Section: Medicine

Original Research Article

ANALYSIS OF CLINICAL AND INVESTIGATIONAL PROFILE OF SYSTEMIC ENVENOMATION WITH HUMP NOSED PIT VIPER

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ABSTRACT

Background: The aim is to study the clinical profile, laboratory abnormalities, and outcomes of patients with systemic envenomation following hump-nosed pit viper (Hypnale hypnale) bites presenting to a tertiary care centre in North Kerala.

Materials and Methods: This Prospective observational study-cross sectional was conducted in Department of General Medicine (OP and IP patients), Government Medical College, Kozhikode for the duration of 1.5year from ethical committee clearance of the study(december 2024-july 2026). A total of 46 patients aged >13 years with confirmed hump-nosed pit viper bites were included. Clinical features, laboratory parameters, and outcomes were recorded. Statistical analysis was performed using SPSS, with associations assessed using Chi-square and Fisher's exact tests, and multivariable logistic regression used to identify predictors of AKI.

Results: The mean age was 42.98 ± 15.86 years, with a male predominance (73.9%). Most bites occurred during the monsoon season (67.4%) and involved the lower limb (67.4%). AKI developed in 33% of patients, with 9% requiring dialysis. Bleeding manifestations were observed in 30% of cases. Laboratory abnormalities included prolonged clotting parameters (mean INR 2.17 ± 1.20), elevated LDH and CPK, and thrombocytopenia. Albuminuria (46.7% vs 3.2%, $p<0.01$), elevated CPK (>600 IU/L), elevated LDH (>480 IU/L), microangiopathic hemolytic anemia, hypotension at presentation, and delayed hospital presentation (>6 hours) were significantly associated with AKI. Multivariable analysis identified albuminuria and elevated CPK as independent predictors. The 20-minute whole blood clotting test showed moderate sensitivity (72.9%) but poor specificity (11.1%) for detecting coagulopathy. Mortality was 4%.

Conclusion: Hump-nosed pit viper envenomation is associated with significant morbidity, particularly due to AKI. Early identification of high-risk patients using markers such as albuminuria and elevated muscle enzymes, along with prompt supportive care, is crucial in improving outcomes. Reliance solely on bedside clotting tests may be inadequate, and laboratory monitoring remains essential.

Keywords: Hump-nosed pit viper, Hypnale hypnale, snakebite, acute kidney injury, coagulopathy, envenomation, Kerala.

INTRODUCTION

Snakebite envenomation is a major public health problem in tropical and subtropical regions of the world, particularly in South and Southeast Asia. The World Health Organization has recognized snakebite envenomation as a neglected tropical disease due to its high morbidity, mortality, and socioeconomic impact, especially among rural and agricultural populations.[1]

India accounts for a substantial proportion of the global snakebite burden, with an estimated 46,000–

58,000 deaths annually, in addition to a large number of non-fatal envenomations resulting in significant disability.[2]

India is home to a wide diversity of venomous snakes, with more than 60 species considered medically important. Traditionally, clinical attention has focused on the so-called —Big Four snakes— Indian cobra (Naja naja), common krait (Bungarus caeruleus), Russell's viper (Daboia russelii), and saw-scaled viper (Echis carinatus)—as they are responsible for the majority of severe envenomation and fatalities.[3]

However, increasing evidence suggests that other venomous species, particularly pit vipers, contribute significantly to snakebite morbidity, especially in certain geographical regions.

The hump-nosed pit viper (Hypnale species) has emerged as an important cause of snakebite envenomation in Sri Lanka and the Western Ghats region of South India, including Kerala. Three species of Hypnale are recognized: Hypnale hypnale, Hypnale nepa, and Hypnale zara. Among these, Hypnale hypnale is the only species reported from India and is responsible for most hump-nosed pit viper bites in the Indian subcontinent.[4]

The ecological conditions of the Western Ghats—characterized by heavy rainfall, dense vegetation, and extensive agricultural activity—facilitate frequent human–snake interactions, predisposing to snakebite incidents in this region.

Hump-nosed pit viper envenomation is clinically significant due to its variable and sometimes unpredictable systemic manifestations. The venom predominantly exhibits hemotoxic and cytotoxic effects. Venom-induced consumptive coagulopathy (VICC) is the most commonly reported systemic manifestation, characterized by prolonged clotting times and abnormalities in coagulation parameters. In addition, acute kidney injury (AKI) has been reported as a serious complication and may occur due to a combination of mechanisms including hemolysis, rhabdomyolysis, microangiopathy, hypotension, and direct nephrotoxic effects of the venom.[5]

The largest descriptive observational study on hump-nosed viper envenomation was conducted in Sri Lanka by Wijewantha and Sellahewa, involving 1543 patients. This study demonstrated that while local envenomation is common, systemic manifestations are not rare. Coagulopathy was observed in a significant proportion of patients, and acute kidney injury occurred in approximately 13% of cases, with a subset developing severe complications and mortality.[6]

These findings challenged the earlier perception that hump-nosed pit viper bites are relatively benign.

Management of hump-nosed pit viper envenomation poses unique challenges due to the lack of a species-specific antivenom. The currently available Indian polyvalent antivenom is manufactured using venoms from the —Big Four snake species and has limited or no efficacy against Hypnale venom.[7]

As a result, treatment remains largely supportive, emphasizing early detection and management of coagulopathy, renal involvement, and other systemic complications. This highlights the importance of careful clinical evaluation and appropriate laboratory monitoring in affected patients.

Despite the clinical importance of hump-nosed pit viper envenomation, there is a relative paucity of systematic data from India, particularly from Kerala. Most available evidence is derived from Sri Lankan studies, and regional differences in snake ecology, healthcare access, and clinical practices may influence the spectrum of envenomation and outcomes. There is therefore a need for region-specific studies focusing on the clinical profile, laboratory abnormalities, complications, and outcomes of patients with systemic envenomation due to hump-nosed pit viper bites.

The present study was undertaken to evaluate the clinical and investigational profile of patients with systemic envenomation following hump-nosed pit viper bites in a tertiary care center in North Kerala. By analyzing demographic characteristics, seasonal variation, clinical features, laboratory parameters, complications such as coagulopathy and acute kidney injury, and patient outcomes, this study aims to contribute region-specific evidence that may aid in early recognition, risk stratification, and improved management of hump-nosed pit viper envenomation.

MATERIALS AND METHODS

This Prospective observational study-cross sectional was conducted in Department of General Medicine (OP and IP patients), Government Medical College, Kozhikode for the duration of 1.5year from ethical committee clearance of the study(december 2024-july 2026)

Sample Size

Calculated using the formula 4pq/ d2

- d = precision = 6%
- p =prevalence of systemic features of envenomation in pit viper envenomation

=4.34% (according to a study conducted by Wijewantha HS, Sellahewa KH.

Hump-nosed viper bite in Sri Lanka: descriptive observational study of 1543 cases.)(1)

- q = 100 – p = 95.66 %
- Sample size = 46

Study Population:

Inclusion criteria:

1. All Patients more than 13 years with the snake being brought live or dead identified as hump nosed pit viper admitted in Medical wards and Medical ICU in the Department of General Medicine, Government Medical College Kozhikode

Exclusion criteria:

1. Unknown bites
2. Patients taking drugs causing haematological abnormalities like anticoagulant.

Method of Data Collection

Eligible patients satisfying the inclusion and exclusion criteria were recruited consecutively after obtaining written informed consent. Upon enrollment, a detailed clinical history was obtained, followed by thorough vital assessment, including temperature, pulse rate, blood pressure, respiratory rate, and urine output. A comprehensive systemic examination was performed with particular emphasis on cardiovascular, respiratory, nervous system, and gastrointestinal involvement to identify evidence of systemic envenomation.

Baseline laboratory investigations were obtained at admission for all patients and included complete blood count, prothrombin time with INR, activated partial thromboplastin time, whole blood clotting test, renal function tests, liver function tests, C-reactive protein, urine routine examination, electrocardiogram, chest X-ray, urine albumin-creatinine ratio, ultrasonography of the abdomen and thorax, and serum lactate dehydrogenase levels. A 4-hourly whole blood clotting test was performed to monitor evolving coagulopathy. Peripheral blood smear examination was carried out in patients with clinical or laboratory suspicion of hemolysis.

Patients who developed features of systemic envenomation were subjected to serial monitoring, including daily measurements of blood urea, serum creatinine, prothrombin time, and activated partial thromboplastin time. Urine output was closely monitored, and renal involvement was documented based on biochemical parameters and clinical course. All relevant clinical findings, laboratory results, and progression of systemic manifestations were recorded using a structured proforma through direct patient interviews, clinical examination, and review of investigation reports.

Plan of Data Analysis

1) Data will be entered in MS Excel
2) Analysis will be done using Statistical Software SPSS
3) Qualitative variables will be expressed in percentages.
4) Quantitative variables will be expressed in mean and Standard Deviation
5) Chi-Square test will be done to study the association between categorical variables.

RESULTS

Sociodemographic Analysis

Age Distribution

The age of patients in the present study ranged from 15 to 68 years, with a mean age of 42.98 ± 15.86 years. The majority of patients belonged to the middle-aged group, indicating that individuals in their economically productive years were most commonly affected. This observation suggests that occupational exposure and outdoor activity may play a significant role in the risk of envenomation. The relatively lower representation of extremes of age indicates that hump-nosed pit viper bites predominantly affect active adults rather than dependent age groups.

Sex Distribution

A marked male predominance was observed in the study population. Of the 46 patients, 73.9% were male, while 26.1% were female .

This gender disparity likely reflects increased outdoor exposure among men, particularly in agricultural and plantation-based occupations. Although females constituted a smaller proportion of cases, their presence indicates that domestic and peri-household activities may also carry a risk of snake encounters. The male predominance observed in this study aligns with established epidemiological patterns of snakebite in rural settings.

Seasonal Distribution

A clear seasonal variation was noted. The majority of cases occurred during the monsoon season (67.4%), whereas 32.6% occurred during the non-monsoon period.

This clustering of cases during the monsoon suggests a possible association with increased snake activity, flooding of habitats, and heightened agricultural work during this period. The rainy season may force snakes out of their natural shelters, increasing the likelihood of human encounters.

On month-wise analysis, the highest number of cases was recorded in July (28.3%), followed by June and August (13% each).

These findings further reinforce the strong seasonal pattern observed in the study. The concentration of cases in peak monsoon months suggests that environmental conditions during this period significantly influence the incidence of envenomation. Sporadic case during other months indicate that snakebite remains a year-round risk, albeit at lower frequency.

Time to Hospital Presentation

The majority of patients (80.4%) presented within 6 hours of the bite, while 19.6% presented after 6 hours .

Early presentation in most patients reflects good healthcare accessibility and awareness in the study region. Prompt hospital arrival is particularly important in venomous snakebites, as early monitoring and intervention may influence outcomes.

However, the delayed presentation in a subset of patients indicates that barriers such as transport, distance, or initial reliance on traditional remedies may still exist.

Clinical Observations

Site of Bite

In the present study, the lower limb was the most commonly involved site, accounting for 31 cases (67.4%), while the upper limb was involved in 15 cases (32.6%) .The predominance of lower limb bites suggests accidental encounters during walking in fields, plantations, or outdoor environments. This distribution pattern indicates that most bites likely occurred during routine occupational or agricultural

activities. Upper limb bites, though less frequent, may reflect handling activities or inadvertent contact with vegetation.

Bleeding Manifestations

Bleeding manifestations were observed in a subset of patients. The majority (69.6%) had no bleeding manifestations.

Among those with bleeding:

- Bleeding from bite site – 13.0%
- Gum bleeding – 6.5%
- Hematuria – 6.5%
- Ecchymosis – 2.2%
- Melena – 2.2%

The most common bleeding presentation was localized bleeding from the bite site. Systemic bleeding manifestations such as hematuria and gum bleeding were less frequent, suggesting that although coagulopathy may occur in hump-nosed pit viper envenomation, clinically significant systemic bleeding was not predominant in this cohort.

Table 1: Bleeding Manifestations

Bleeding manifestation	Frequency	Percentage
Bleeding from bite site	6	13%
Gum bleed	3	6.5%
Haematurea	3	6.5%
Echymoses	1	2.2%
Melena	1	2.2%
Nil	32	69.6%

Comorbidities

The majority of patients (60.9%) had no documented comorbidities . Among those with comorbid conditions:

- Diabetes mellitus (alone or combined) was present in 19.6%
- Hypertension (alone or combined) was present in 21.7%
- Coronary artery disease was observed in smaller proportions
- Dyslipidemia was noted in a few cases

The predominance of patients without comorbid illness suggests that snakebite risk in this cohort was largely environmental rather than disease-related so the disease burden comes mainly on healthy individuals.. However, the presence of metabolic and cardiovascular comorbidities in a subset of patients may have implications for clinical severity and complications such as AKI.

Laboratory findings

Bleeding manifestations were observed in 14 patients (30%). Albuminuria was present in 8 patients (17%), and schistocytes suggestive of microangiopathic hemolysis were seen in 4 patients (9%). Prolonged 20-minute whole blood clotting test (WBCT) was noted in 35 patients (76%) though in those patients inr or aptt was elevated.

Table 2: Mean and standard deviation of laboratory parameters in this study

Laboratory parameters	Mean ± SD
Hemoglobin (g/dL)	12.1 ± 1.4
WBC count	11.5 ± 3.4
Platelet count	193 ± 51
Serum Creatinine (mg/dL)	1.37 ± 0.92
INR	2.17 ± 1.20
LDH (IU/L)	447.6 ± 263.7
CPK (IU/L)	359.7 ± 161.5

15 patients developed AKI according to KDIGO criteria for AKI (33%).

Four patients (9%) required dialysis and two patients (4%) expired during hospital stay.

Comparison between AKI and non AKI groups

Patients were categorized into AKI (n=15) and Non-AKI (n=31) groups.

Albuminuria

Albuminuria was significantly more common among AKI patients.

7 out of 15 AKI patients (46.7%) had albuminuria compared to 1 out of 31 (3.2%) in the non-AKI group (χ^2, $p<0.01$).

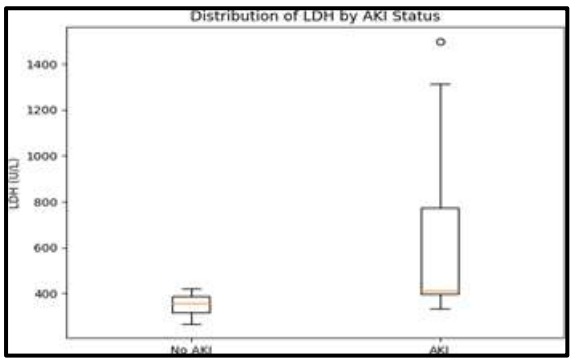
Thrombocytopenia (Platelets <150,000/mm³)

Using the updated cutoff of <150,000/mm³, thrombocytopenia was more frequent in AKI patients compared to non-AKI patients.

Albuminuria, thrombocytopenia (<150,000/mm³), MAHA, elevated CPK, and delayed presentation were more frequent among AKI patients. Leukocytosis and anemia showed weaker associations.

LDH AND CPK distribution by AKI status

Figure- box and whisker plot showing distribution of LDH by AKI status.



LDH levels were significantly higher in AKI patients compared to non-AKI patients. All patients with LDH >480 IU/L developed AKI.

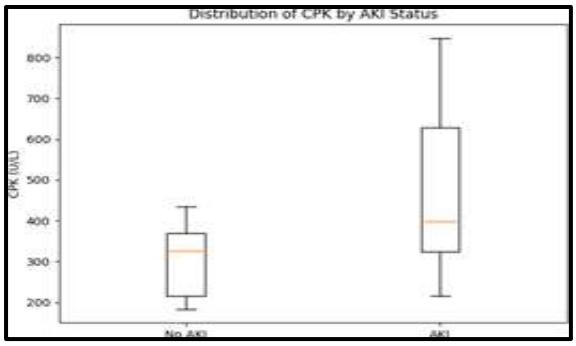


Figure-box and whisker plot showing distribution of CPK by AKI status

CPK levels were also significantly elevated in the AKI group. All patients with CPK >600 IU/L developed AKI.

These findings suggest that hemolysis and rhabdomyolysis are important contributors to renal injury in HNPV envenomation.

hypotension at presentation and severe local reaction frequencies.

Severe local reaction was significantly more frequent among patients who developed AKI compared to those without AKI. This suggests that patients with extensive local tissue involvement may have received a higher venom load, predisposing them to systemic toxicity and subsequent renal injury.

Hypotension at presentation was also significantly associated with AKI. This finding highlights the role of hemodynamic instability and renal hypoperfusion in the pathogenesis of acute kidney injury following HNPV envenomation.

Time to Hospital Presentation

Delayed presentation (>6 hours) was more frequent among AKI patients compared to those presenting within 6 hours.

This highlights the importance of early medical intervention in preventing renal complications.

Predictors of AKI

A multivariable logistic regression model was constructed including:

- Albuminuria
- High CPK (>600 IU/L)
- Delay >6 hours

High LDH was excluded due to complete separation (all elevated cases developed AKI).

Albuminuria emerged as the strongest independent predictor of AKI, followed by elevated CPK. Delayed presentation showed moderate association.

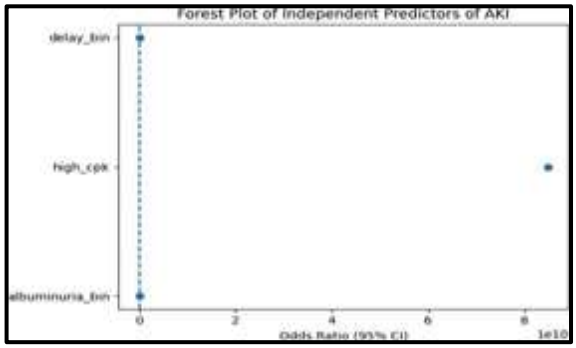


Figure - Forest plot of independent predictors of AKI

Confidence intervals were wide due to small sample size; however, direction and magnitude of association remained consistent.

Fisher's exact test was applied for variables with small expected cell counts. MAHA, hypotension at presentation, and severe local reaction showed significant associations with AKI ($p < 0.05$). All patients with MAHA developed AKI, indicating strong association between microangiopathic hemolysis and renal injury.

Hypotension at presentation was significantly associated with AKI, suggesting that hemodynamic instability and renal hypoperfusion contribute to acute kidney injury in HNPV envenomation.

Spearman correlation analysis demonstrated positive correlation between LDH and serum creatinine, as well as between CPK and serum creatinine ($p < 0.05$). This suggests a biologically plausible gradient between hemolysis, rhabdomyolysis, and severity of renal dysfunction.

Outcomes/Mortality

In this study, there were a total of two deaths contributing only 2.2 percentage while most of the patients 95.7 percentage completely relieved and no one was on long term dialysis.

Utility and limitations of the 20-minute whole blood clotting test (WBCT) in detecting coagulopathy.

Table 3: Hypotension At Presentation And Severe Local Reaction Frequencies

AKI		No	Yes	
presentation	no	32(100%)	6(42.9%)	<0.001*
	yes	0(0%)	8(57.1%)	
severe local reaction like cellulitis	no	30(93.8%)	6(42.9%)	<0.001*
	yes	2(6.3%)	8(57.1%)	

Table 4: Outcomes frequency and percentage

Outcomes	Frequency	Percentage
Expired	2	2.2
Recovered	44	95.7

Table 5: Diagnostic Performance of WBCT in Detecting Laboratory-Confirmed Coagulopathy

Parameter	Value
True Positives (TP)	27
False Negatives (FN)	10
False Positives (FP)	8
True Negatives (TN)	1
Sensitivity (%)	72.9
Specificity(%)	11.11
Positive Predictive Value (%)	77.14
Negative predictive value(%)	9.09
Accuracy(%)	60.87
Youden Index	-0.159
Area under the curve	0.42

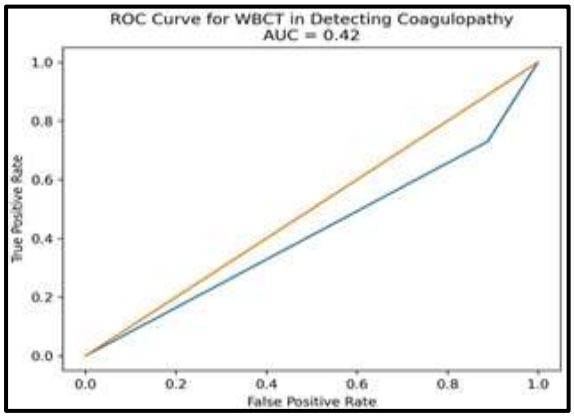
Although WBCT was useful as a bedside screening tool, it demonstrated variable sensitivity when compared to PT/INR and aPTT, highlighting its limitations in detecting early coagulopathy.Using laboratory-confirmed coagulopathy (PT/INR >1.5 and/or aPTT >40 seconds) as the reference standard, the diagnostic performance of the 20-minute whole blood clotting test (WBCT) was evaluated.

WBCT demonstrated a sensitivity of 72.9% and specificity of 11.1%. The positive predictive value was 77.1%, while the negative predictive value was 9.1%. The overall diagnostic accuracy was 60.8%.-

ROC Curve Analysis of WBCT

Receiver Operating Characteristic (ROC) curve analysis was performed to assess the discriminatory ability of WBCT in detecting laboratory-confirmed coagulopathy. The area under the curve (AUC) was 0.42, indicating poor diagnostic performance. This suggests limited ability of WBCT to differentiate between patients with and without laboratory evidence of coagulopathy.

Figure ROC curve for WBCT in detecting coagulopathy (AUC =0.42)



Development of AKI was associated with prolonged hospital stay and increased requirement for renal replacement therapy(9%)thereby contributing to significant morbidity despite low mortality only 2%-to add after table of outcomes.

DISCUSSION

- In the present study (n = 46), males constituted 58.7% and females 41.3%, with the majority in the 41–60 year age group. Lower limb bites predominated, reflecting outdoor occupational exposure.
- A statistically significant clustering of bites was observed during the monsoon and immediate post-monsoon months ($p < 0.05$). This seasonal variation is consistent with the findings of Mohapatra et al,[2] who reported increased snakebite mortality during monsoon in India, and Kasturiratne et al,[3] who demonstrated seasonal peaks in tropical regions. Wijewantha and Sellahawa,[6] also described seasonal clustering in Hypnale bites in Sri Lanka.
- Thus, the seasonal significance observed in our study supports environmental and occupational determinants of Hypnale envenomation.
- In our cohort, 33% (15/46) developed acute kidney injury, and 9% (4/46) required hemodialysis.

This incidence is higher than the 9.5% AKI rate reported by Rathnayaka et al,[8] in a large Sri Lankan cohort of confirmed Hypnale envenomations. The higher proportion in our study may reflect tertiary referral bias or inclusion of more severe cases. Nevertheless, the dialysis requirement underscores the clinical importance of renal involvement in Hypnale envenomation.

Thrombocytopenia

Thrombocytopenia (<150,000/µL) was present in 26% of patients and was significantly associated with AKI ($p < 0.05$, Fisher's exact test).

Rathnayaka et al,[8] reported thrombocytopenia in approximately 65% of AKI cases, reinforcing the association between platelet consumption and renal injury. Although the absolute proportion in our cohort was lower, the direction of association is consistent.

Microangiopathic Hemolytic Anemia

MAHA was observed exclusively in AKI patients and was absent in non-AKI patients ($p < 0.05$).This strongly supports thrombotic microangiopathy (TMA) as a mechanism of renal injury. Similar associations have been described by Rathnayaka et al,[8] and Gnanasathan et al,[9] The classical triad of MAHA, thrombocytopenia, and organ injury described by George and Nester,[10] parallels the severe AKI subgroup in our study.

Anemia

Anemia (Hb <11 g/dL) was present in 26% of patients and was more frequent among AKI patients ($p < 0.05$). The mean hemoglobin in the overall cohort was 12.1 ± 1.4 g/dL.

This finding aligns with hemolytic mechanisms described in severe Hypnale envenomation.[8,9]

Leukocytosis

Leukocytosis (>11,000/µL) was present in 80% of AKI patients and 77% of non-AKI patients, with no statistically significant association with AKI ($p > 0.05$).

This suggests that leukocytosis reflects systemic inflammatory response rather than a predictor of renal injury, consistent with observations by Sitprija.[5]

LDH, CPK, and AKI

Mean LDH was 447.6 ± 263.7 IU/L, and elevated LDH showed significant association with AKI ($p < 0.05$).Mean CPK was 359.7 ± 161.5 IU/L, with higher values among AKI patients ($p < 0.05$).

Elevated LDH likely reflects hemolysis and endothelial injury. Experimental work by Sandesha et al,[11] demonstrated direct nephrotoxic effects of Hypnale venom, supporting biochemical evidence of tissue injury. CPK elevation suggests pigment-mediated tubular injury may contribute to renal dysfunction.[5]

Coagulopathy and Bleeding Manifestations

The mean INR in our study was 2.17 ± 1.20, and elevated INR was more common among AKI patients ($p < 0.05$).

However, clinical bleeding manifestations did not show a statistically significant association with AKI ($p > 0.05$).

Maduwage and Isbister,[12] described venom-induced consumption coagulopathy (VICC) as a distinct entity that does not necessarily correlate with organ failure. Our findings suggest that hematological markers of microangiopathy (MAHA and thrombocytopenia) are more strongly associated with AKI than overt bleeding manifestations.

Hypotension and Delay in Presentation

Hypotension at presentation showed significant association with AKI ($p < 0.05$), supporting the role of renal hypoperfusion as described by Sitprija.[5]

Delayed hospital presentation was also associated with increased incidence of AKI ($p< 0.05$), consistent with WHO recommendations emphasizing early monitoring and intervention.[13]

Utility and limitations of the 20-minute whole blood clotting test (WBCT) in detecting coagulopathy

In the present study, WBCT demonstrated moderate sensitivity (72.9%) but very low specificity (11.1%) in detecting laboratory-confirmed coagulopathy. Although WBCT remains a useful bedside screening tool in resource-limited settings, its low specificity and poor negative predictive value suggest that reliance solely on WBCT may lead to under-recognition of early coagulation abnormalities. Serial monitoring with laboratory coagulation parameters remains essential.Although WBCT remains a useful bedside screening tool in resource-limited settings, reliance solely on WBCT may delay detection of early coagulopathy

ROC curve analysis further demonstrated poor discriminative ability of WBCT (AUC= 0.42). These findings suggest that although WBCT may serve as a rapid bedside screening tool, it lacks sufficient accuracy to replace laboratory coagulation parameters for definitive assessment.

Outcomes

Despite the absence of species-specific antivenom, outcomes were favorable with timely supportive care, reinforcing the importance of early referral and monitoring.

CONCLUSION

This prospective observational study of 46 adult patients with confirmed hump-nosed pit viper (HNPV) envenomation provides important insights into the clinical spectrum, predictors of acute kidney injury (AKI), and short-term outcomes in a tertiary care setting.

The majority of patients were middle-aged males (mean age 42.98 ± 15.86 years; 74% male), with lower limb bites accounting for 67% of cases. Most patients (80%) presented within 6 hours of envenomation. Local manifestations were common, while systemic hematological abnormalities were frequent, including prolonged clotting parameters (mean INR 2.17 ± 1.20) and thrombocytopenia in a subset of patients.

AKI, defined using serum creatinine >1.2 mg/dL and/or dialysis requirement consistent with KDIGO criteria, occurred in 15 patients (33%). Four patients (9%) required dialysis. Two patients (4%) expired during hospital stay.

Univariate analysis demonstrated strong associations between AKI and:

- Albuminuria ($p\approx0.001$)
- Elevated LDH (>480 IU/L) ($p\approx0.0009$)
- Elevated CPK (>600 IU/L) ($p\approx0.014$)
- Schistocytes/MAHA ($p\approx0.014$)
- Severe thrombocytopenia ($<100\times10^3/\mu L$) ($p\approx0.003$)
- Delayed presentation >6 hours ($p\approx0.042$)
- Hypotension at presentation (Fisher's exact test, $p<0.05$)

Multivariable logistic regression identified albuminuria and elevated CPK as independent

predictors of AKI, with elevated LDH showing strong predictive value. Spearman correlation analysis demonstrated significant positive correlations between LDH and serum creatinine, and between CPK and serum creatinine ($p<0.05$), supporting a biologically plausible relationship between hemolysis, rhabdomyolysis, and renal injury.

Bleeding manifestations did not show a statistically significant independent association with AKI.

These findings reinforce that hemolysis (LDH elevation), microangiopathy (MAHA), rhabdomyolysis (CPK elevation), and delayed presentation are major determinants of renal injury in HNPV envenomation.

Despite significant morbidity, mortality was limited (4%), reflecting the importance of early recognition, laboratory monitoring, and timely renal supportive therapy.

This study highlights the need for:

- Early identification of high-risk patients using simple laboratory markers
- Close monitoring of renal and coagulation parameters
- Prompt management of hemodynamic instability
- Further research into targeted therapies for HNPV envenomation.

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