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SNAKEBITE ENVENOMATION IN THE TRIBAL BELT OF GUJARAT: CLINICAL PROFILE, COMPLICATIONS, TREATMENT OUTCOMES, AND REHABILITATION — A CROSS-SECTIONAL STUDY

Internal Medicine

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ABSTRACT

Background: Snakebite envenomation poses a significant but often neglected public health challenge in tribal and rural India. The Dahod district of Gujarat, home to a predominantly tribal population engaged in agricultural labor, carries a disproportionate burden due to limited healthcare access and delayed treatment-seeking behavior. Region-specific data on clinical patterns, complications, and rehabilitation are sparse.**Methods:** A cross-sectional observational study was conducted at Zydus Medical College and Hospital (ZMCH), Dahod, enrolling 50 patients who presented with confirmed or suspected snakebite. Detailed clinical, laboratory, treatment, and follow-up data were collected using a structured proforma. Statistical analyses included independent-samples t-tests, one-way ANOVA, and chi-square tests, with $p < 0.05$ considered significant.**Results:** The cohort had a mean age of 32.9±13.1 years; 64% were male and 76% were from rural areas. Bites peaked during the monsoon season (44%) and in the evening/night hours (62%). Neurotoxic (40%) and vasculotoxic (38%) bites predominated. Antivenom requirement differed significantly across bite types (ANOVA $F = 16.05$, $p < 0.001$). Vasculotoxic bites were associated with higher INR (1.50 vs 1.19; $p < 0.001$) and a trend toward greater acute kidney injury (AKI). Overall, 72% of patients recovered fully, 24% had residual disability, and mortality was 4%. Delayed hospital arrival strongly predicted adverse outcomes ($F = 12.15$, $p < 0.001$). Patients who developed complications required significantly longer rehabilitation (13.6 vs 9.6 days; $p = 0.009$).**Conclusion:** Snakebite envenomation in tribal Gujarat follows a recognizable clinical pattern amenable to protocol-driven management. Expediting transport, ensuring round-the-clock antivenom availability at peripheral centers, and embedding structured rehabilitation into discharge planning can substantially reduce morbidity and preventable mortality.

KEYWORDS

Snakebite Envenomation; Tribal Gujarat; Neurotoxic; Vasculotoxic; Antivenom; Acute Kidney Injury; Rehabilitation; Rural India

INTRODUCTION

Snakebite envenomation remains one of the most under-recognized causes of preventable death and disability in tropical and subtropical countries. India shoulders approximately 45,900 snakebite deaths annually, representing roughly half of the global toll [1, 2]. The problem is not evenly distributed: tribal and rural communities that depend on agriculture face the highest exposure, compounded by delayed care-seeking, inadequate antivenom supplies at primary health centers, and deeply rooted reliance on traditional remedies before formal medical consultation [3].

Gujarat's Dahod district exemplifies this vulnerability. Situated in the eastern tribal belt bordering Rajasthan and Madhya Pradesh, the district is home to Bhil and Bhilala tribal communities whose livelihood centers on rain-fed agriculture. Occupational exposure to snake habitats is therefore maximal during the monsoon season, precisely when transport links deteriorate and round-the-clock emergency services are most stretched [4]. Despite the clinical importance of the problem, region-specific data from this district remain sparse, limiting the ability to calibrate resource allocation and prevention strategies.

Current literature establishes that the four species responsible for most serious envenomations in India — the Indian cobra ('Naja naja'), common krait ('Bungarus caeruleus'), Russell's viper ('Daboia russelii'), and saw-scaled viper ('Echis carinatus') — produce clinically distinct syndromes [3]. Neurotoxic envenomation from elapids characteristically causes descending paralysis and life-threatening respiratory failure, while viperid envenomation typically produces local tissue destruction, coagulopathy, and acute kidney injury (AKI) [5, 6]. Accurate early categorization of envenomation type is therefore fundamental to guiding antivenom dosing, intensive monitoring priorities, and secondary prevention of organ failure.

Equally important, yet poorly studied, is the rehabilitation trajectory of survivors. Limb complications such as cellulitis, compartment syndrome, and post-AKI renal impairment contribute to long-term disability that impoverishes already marginalized households [7]. Addressing rehabilitation needs alongside acute management offers a more complete model of care.

This study was designed to generate a comprehensive, data-driven clinical profile of snakebite envenomation in the tribal belt of Gujarat, with the following objectives: (i) characterize the epidemiological and demographic profile of victims; (ii) describe clinical manifestations stratified by venom type; (iii) quantify treatment requirements, complications, and outcomes; and (iv) identify prognostic determinants of poor outcome and extended rehabilitation need.

MATERIALS AND METHODS

Study Setting and Design

This cross-sectional observational study was conducted at Zydus Medical College and Hospital (ZMCH), Dahod — a 700-bed tertiary-care teaching institution that serves as the primary referral center for the predominantly tribal Dahod district of Gujarat. Patient enrollment commenced in March 2024 and continued through September 2026.

Study Population

Consecutive patients of any age and sex who presented to the outpatient department, casualty, or intensive care unit with a history of snakebite, with or without clinical features of envenomation, were screened. A total of 50 eligible patients were enrolled. Exclusion criteria comprised bites by non-snake species (insects, scorpions, rodents), pre-existing neuromuscular disorders (myasthenia gravis, Guillain–Barré syndrome, congenital myopathy, poliomyelitis), and refusal of informed consent.

Data Collection and Clinical Assessment

A structured proforma captured demographic data (age, sex, residence, occupation), circumstantial details (time and season of bite, anatomical site, activity at time of bite, pre-hospital first-aid measures), and clinical examination findings on admission. Envenomation was classified as neurotoxic (ptosis, ophthalmoplegia, bulbar palsy, respiratory weakness), vasculotoxic (local swelling, bleeding tendencies, ecchymosis, coagulopathy), or non-venomous/unknown based on clinical and laboratory criteria. Investigations performed at admission included complete blood count (CBC), renal function tests (RFT), liver function tests (LFT), serum electrolytes, coagulation profile (PT/INR, APTT), blood glucose, electrocardiogram (ECG), and the 20-minute whole blood clotting test (20WBCT), which was repeated hourly for the first three hours and then every six hours for 24 hours. Arterial blood gas analysis and chest radiograph were performed when clinically indicated.

Treatment Protocol

All patients received tetanus toxoid and wound care at presentation. Anti-snake venom (ASV) was administered intravenously according to the ZMCH institutional protocol, with dosing titrated to clinical and coagulation response. Pre-medication with adrenaline, hydrocortisone, and chlorpheniramine was given routinely before ASV infusion. Neostigmine with atropine was used for neurotoxic envenomation. Supportive measures included intravenous fluids, blood products (fresh frozen plasma, packed red cells), antibiotics, diuretics, mechanical ventilation for respiratory failure, and hemodialysis for AKI unresponsive to conservative management.

Outcome Measures

Primary outcomes were: (i) final clinical disposition categorized as full recovery, residual disability, or in-hospital death; and (ii) total length of hospital stay (LOS). Secondary outcomes included development of specific complications (AKI, disseminated intravascular coagulation [DIC], respiratory failure, cellulitis, compartment syndrome, sepsis), antivenom requirement (number of vials), ventilation requirement, and rehabilitation duration (days from admission to functional independence as documented in physiotherapy records).

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables are reported as mean ± standard deviation (SD) or median with interquartile range (IQR). Categorical variables are expressed as frequencies and percentages. Group comparisons for continuous outcomes were performed using the independent-samples t-test (two groups) or one-way analysis of variance (ANOVA; three or more groups). Categorical associations were evaluated with the chi-square (χ^2) test. A two-tailed p-value of < 0.05 was considered statistically significant.

RESULTS

Epidemiological and Demographic Profile

Fifty patients were enrolled over the study period. The mean age was 32.9 ± 13.1 years (median 33 years; IQR 24–41). Males accounted for 64.0% (n = 32) of cases, consistent with occupational outdoor exposure common among working-age men in the tribal district. Rural residents constituted 76.0% (n = 38) of the cohort. The 15–44 year age band carried the highest burden (74.0% of all cases), reflecting active workforce involvement in agricultural activities. Detailed demographic characteristics and epidemiological data are presented in Table 1.

Most bites occurred during the evening and night (62.0% combined), while the monsoon season accounted for 44.0% of annual presentations, nearly double the next highest season (post-monsoon, 28.0%). Summer and winter together contributed only 28.0% of cases.

Table 1. Demographic and Epidemiological Profile of Snakebite Patients (n = 50)

Variable	Category	n (%) or Mean ± SD
Age (years)	Mean ± SD	32.9 ± 13.1
	Median (IQR)	33 (24–41)
	0–14 years	4 (8.0%)
	15–29 years	16 (32.0%)
	30–44 years	21 (42.0%)
	45–59 years	8 (16.0%)
	≥60 years	1 (2.0%)
Sex	Male	32 (64.0%)
	Female	18 (36.0%)
Residence	Rural	38 (76.0%)
	Urban	12 (24.0%)
Time of bite	Morning	8 (16.0%)
	Afternoon	11 (22.0%)
	Evening	16 (32.0%)
	Night	15 (30.0%)
Season	Summer	10 (20.0%)
	Monsoon	22 (44.0%)
	Post-monsoon	14 (28.0%)
	Winter	4 (8.0%)

IQR = interquartile range. Age group and seasonal data presented as n (%).

Bite Type Distribution and Clinical Manifestations

Venomous bites represented 78.0% of the cohort: 20 were neurotoxic (40.0%) and 19 were vasculotoxic (38.0%), with non-venomous (16.0%) and unclassified (6.0%) cases making up the remainder (Table 2). Among neurotoxic envenomations, dysphagia (8/20, 40.0%) and ptosis (6/20, 30.0%) were the most common neurological findings, while respiratory failure requiring ventilatory support occurred in 5 patients (25.0%). Among vasculotoxic cases, gingival bleeding was the most frequent hemorrhagic feature (9/19, 47.4%), followed by hematuria (5/19, 26.3%) and DIC (3/19, 15.8%). Across all 50 patients, cellulitis was the most prevalent complication (13/50, 26.0%), followed by respiratory failure (7/50, 14.0%) and AKI (6/50, 12.0%).

Table 2. Bite Type Distribution, Clinical Manifestations, and Complication Spectrum

Domain / Variable	Category	n (%)
Bite type	Neurotoxic	20 (40.0%)
	Vasculotoxic	19 (38.0%)
	Non-venomous	8 (16.0%)
	Unknown/unclassified	3 (6.0%)
Neurotoxic manifestations (n = 20)	Ptosis	6 (30.0%)
	Dysphagia	8 (40.0%)
	Respiratory failure	5 (25.0%)
Vasculotoxic manifestations (n = 19)	Gingival bleeding	9 (47.4%)
	Hematuria	5 (26.3%)
	Disseminated intravascular coagulation (DIC)	3 (15.8%)
Overall complication spectrum (n = 50)	Cellulitis	13 (26.0%)
	Respiratory failure	7 (14.0%)
	Acute kidney injury (AKI)	6 (12.0%)
	Blood transfusion required	6 (12.0%)
	Compartment syndrome	4 (8.0%)
	DIC	3 (6.0%)
	Sepsis	1 (2.0%)

Manifestation percentages for neurotoxic and vasculotoxic categories are calculated within respective bite-type subgroups.

Treatment Interventions and Clinical Outcomes by Bite Type

Antivenom use differed markedly across bite categories (ANOVA F = 16.05, p < 0.001): neurotoxic bites required a mean of 9.2 ± 4.51 vials and vasculotoxic bites 9.05 ± 2.86 vials, whereas non-venomous bites required no antivenom (Table 3). Mechanical ventilation was needed predominantly in neurotoxic cases (4/20, 20.0% vs 1/19, 5.3% in vasculotoxic bites; χ^2 = 3.92, p = 0.270). AKI occurred exclusively or predominantly in vasculotoxic envenomation (5/19, 26.3%; χ^2 = 6.83, p = 0.078). Mean hospital LOS was longest in neurotoxic cases (6.2 ± 2.67 days), though inter-group differences did not reach statistical significance (ANOVA F = 1.01, p = 0.398). Overall, 72.0% of patients recovered completely, 24.0% had residual disability, and 4.0% died; both deaths occurred in the neurotoxic envenomation group (χ^2 = 8.85, p = 0.182).

Table 3. Treatment Interventions and Clinical Outcomes Stratified by Bite Type

Parameter	Neurotoxic (n = 20)	Vasculotoxic (n = 19)	Non-venomous (n = 8)	Unknown (n = 3)	p-value
ASV vials, mean ± SD	9.2 ± 4.51	9.05 ± 2.86	0.0 ± 0.0	9.33 ± 1.15	F=16.05 <0.001[a]
Ventilation required, n (%)	4 (20.0%)	1 (5.3%)	0 (0.0%)	0 (0.0%)	χ^2=3.92 p=0.270
AKI, n (%)	0 (0.0%)	5 (26.3%)	1 (12.5%)	0 (0.0%)	χ^2=6.83 p=0.078
LOS, days, mean ± SD	6.2 ± 2.67	5.45 ± 2.15	5.05 ± 1.37	4.27 ± 1.00	F=1.01 p=0.398

Recovered, n (%)	12 (60.0%)	17 (89.5%)	6 (75.0%)	1 (33.3%)	χ^2=8.85 p=0.182
Residual disability, n (%)	6 (30.0%)	2 (10.5%)	2 (25.0%)	2 (66.7%)	
In-hospital death, n (%)	2 (10.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	

ASV = anti-snake venom; AKI = acute kidney injury; LOS = length of stay; SD = standard deviation. ANOVA; all other p-values from independent chi-square or t-test as appropriate. Outcomes for disability and death share the same χ^2 statistic as 'recovered' row (df = 6).

Prognostic Determinants and Rehabilitation Outcomes

Table 4 consolidates the key prognostic parameters. Time to hospital arrival did not differ significantly between rural (3.74 ± 1.84 h) and urban patients (3.78 ± 1.46 h; t = −0.07, p = 0.942), suggesting comparable access delays irrespective of residence. However, time to hospital was strongly associated with final outcome: patients who died had a mean pre-hospital delay of 8.64 ± 3.95 h compared with 3.46 ± 1.14 h in those who recovered (ANOVA F = 12.15, p < 0.001). A parallel pattern was observed for time to antivenom administration among ASV recipients (F = 9.80, p < 0.001; mean 9.43 ± 4.22 h in non-survivors vs 4.27 ± 1.30 h in those who recovered).

Coagulation profiling confirmed significantly higher INR in vasculotoxic envenomation (1.50 ± 0.27 vs 1.19 ± 0.28 in other bites; t = 3.91, p < 0.001), reinforcing the coagulopathic phenotype of viper venom. Platelet counts showed a trend toward depression in vasculotoxic bites (175.1 ± 75.2 $\times 10^3/\mu L$ vs 239.8 ± 82.2 in neurotoxic bites), though the overall ANOVA did not reach significance (F = 2.73, p = 0.055). Patients with any complication required significantly longer rehabilitation (13.6 ± 5.9 days vs 9.6 ± 4.5 days without complications; t = 2.70, p = 0.009), highlighting the downstream functional burden of complications. LOS was modestly prolonged in patients with DIC (6.1 vs 5.6 days), though this difference was not statistically significant in the small DIC subgroup (t = 0.50, p = 0.659).

Table 4. Prognostic Parameters and Rehabilitation Outcomes

Parameter	Group / Subgroup	Mean ± SD	n	Test statistic	p-value
Time to hospital by residence (h)	Rural	3.74 ± 1.84	38	t = −0.07	0.942
	Urban	3.78 ± 1.46	12		
Time to hospital by outcome	Recovered	3.46 ± 1.14	36	F = 12.15	<0.001
	Disability	3.81 ± 1.84	12		
	Death	8.64 ± 3.95	2		
Time to ASV by outcome (h)	Recovered	4.27 ± 1.30	29	F = 9.80	<0.001
	Disability	4.40 ± 1.92	9		
	Death	9.43 ± 4.22	2		
INR (coagulation)	Vasculotoxic	1.50 ± 0.27	19	t = 3.91	<0.001
	Other bite types	1.19 ± 0.28	31		
Platelet count ($\times 10^3/\mu L$)	Neurotoxic	239.8 ± 82.2	20	F = 2.73	0.055
	Vasculotoxic	175.1 ± 75.2	19		
	Non-venomous	182.9 ± 49.0	8		
	Unknown	213.0 ± 61.5	3		
Rehabilitation duration (days)	Any complication	13.6 ± 5.9	27	t = 2.70	0.009
	No complication	9.6 ± 4.5	23		
LOS vs DIC presence (days)	DIC present	6.1 ± 1.7	3	t = 0.50	0.659
	DIC absent	5.6 ± 2.3	47		

ASV = anti-snake venom; INR = international normalized ratio; LOS = length of stay; DIC = disseminated intravascular coagulation. F = ANOVA statistic; t = independent-samples t-test statistic. Time to ASV analysis restricted to ASV recipients only (n = 40).

DISCUSSION

This study provides a comprehensive, data-driven clinical profile of snakebite envenomation from the tribal belt of Dahod, Gujarat — a region that, to the best of our knowledge, has not previously been described in peer-reviewed literature as a distinct epidemiological unit. The key findings are: (i) a predominantly young male, rural demographic; (ii) near-equal proportions of neurotoxic and vasculotoxic envenomation; (iii) marked monsoon seasonality; (iv) a strong association between prehospital delay and adverse outcomes; and (v) significantly prolonged rehabilitation in patients who develop complications.

The preponderance of males in the 15–44-year age range mirrors the occupational risk structure of tribal agriculture, where men predominate in field labor during planting and harvest seasons [8, 9]. The 76.0% rural residence rate and the evening/night clustering of bites are consistent with agricultural and livestock-related outdoor activities in low-light environments — a pattern well documented from comparable settings in South Asia [3, 4]. The 44.0% monsoon concentration aligns with the ecological reality that rainfall displaces snakes from waterlogged burrows, drives prey species into human habitation zones, and intensifies snake-human contact during peak agricultural activity [5, 6].

The near-equal split between neurotoxic and vasculotoxic envenomation reflects the regional snake fauna, where cobras and kraits (neurotoxic) coexist with Russell's and saw-scaled vipers (vasculotoxic). Neurological signs — ptosis, dysphagia, and respiratory failure — are the hallmark of elapid envenomation and require urgent airway surveillance [10, 11]. In the present cohort, 25.0% of neurotoxic patients required mechanical ventilation, underscoring the rapidity with which elapid toxins can paralyze respiratory muscles. Early recognition of bulbar signs and pre-emptive ICU admission for all neurotoxic bites is therefore clinically imperative. Conversely, the coagulopathic profile of vasculotoxic envenomation — manifested as gingival bleeding, hematuria, elevated INR, and thrombocytopenia — has been well characterized in viper bites [12]. The significantly higher INR in vasculotoxic cases (1.50 vs 1.19; p < 0.001) and the trend toward AKI (26.3% vs 0% in neurotoxic cases; p = 0.078) emphasize the need for serial coagulation testing and proactive renal monitoring from the time of admission.

The antivenom dosing data confirm that both major envenomation types require comparable vial loads (≈9 vials each), consistent with national dosing literature [13]. The ANOVA-significant difference across categories (F = 16.05, p < 0.001) is entirely driven by the zero-requirement in non-venomous bites, highlighting the clinical and cost importance of accurate early categorization to avoid unnecessary antivenom exposure and its attendant anaphylactic risk.

Perhaps the most actionable finding in this study is the dose-response relationship between prehospital delay and outcome severity. Patients who died had waited more than twice as long before reaching hospital as those who recovered (8.64 h vs 3.46 h; p < 0.001). A parallel gradient was observed for time to antivenom. These associations — though observational in a cross-sectional design — are biologically plausible and consistent with multiple prior studies documenting that early antivenom administration substantially reduces paralytic and coagulopathic endpoints [13, 14]. Community-level interventions including village-based first-aid training, pre-positioned oral communication cards on "when to seek care immediately", and rapid ambulance protocols during monsoon months could collectively shorten this critical window.

Rehabilitation represents an under-studied dimension of snakebite management. The significantly longer functional recovery period among patients with complications (13.6 vs 9.6 days; p = 0.009) quantifies the downstream cost of untreated or delayed complications [7]. Structured physiotherapy referral at the point of discharge — particularly for patients with cellulitis-related immobility or post-compartment syndrome stiffness — appears justifiable from the data and warrants integration into standard snakebite management pathways at tribal hospitals [14].

The study has limitations inherent to its cross-sectional, single-center design. Causal inference is precluded; species identification was possible in fewer than half of cases; and the sample size of 50, while adequate for descriptive and exploratory analyses, limits the power of subgroup comparisons. Multivariate regression to adjust for confounders was not performed given the sample size. Future prospective cohort studies with larger enrollment, genetic or proteomics-based venom identification, and long-term follow-up will be needed to establish causality and refine regional management algorithms.

CONCLUSION

Snakebite envenomation in the tribal belt of Dahod, Gujarat follows predictable clinical patterns that are amenable to protocol-driven management. Neurotoxic bites demand early airway surveillance and readiness for mechanical ventilation, while vasculotoxic bites require proactive coagulation monitoring and renal protection. Prehospital delay was the strongest determinant of fatal or disabling outcomes, making community education and rapid transport the highest-priority public health interventions. Ensuring 24-hour antivenom availability at peripheral health centers during the monsoon season and embedding structured rehabilitation pathways into discharge planning can further reduce the long-term burden of this preventable condition. Region-specific data such as those generated in this study are essential for calibrating resource allocation, staff training programs, and community outreach in tribal healthcare settings.

STRENGTHS AND LIMITATIONS

This study is among the first to generate a structured clinical dataset from the tribal belt of Dahod, addressing a meaningful gap in regional snakebite epidemiology. The inclusion of rehabilitation outcomes as a formal endpoint adds practical value to the clinical narrative. Limitations include the single-center cross-sectional design, inability to confirm snake species in the majority of cases, a sample size that limits multivariable analysis, and the potential for referral bias toward more severe presentations at a tertiary-care hospital.

DECLARATIONS

Ethics approval and consent to participate: Approved by the Institutional Ethics Committee, Zydus Medical College and Hospital, Dahod. Written informed consent was obtained from all participants or legally acceptable representatives.

Conflict of interest: The authors declare no conflicts of interest.

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