative evaluation including detailed history taking with emphasis on comorbid conditions, drug allergies, and current medications. A complete physical examination, including general and systemic examination, was performed. Baseline laboratory investigations included complete blood count, renal function tests, random blood sugar, serum electrolytes, coagulation profile, and urine analysis. Additional investigations such as chest X-ray and electrocardiogram were performed for all patients. Intravenous pyelography was carried out to assess stone characteristics.

Patients were kept nil per oral for 6–8 hours prior to surgery. In CKD patients, morning antihypertensive medications were continued, and serum potassium along with arterial or venous blood gas analysis was performed on the day of surgery. Upon arrival in the operation theatre, standard ASA monitors including electrocardiogram, noninvasive blood pressure, pulse oximetry, and temperature monitoring were attached. A peripheral intravenous cannula, preferably 18-gauge, was secured. In CKD patients, intravenous fluids were administered cautiously using normal saline according to allowable fluid replacement following fasting.

All patients in both groups received balanced general anaesthesia. Premedication was administered with glycopyrrolate at a dose of 0.004 mg/kg, ondansetron at 0.15 mg/kg, and fentanyl at 2 µg/kg intravenously. Prophylactic intravenous antibiotics were given to all patients. Induction of anaesthesia was achieved using thiopentone sodium at a dose of 3–4 mg/kg, followed by administration of atracurium 0.5 mg/kg to facilitate endotracheal intubation. Intravenous lignocaine 1.5 mg/kg was administered prior to laryngoscopy to attenuate the stress response.

Anaesthesia was maintained with a mixture of oxygen, air or nitrous oxide, and isoflurane at a concentration of 1–2%, along with intermittent doses of atracurium for muscle relaxation. Controlled ventilation was provided using a ventilator to maintain end-tidal carbon dioxide around 35 mmHg. Continuous intraoperative monitoring of heart rate, blood pressure, oxygen saturation, end-tidal carbon dioxide, and temperature was carried out at regular intervals.

Following induction of anaesthesia, patients were initially placed in lithotomy position for retrograde pyelography and urinary catheterization, after which they were repositioned into the standard prone position for PCNL. Care was taken to ensure proper positioning and padding to avoid pressure-related complications. Hemodynamic parameters including heart rate and blood pressure were recorded at baseline, immediately after positioning in prone position, and subsequently at 30 minutes, 1 hour, and 2 hours after prone positioning.

At the end of the procedure, neuromuscular blockade was reversed using neostigmine at a dose of 0.05 mg/kg along with glycopyrrolate at 4 µg/kg. Postoperative analgesia was provided using intravenous paracetamol along with peritubal block. The sample size was determined based on pilot observations in consultation with a statistician, indicating that approximately 20–23 patients per group would be required to achieve a power of 0.80 for detecting clinically significant changes in heart rate and mean arterial pressure. Considering a possible dropout rate of 5%, the final sample size was fixed at 100 patients.

Statistical analysis was performed using SPSS version 20. Continuous data were expressed as mean ± standard deviation. Both parametric and non-parametric tests were applied as appropriate. Independent t-test and Mann–Whitney test were used for comparison of continuous variables, while categorical data were expressed as frequencies and percentages and analyzed using Chi-square test. A p-value of less than 0.05 was considered statistically significant.

RESULTS

In the present study, a total of 100 patients were divided equally into two groups, with 50 normal patients (Group A) and 50 chronic kidney disease patients (Group B). Table 1 shows the gender distribution among both groups. Out of 100 patients, 76 were males and 24 were females. Group A had 36 males and 14 females, while Group B had 40 males and 10 females. The p-value was 0.92781, indicating no statistically significant difference between the groups, suggesting that both groups were comparable in terms of gender distribution.

Table 2 presents the age-wise distribution of patients. The majority of patients were in the age group of 51–60 years, with 21 patients in Group A and 26 patients in Group B. The least number of patients were in the 18–30 years category. The p-value was 0.46826, which is statistically insignificant, confirming that both groups were comparable with respect to age distribution.

Table 3 depicts the comparison of mean heart rate between both groups at different time intervals. At baseline, mean heart rate was higher in CKD patients (91.16 ± 3.783) compared to normal patients (87.32 ± 3.206). After induction and positioning, heart rate gradually decreased in both groups. However, at 30 minutes and 1 hour after prone positioning, the heart rate remained significantly higher in CKD patients (87.32 ± 2.715 and 87.18 ± 2.558) compared to normal patients (85.42 ± 2.779 and 84.10 ± 2.461), with statistically significant p-values (<0.001), indicating altered hemodynamic response in CKD patients.

Table 4 shows the comparison of systolic blood pressure between both groups. At baseline, systolic blood pressure was higher in CKD patients (137.56 ± 4.723) compared to normal patients (130.6 ± 4.209). After induction and prone positioning, systolic blood pressure showed a declining trend in both groups; however, the reduction was more pronounced in normal patients. At 1 hour after prone position, systolic blood pressure in normal patients was 109.56 ± 2.854 compared to 119.86 ± 3.848 in CKD patients, with statistically significant p-values (<0.001), indicating greater hemodynamic fluctuation in normal individuals.

Table 5 demonstrates the comparison of mean arterial pressure between both groups. At baseline, MAP was higher in CKD patients (107.04 ± 3.852) compared to normal patients (101.48 ± 3.598). Following prone positioning, MAP decreased in both groups; however, a more significant decline was observed in normal patients. At 1 hour after prone position, MAP was 83.4 ± 2.566 in normal patients compared to 91.84 ± 3.341 in CKD patients, with statistically significant p-values (<0.001), suggesting that normal patients experienced more pronounced hemodynamic changes compared to CKD patients.

Table 1: Gender Distribution

SEX	GROUP-A (NORMAL PT)	GROUP-B (CKD PT)	TOTAL
MALE	36	40	76
FEMALE	14	10	24
TOTAL	50	50	100

Table 2: Age Distribution in Group A and Group B

AGE	GROUP-A (NORMAL PT)	GROUP-B (CKD PT)	TOTAL

18-30	9	1	10
31-40	10	9	19
41-50	10	14	24
51-60	21	26	47
TOTAL	50	50	100

Table 3: Comparison of Mean Heart Rate in Both Groups (Mean ± SD)

HEART RATE	GROUP A (NORMAL PT)	GROUP B (CKD PT)	P VALUE
BASELINE	87.32 ± 3.206	91.16 ± 3.783	<0.001
PREINDUCTION	89.22 ± 2.454	90.68 ± 3.192	0.0119
AFTER INDUCTION/LITHOTOMY	86.92 ± 2.645	88.92 ± 3.009	0.0006
PRONE POSITION	86.22 ± 2.75	87.02 ± 2.816	0.1538
30 MIN AFTER PRONE POSITION	85.42 ± 2.779	87.32 ± 2.715	<0.001
1 HR AFTER PRONE POSITION	84.10 ± 2.461	87.18 ± 2.558	<0.001

Table 4: Comparison of Systolic Blood Pressure in Both Groups (Mean ± SD)

SBP	GROUP A	GROUP B	P VALUE
BASELINE	130.6 ± 4.209	137.56 ± 4.723	<0.001
PREINDUCTION	136.06 ± 4.261	139.52 ± 4.01	0.0001
AFTER INDUCTION/LITHOTOMY	130.84 ± 2.913	134.64 ± 3.731	<0.001
PRONE POSITION	121.52 ± 2.447	127 ± 4.006	<0.001
30 MIN AFTER PRONE POSITION	115 ± 2.633	123.2 ± 4.136	<0.001
1 HR AFTER PRONE POSITION	109.56 ± 2.854	119.86 ± 3.848	<0.001

Table 5: Comparison of Mean Blood Pressure in Both Groups (Mean ± SD)

MAP	GROUP A	GROUP B	P VALUE
BASELINE	101.48 ± 3.598	107.04 ± 3.852	<0.001
PREINDUCTION	106.16 ± 3.531	109.1 ± 3.348	<0.001
AFTER INDUCTION/LITHOTOMY	101.26 ± 2.6	103.98 ± 3.104	<0.001
PRONE POSITION	108.98 ± 30.662	97.18 ± 3.18	0.0080
30 MIN AFTER PRONE POSITION	87.68 ± 2.349	94.5 ± 3.493	<0.001
1 HR AFTER PRONE POSITION	83.4 ± 2.566	91.84 ± 3.341	<0.001

DISCUSSION

The present study was conducted to compare the hemodynamic changes occurring in normal patients and chronic kidney disease (CKD) patients undergoing percutaneous nephrolithotomy (PCNL) in the prone position. The findings of the study demonstrate that both groups experienced significant hemodynamic alterations following induction and prone positioning; however, these changes were more pronounced in normal patients compared to CKD patients. This observation highlights the differential physiological responses in patients with underlying renal pathology.

In the present study, baseline heart rate, systolic blood pressure, diastolic blood pressure, and mean arterial pressure were consistently higher in CKD patients compared to normal individuals. This finding can be attributed to the underlying pathophysiology of CKD, where chronic hypertension and increased sympathetic activity are commonly observed. Mohta et al. reported similar findings, demonstrating that patients undergoing PCNL may exhibit significant cardiovascular responses due to fluid shifts and stress response during surgery [11]. The elevated baseline parameters observed in CKD patients in our study further support the presence of pre-existing cardiovascular alterations in this population.

Following induction of anesthesia and transition to prone position, both groups exhibited a decline in heart rate and blood pressure parameters. However, the reduction was significantly greater in normal patients, particularly at 30 minutes and 1 hour after prone positioning. This can be explained by the physiological effects of prone positioning, which include decreased venous return due to inferior vena cava compression, reduced cardiac output, and increased intrathoracic pressure. Dabrowski et al. highlighted that prone positioning leads to increased intra-abdominal pressure, which significantly affects venous return and cardiac output, thereby contributing to hemodynamic instability [12].

The findings of the present study also demonstrate that mean arterial pressure decreased more prominently in normal patients compared to CKD patients during the intraoperative period. This observation is consistent with the study conducted on patients undergoing spine surgery, where significant reductions in stroke volume and cardiac index were noted in the prone position, resulting in decreased arterial pressure [13]. The relatively attenuated decline in CKD patients may be due to chronic vascular changes, including increased systemic vascular resistance and reduced vascular compliance, which help maintain blood pressure despite positional changes.

Furthermore, studies evaluating positional effects on cardiovascular physiology have shown that prone positioning can lead to redistribution of blood volume and activation of compensatory mechanisms such as increased sympathetic tone and peripheral vascular resistance. Pump et al. demonstrated that although cardiac output may decrease in the prone position, mean arterial pressure can be maintained through increased systemic vascular resistance [14]. In CKD patients, this compensatory mechanism may be exaggerated due to pre-existing hypertension, thereby explaining the comparatively lesser decline in hemodynamic parameters observed in this group.

Another important observation in the present study was that the changes in systolic and diastolic blood pressure were statistically significant at multiple time points, particularly after induction and during sustained prone positioning. These findings are supported by reports of sudden hemodynamic compromise in prone position due to venous pooling and obstruction of venous return, as described by Park et al., who emphasized the role of inferior vena cava compression in causing hypotension [15]. Such mechanisms may explain the progressive decline in blood pressure observed in the normal group over time.

Overall, the present study demonstrates that while prone positioning during PCNL leads to significant hemodynamic alterations in both normal and CKD patients, the magnitude of these changes is greater in normal individuals. The relatively stable hemodynamic profile in CKD patients may be attributed to chronic adaptive mechanisms such as increased vascular tone and altered autonomic regulation. These findings underscore the importance of careful intraoperative monitoring and individualized anesthetic management, particularly during position changes in PCNL procedures.

CONCLUSION

The present study concludes that prone positioning during percutaneous nephrolithotomy results in significant hemodynamic changes in both normal and chronic kidney disease patients. However, the degree of variation in heart rate and blood pressure parameters is more pronounced in normal patients compared to CKD patients. CKD patients exhibit relatively stable hemodynamic parameters, likely due to chronic compensatory mechanisms such as increased systemic vascular resistance and baseline hypertension. These findings emphasize the need for vigilant monitoring and tailored anesthetic management during prone positioning to prevent perioperative complications and ensure patient safety.

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