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Anatomical Site of Envenomation as a Predictor of Severe Renal Injury in Snakebite Fatalities-Medico-Legal Autopsy-based Analysis

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ABSTRACT

Background: Snakebite envenomation remains a major public health problem in rural India, associated with significant morbidity and mortality. Renal complications are among the leading causes of death in severe cases. Limited data exist on post-mortem patterns of snakebite fatalities in the Thanjavur region.

Methods: A retrospective observational study was conducted on 116 snakebite cases that underwent post-mortem examination at Thanjavur Medical College. Data on age, sex, season, location and site of bite, presence of fang marks, and renal involvement were collected. Associations were assessed using chi-square tests and multivariable logistic regression. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated; $p<0.05$ was considered significant.

Results: Most victims were aged 41–60 years (32.76%) and male (56.03%). Nearly half of the cases occurred during the rainy season (47.41%). Common locations were paddy fields (48.28%) and ponds (37.93%). The foot/lower leg was the most frequent bite site (55.17%), with 75% of bites involving the lower limb. Fang marks were visible in 31.9% of cases. Severe renal involvement occurred in 39.66% of cases. Significant associations were found with age, sex, location, bite site, lower-limb bites, and the absence of fang marks. Age remained an independent predictor, while lower limb bites increased the odds of severe renal complications by approximately 4.3 times.

Conclusion: Snakebite fatalities in Thanjavur predominantly affect working-age adults during the rainy season in agricultural settings. Lower limb bites were strongly associated with severe renal involvement, emphasizing the need for early recognition and prompt management.

Key-words: Snake bite, Envenomation, Post-mortem, Acute kidney injury, Fang marks

INTRODUCTION

Snakebite envenomation remains a significant public health challenge in tropical and subtropical regions, particularly in India, which accounts for a substantial proportion of global snakebite mortality.

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The World Health Organization has recognized snakebite envenomation as a neglected tropical disease, emphasizing its disproportionate impact on rural and socioeconomically vulnerable populations [1]. Recent national estimates suggest that India accounts for nearly half of global snakebite deaths, with higher incidence observed among young adult males and during the monsoon season, reflecting occupational and environmental exposure risks [2,3]. Despite its magnitude, detailed analyses of fatal cases especially those evaluated through medico-legal autopsy, remain limited.

Renal involvement is one of the most serious systemic complications of snake envenomation and a major contributor to mortality. Snakebite-associated acute kidney injury (AKI) results from complex mechanisms,

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including hemotoxic venom effects, intravascular hemolysis, rhabdomyolysis, hypotension, disseminated intravascular coagulation, and direct nephrotoxicity [4]. Histopathological findings in fatal cases commonly demonstrate acute tubular necrosis, cortical necrosis, and interstitial nephritis, highlighting the multifactorial nature of venom-induced renal damage [5]. Severe renal failure significantly worsens prognosis and increases fatality rates, particularly when treatment is delayed or access to antivenom and renal replacement therapy is limited [6].

Epidemiological profiling of snakebite fatalities based on age, sex, seasonal variation, and geographic distribution helps identify high-risk groups and vulnerable periods [2,3]. Anatomical assessment, including identification of bite sites and fang marks, is equally important, as lower-limb bites are frequently reported following accidental encounters during agricultural activities [7]. However, the relationship between demographic and anatomical variables and the development of severe renal involvement has not been adequately explored in fatal cases.

Medico-legal autopsy studies provide a unique opportunity to evaluate pathological changes and correlate them with epidemiological variables systematically. Advanced statistical approaches, such as logistic regression and multivariable modeling allow identification of independent predictors of severe renal complications while controlling for confounding factors [8].

The present study, conducted at Thanjavur Medical College, aimed to analyze the epidemiological patterns, clinical characteristics, and factors associated with severe renal involvement in fatal snakebite cases brought for post-mortem examination, thereby generating region-specific evidence to improve risk stratification, preventive strategies, and clinical management.

MATERIALS AND METHODS

Study Design and Setting- This is a retrospective, hospital-based descriptive study conducted at the Department of Forensic Medicine and Toxicology, Thanjavur Medical College. The study analyzes the records of snake bite victims who underwent medico-legal autopsy (post-mortem examination) at this center.

Study Population

- **Sample Size (n):** 116 cases.
- **Inclusion Criteria:** All recorded cases of snake bite where a post-mortem examination was conducted at Thanjavur Medical College.
- **Exclusion Criteria:** Cases with decomposed bodies where internal organ pathology could not be clearly established, or cases with incomplete medical/autopsy records.

Data Collection- Data was extracted from official autopsy reports, police inquest papers (Form 145/174 CrPC), and available hospital clinical records. The following parameters were recorded: Demographics, Environmental Factors, Physical Findings, Clinical/ Pathological Outcome.

Statistical Analysis- The data were entered into MS Excel and analyzed using SPSS. Descriptive statistics were expressed as frequencies and percentages. Associations between independent variables (age, sex, season, site of bite) and severe renal involvement were assessed using Chi-square or Fisher's Exact tests. Univariable logistic regression calculated odds ratios for individual risk factors, and multivariable logistic regression identified independent predictors after adjusting for confounders.

Ethical Considerations- The study protocol was reviewed and approved by the Institutional Ethical Committee (IEC) of Thanjavur Medical College (Certificate No: 1324/2024; Reg. No: EC/NEW/INST/2023/TN/0246) in accordance with the standard ethical guidelines for biomedical research.

RESULTS

Among 116 cases, most victims were aged 41–60 years (32.76%), followed by 21–40 years (25.86%). Males constituted 56.03% and females 43.97%. Most incidents occurred during the rainy season (47.41%), followed by summer (37.93%). Paddy fields (48.28%) and ponds (37.93%) were the most common locations. The foot/lower leg was the most frequent bite site (55.17%), with overall lower limb involvement in 75% of cases. Visible fang marks were present in 31.9%. Severe renal involvement occurred in 39.66% of cases. Severe renal involvement was significantly higher in participants aged

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<60 years (45.56% vs 19.23%; p=0.01) and in females (52.94% vs 29.23%; p=0.01). Season showed no significant association (p=0.42). Renal complications were highest in the pond (70.45%) and home cases (100%, small sample). Location showed a highly significant association with severe renal involvement (p<0.001).

Table 1 shows that ankle bite shows 100% severe renal involvement. Hands/fingers show no cases of severe renal involvement (0%). The foot/lower leg has moderate renal involvement (28.13%). Calf/knee shows 41.67% severe renal involvement. There is a highly statistically significant association between the site of bite and severe renal involvement (χ^2=49.75, df=3, p<0.001).

Table 1: Association between Site of Bite and Severe Renal Involvement (n=116)

Site of Bite	No Severe Renal n (%)	Severe Renal n (%)	Total n (%)	χ^2 (df)	p-value
Foot/ lower leg	46 (71.88)	18 (28.13)	64 (100)	49.75 (3)	<0.001
Ankle	0 (0.00)	23 (100.00)	23 (100)		
Hand/Fingers	17 (100.00)	0 (0.00)	17 (100)		
Calf/knee	7 (58.33)	5 (41.67)	12 (100)		
Total	70 (60.34)	46 (39.66)	116 (100)		

Table 2 shows that patients with lower limb bites had a higher proportion of severe renal involvement (47.13%). Patients without lower limb bites had a lower proportion (17.24%).There is a statistically significant association between lower limb bite and severe renal involvement (χ^2=8.12, df=1, p=0.004). Among patients without fang marks, 58.23% developed severe renal involvement. Among patients with fang marks, none developed severe renal involvement (0%). There is a highly statistically significant association between fang marks and severe renal involvement (χ^2=35.70, df=1, p<0.001).

Table 2: Association Between Lower Limb Bite and Severe Renal Involvement (n=116)

Lower Limb Bite	No Severe Renal n (%)	Severe Renal n (%)	Total n (%)	χ^2 (df)	p-value
No (0)	24 (82.76)	5 (17.24)	29 (100)	8.12 (1)	0.004
Yes (1)	46 (52.87)	41 (47.13)	87 (100)		
Total	70 (60.34)	46 (39.66)	116 (100)		

Table 3 shows that the age group is significantly associated with severe renal involvement. Increasing age category reduces the odds of severe renal involvement by approximately 47% (OR=0.53, p=0.02). Sex is significantly associated with severe renal involvement. The odds of severe renal involvement are 2.72 times higher in the higher-coded sex category compared to the reference category (OR=2.72, p=0.01).

Table 3: Logistic Regression Analysis for Severe Renal Involvement by Age Group and sex (n=116)

Variable	Odds Ratio (OR)	Std. Error	p-value	95% CI (Lower–Upper)
Age group (age_r)	0.53	0.14	0.02	0.31 – 0.91
Constant	0.84	0.18	0.40	0.55 – 1.27
Sex	2.72	1.07	0.01	1.27 – 5.86
Constant	0.15	0.09	0.002	0.05 – 0.50

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Table 4 shows that location is significantly associated with severe renal involvement (p=0.003). The odds ratio of 0.40 indicates that with each increase in the coded location category, the odds of severe renal involvement decrease by approximately 60% (1−0.40). Since the 95% confidence interval (0.22–0.73) does not include 1, this association is statistically significant. Site of bite is not significantly associated with severe renal involvement (p=0.83). The odds ratio of 1.03 indicates almost no change in the odds of severe renal involvement across site categories. Since the 95% confidence interval (0.77–1.38) includes 1, the association is not statistically significant.

Table 4: Logistic Regression Analysis for Severe Renal Involvement by Location and Site of bite (n=116)

Variable	Odds Ratio (OR)	Std. Error	p-value	95% CI (Lower–Upper)
Location	0.40	0.12	0.003	0.22 – 0.73
Constant	3.17	1.73	0.03	1.09 – 9.21
Site_Bite	1.03	0.15	0.83	0.77 – 1.38
Constant	0.62	0.21	0.16	0.32 – 1.21

Table 5 shows that lower limb bites are significantly associated with severe renal involvement (p=0.007). Patients bitten on the lower limb have approximately 4.3 times higher odds of developing severe renal complications compared to those bitten elsewhere. The 95% confidence interval (1.49–12.24) does not include 1, confirming statistical significance. The model shows that Fang_Mark predicts failure perfectly (complete separation).

Table 5: Logistic Regression Analysis for Severe Renal Involvement by Lower Limb Bite and Severe Renal Involvement by Fang Mark (n=116)

Variable	Odds Ratio (OR)	Std. Error	p-value	95% CI (Lower–Upper)
Lower_Limb	**4.28**	2.30	**0.007**	1.49 – 12.24
Constant	0.21	0.10	0.001	0.08 – 0.55
Fang_Mark	1 (Omitted)*	—	—	—

Table 6 shows that after adjusting for other variables, Age remains an independent and statistically significant predictor of severe renal involvement. Sex, location, and site of bite do not show statistically significant independent associations in the multivariable model. The model explains approximately 24% of the variability in severe renal involvement.

Table 6: Multivariable Logistic Regression Analysis for Severe Renal Involvement (n=116)

Variable	Adjusted Odds Ratio (AOR)	Std. Error	p-value	95% Confidence Interval
Age (age_r)	**0.07**	0.06	**<0.001**	0.01–0.32
Sex	3.12	3.96	0.37	0.25–37.56
Location	0.60	0.32	0.34	0.21–1.71
Site_Bite	3.43	2.41	0.08	0.86–13.62
Constant	0.10	0.16	0.16	0.004–2.53

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DISCUSSION

This retrospective analysis of 116 post-mortem snakebite cases at Thanjavur Medical College provides critical insights into the demographic and clinical patterns of fatal envenomations in a rural South Indian setting. The predominance of cases in the 21–60-year age group (58.62%) in the present study aligns with the existing literature, which shows that snakebite disproportionately affects the economically active population engaged in outdoor activities such as farming and fieldwork [9,10]. Kasturiratne *et al.* reported that adults aged 15-45 years comprise the largest proportion of snakebite victims globally, reflecting occupational exposure risks, consistent with our findings [9].

The male predominance observed (56.03%) is also widely reported in snakebite epidemiology. Chippaux and Alirol *et al.* documented higher incidence rates in males, attributed to greater outdoor exposure [11,12]. However, our study identified a significantly higher proportion of severe renal involvement among females in univariate analysis. This contrasts with multiple clinical cohorts, in which males consistently exhibit higher complication rates, possibly due to delayed health care access or higher venom doses from interactions with larger species [12]. The lack of independent significance in multivariable analysis suggests possible confounding by exposure context, warranting further exploration in future studies.

Seasonal trends in Thanjavur demonstrated higher mortality during the rainy season (47.41%), similar to patterns observed in studies from Sri Lanka and Bangladesh. Waiddyanatha *et al.* and Rahman *et al.* reported peak snakebite incidence during monsoon months when snakes are displaced and agricultural activity increases [13,14]. Although season did not significantly associate with renal outcomes in our cohort, it underscores the influence of climate and occupational patterns on snakebite risk.

The environmental locations of bites in the current dataset revealed that paddy fields and ponds accounted for the majority of cases (86.21%). These findings echo the ecological associations described by Gutiérrez *et al*., who highlighted wetland and agricultural landscapes as high-risk areas due to their suitability for venomous species such as Russell's viper (*Daboia russelii*) and common krait (*Bungarus caeruleus*) [15]. Notably, pond locations demonstrated higher proportions of severe renal involvement, possibly due to encounters with species exhibiting potent hemotoxic venom. This observation parallels findings from the SBE (snakebite envenoming) registry in India, where victims bitten near water bodies had increased systemic complications [9].

The distribution of bite sites in this post-mortem series showed the lower limbs (foot, ankle, calf) were most affected, accounting for 75% of cases. This is consistent with global reports indicating that lower extremity sites are most commonly involved, due to ground-level strike heights of venomous snakes [9,11]. However, the strong association between ankle bites and severe renal involvement in our cohort is relatively unique. Studies from rural Tamil Nadu and Sri Lanka have reported increased severity with bites closer to major vascular structures, but have not consistently identified the ankle as a high-risk site [17,18]. This finding may reflect local behavioral factors such as barefoot farming practices or delayed recognition of envenomation at that anatomical level.

One of the most striking findings in this study was the significant association between the absence of visible fang marks and severe renal involvement. Nearly 58.23% of those without fang marks experienced severe renal complications, compared to 0% among those with visible marks. This pattern is somewhat unusual, as most clinical studies report fang mark visibility as a diagnostic aid rather than a prognostic marker [13,14]. Bites without visible marks may involve species with smaller or less penetrating dentition, leading to more insidious systemic effects that delay clinical recognition and antivenom administration. Further research is needed to validate this association and elucidate its biological and clinical implications.

Severe renal involvement, observed in 39.66% of cases, underscores the importance of acute kidney injury as a significant cause of morbidity and mortality in venomous snakebite victims. Similar rates of renal complications have been documented in hospital-based cohorts from southern India, where nephrotoxic venom components contribute to coagulopathy and direct renal injury [19,20]. Mohapatra *et al.* identified AKI as a major driver of mortality in a large Indian mortality survey, highlighting the need for early antivenom therapy and renal support [19]. The multivariable model in the present study identified age as the only independent predictor of severe renal involvement, potentially reflecting

differences in physiological resilience and comorbidity profiles among age groups.

The lack of independent significance for sex, location, and bite site after adjustment contrasts with previous clinical studies, where these factors often influence outcome severity [15]. This discrepancy may be due to the post-mortem nature of this cohort, where fatal cases represent the end of the clinical spectrum and may mask associations seen in broader clinical populations. Additionally, time to treatment and species identification were not available for analysis, but are known determinants of systemic complications in snakebite envenoming [9,12].

CONCLUSIONS

In summary, this study reinforces patterns observed globally that snakebite mortality is concentrated among young to middle-aged adults, occurs predominantly in rural agricultural settings, and frequently involves lower limb bites. Associations with severe renal involvement underscore the need for strengthened community awareness, early recognition, and rapid access to antivenom and renal supportive care. The unique observations regarding fang mark visibility and anatomical bite site warrant further investigation in prospective studies.

CONTRIBUTION OF AUTHORS

Research concept- Arulmathikannan M, Balamurale R
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Supervision- Shanmugam K
Materials- Arulmathikannan M, Balamurale R
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Data analysis and interpretation- Shanmugam K
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Critical review- Shanmugam K
Article editing- Arulmathikannan M, Balamurale R
Final approval- Shanmugam K

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