Section: Pediatrics

Original Research Article

PREDICTIVE VALUE OF CARDIAC TROPONIN I FOR MYOCARDIAL DYSFUNCTION IN CHILDREN WITH SCORPION STING ENVENOMATION: A PROSPECTIVE OBSERVATIONAL STUDY

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Received *: 31/07/2026*
Received in revised form *: 27/08/2026*
Accepted *: 08/09/2026*

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DOI: 10.70034/ijmedph.2026.3.754

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (3); 4891-4897

ABSTRACT

Background: Scorpion sting envenomation is an important paediatric emergency and may result in severe cardiovascular complications, including myocardial dysfunction, myocarditis, pulmonary oedema and cardiogenic shock. Early recognition of myocardial involvement is essential for appropriate monitoring and treatment. Cardiac troponin I (cTnI) may serve as an early biochemical marker of myocardial injury. **Aim:** To determine the predictive value of cardiac troponin I for myocardial dysfunction in children with scorpion sting envenomation and to assess its association with electrocardiographic and echocardiographic abnormalities.

Materials and Methods: This prospective observational study was conducted in the Department of Pediatrics at Villupuram Medical College Hospital from March 2025 to Dec 2025. Forty children aged ≤12 years with definite scorpion sting or an unknown bite associated with clinical features suggestive of scorpion envenomation were enrolled. Serum cTnI was measured using chemiluminescence immunoassay. Twelve-lead electrocardiography was performed within 24 hours and echocardiography within 24–48 hours. Myocardial dysfunction was defined by the presence of congestive cardiac failure, haemodynamic compromise requiring dopamine or dobutamine ≥5 µg/kg/min, left ventricular dysfunction on echocardiography, or an abnormal ECG. Statistical analysis was performed using SPSS. Receiver operating characteristic (ROC) analysis was used to determine the diagnostic performance of cTnI.

Results: Among 40 children, 27 (67.5%) were male and 13 (32.5%) were female. The most commonly affected age group was 5–10 years, comprising 19 (47.5%) children. Myocardial dysfunction occurred in 12 (30.0%) children. Six (15.0%) had echocardiographic abnormalities and 10 (25.0%) had ECG abnormalities. Sweating/cool peripheries, hypotension, tachycardia and breathlessness were significantly associated with myocardial dysfunction. ROC analysis demonstrated an area under the curve of 0.918 ($p<0.0001$).

Conclusion: Cardiac troponin I demonstrated good discriminatory ability for myocardial dysfunction in children with scorpion sting envenomation. It may serve as a useful adjunct to clinical assessment, ECG and echocardiography, particularly where echocardiography is not immediately available. Larger prospective studies are required to validate the reported cutoff and determine its clinical applicability.

Keywords: Scorpion sting; scorpion envenomation; cardiac troponin I; myocardial dysfunction; myocarditis; children; echocardiography.

INTRODUCTION

Scorpion sting envenomation is an important toxicological emergency in tropical and subtropical regions and can cause severe systemic complications. The clinical manifestations range from local pain and autonomic disturbances to respiratory, cardiovascular and neurological complications. Children are particularly vulnerable to severe envenomation because of their smaller body mass and increased susceptibility to venom toxicity.[1]

Management requires early recognition of systemic toxicity, cardiovascular monitoring and appropriate supportive treatment. Antivenom and prazosin have been shown to facilitate resolution of systemic manifestations, particularly in Mesobuthus tamulus envenomation. Early treatment may reduce the progression of severe cardiovascular complications.[2]

Among the medically important scorpion species, Mesobuthus tamulus (Indian red scorpion) is a major cause of severe envenomation in India and is particularly associated with autonomic and cardiovascular toxicity.[3] Cardiovascular involvement may present with tachycardia, hypertension or hypotension, electrocardiographic abnormalities, myocardial injury, ventricular dysfunction, pulmonary oedema and cardiogenic shock.[4]

The pathogenesis of myocardial injury is multifactorial and involves excessive autonomic stimulation, catecholamine release, increased myocardial oxygen demand and inflammatory mechanisms. These processes may result in myocardial stunning, ventricular dysfunction and pulmonary oedema.[5,6]

Echocardiography is useful for detecting ventricular dysfunction but may not be immediately available in all emergency settings. Cardiac biomarkers, particularly cardiac troponin I (cTnI), may provide an additional method for early detection of myocardial injury. Previous pediatric studies have demonstrated elevated cTnI levels and an association with echocardiographic evidence of myocardial dysfunction in children with scorpion envenomation.[7]

Therefore, the present study was undertaken to evaluate the predictive value of serum cardiac troponin I for myocardial dysfunction in children with scorpion sting envenomation and to assess its relationship with clinical manifestations, electrocardiographic findings and echocardiographic evidence of myocardial dysfunction.

Aim

To determine the predictive value of cardiac troponin I as a marker of myocardial dysfunction in children with scorpion sting envenomation and to assess its association with electrocardiographic and echocardiographic abnormalities.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective observational study conducted in the Department of Pediatrics, Villupuram Medical College Hospital, Tamil Nadu, India, over a period of 10 months from March 2025 to Dec 2025.

Study Population

40 Children aged ≤12 years admitted with scorpion sting, with or without systemic envenomation, were considered for inclusion. Children with an unknown bite associated with clinical manifestations suggestive of scorpion sting envenomation were also included.

A **definite scorpion sting** was defined as a history of scorpion sting, with or without features of envenomation, when the scorpion had been seen by a bystander.

A **consistent scorpion sting** was defined as an unknown bite associated with clinical features suggestive of scorpion sting envenomation.

Inclusion Criteria

1. Children aged ≤12 years.
2. Definite scorpion sting with or without systemic envenomation.
3. Unknown bite with clinical features suggestive of scorpion envenomation.
4. Consent from parents/caregivers.

Exclusion Criteria

Children with pre-existing congenital or acquired cardiac disease were excluded.

Data Collection

A detailed history regarding the time and site of scorpion sting, clinical manifestations, and treatment received prior to referral was obtained from the child, parents/caregivers, and referral records. All children underwent a comprehensive clinical assessment at admission, with specific documentation of local pain, vomiting, seizures, sweating, breathlessness, salivation, cool extremities, hypotension, hypertension, bradycardia, tachycardia, gallop rhythm, shock, and priapism. Clinical assessment was repeated at 4 and 8 hours during PICU observation, and the development of cardiovascular manifestations was documented. For cardiac biomarker assessment, approximately 2 mL of peripheral venous blood was collected in a plain tube approximately 2 hours after the sting and subsequently within 24 hours according to the study protocol. Serum cardiac troponin I (cTnI) was measured using a chemiluminescence immunoassay (CLIA) based on antigen–antibody interaction and detection of the resulting immune complex using labelled antibodies. A standard 12-lead electrocardiogram (ECG) was performed within 24 hours of the sting and evaluated for ST-segment elevation or depression, ST-T abnormalities, and cardiac arrhythmias. Echocardiography was performed within 24–48 hours of the sting using standard echocardiographic views, with assessment

of left ventricular ejection fraction, regional hypokinesia, and global hypokinesia. Children with evidence of myocardial dysfunction underwent repeat echocardiography before discharge to assess recovery of cardiac function. The clinical, biochemical, ECG, and echocardiographic findings were subsequently correlated to evaluate the ability of serum cTnI to predict myocardial dysfunction following scorpion sting envenomation.

Definition of Myocardial Dysfunction

Myocardial dysfunction was considered present when any one of the following criteria was fulfilled:

1. Congestive cardiac failure.
2. Haemodynamic compromise requiring dopamine or dobutamine at ≥5 µg/kg/min.
3. Left ventricular dysfunction on echocardiography in the absence of previous cardiomyopathy.
4. Abnormal electrocardiogram.

Statistical Analysis

Data were analysed using SPSS version 19.0. Categorical variables were analysed using the chi-square test. Fisher's exact test was used when expected frequencies were less than five in 2 × 2 tables.

Receiver operating characteristic analysis was performed to determine the optimal cTnI cutoff and its sensitivity and specificity for predicting myocardial dysfunction.

A p value <0.05 was considered statistically significant.

Ethical Considerations

The study was done after getting approval from institutional ethics committee. Written informed consent was obtained from parents/caregivers before enrolment. Assent was obtained from children aged 7–12 years in addition to parental consent.

RESULTS

A total of 40 children aged ≤12 years with scorpion sting and clinical features of envenomation were included.

Table 1: Demographic and admission characteristics according to myocardial dysfunction

Variable	Total, n (%)	Myocardial dysfunction, n (%)	No myocardial dysfunction, n (%)	p value
Age group				
<5 years	16 (40.0)	5 (41.7)	11 (39.3)	
5–10 years	19 (47.5)	5 (41.7)	14 (50.0)	
>10 years	5 (12.5)	2 (16.7)	3 (10.7)	NS
Sex				
Male	27 (67.5)	8 (66.7)	19 (67.9)	
Female	13 (32.5)	4 (33.3)	9 (32.1)	NS
Time to admission				
≤4 hours	34 (85.0)	9 (75.0)	25 (89.3)	0.246
>4 hours	6 (15.0)	3 (25.0)	3 (10.7)	

Statistical test: Chi-square test; Fisher's exact test was used where expected cell frequency was <5. **NS:** Not statistically significant (p>0.05).

Table 2: Clinical characteristics associated with myocardial dysfunction

Clinical characteristic	Total, n (%)	Myocardial dysfunction, n (%)	No myocardial dysfunction, n (%)	p value
Local pain	40 (100.0)	12 (100.0)	28 (100.0)	NS
Sweating	26 (65.0)	11 (91.7)	15 (53.6)	**0.021***
Cool peripheries	26 (65.0)	11 (91.7)	15 (53.6)	**0.021***
Hypertension	17 (42.5)	7 (58.3)	10 (35.7)	0.944
Hypotension	5 (12.5)	5 (41.7)	0	**0.001***
Tachycardia	17 (42.5)	10 (83.3)	7 (25.0)	**0.001***
Bradycardia	1 (2.5)	0	1 (3.6)	0.507
Breathlessness	2 (5.0)	2 (16.7)	0	**0.027***
Priapism*	16 (59.0)	8 (66.7)	8 (28.6)	**0.024***

**Among male children.*

Statistical test: Chi-square test; Fisher's exact test was used where appropriate. **NS:** Not statistically significant (p>0.05).

Table 3: Association between autonomic storm and myocardial dysfunction

Autonomic storm	Total, n (%)	Myocardial dysfunction, n (%)	No myocardial dysfunction, n (%)
Present	31 (77.5)	12 (100.0)	19 (67.9)
Absent	9 (22.5)	0 (0)	9 (32.1)

Statistical test: Fisher's exact test.

Table 4: Comparison of Cardiac Investigation Findings and Serum Troponin I Levels

Cardiac investigation	Category	Number (n)	Mean Troponin I ± SD	*p* value
Echocardiography	Normal	34	0.04 ± 0.09	**0.101**
	Abnormal	6	7.02 ± 8.50	

ECG	Normal	30	0.03 ± 0.08	**0.097**
	Abnormal	10	4.28 ± 7.26	

Test used: Welch's independent-samples *t* test. Statistical significance: $p < 0.05$.

Demographic characteristics

Among the 40 children, 16 (40.0%) were aged <5 years, 19 (47.5%) were aged 5–10 years and 5 (12.5%) were aged >10 years. The 5–10-year age group constituted the largest proportion of the study population. There was a male predominance, with 27 (67.5%) boys and 13 (32.5%) girls. Thirty-four children (85.0%) presented within 4 hours of the sting, while 6 (15.0%) presented after 4 hours. Of the 40 children, 12 (30.0%) developed myocardial dysfunction, while 28 (70.0%) did not. [Table 1]

Clinical characteristics

The commonest clinical manifestation was local pain, which was present in all 40 children (100%). Sweating and cool peripheries were each observed in 26 (65.0%) children. Hypertension and tachycardia were present in 17 (42.5%) children each. Hypotension was observed in 5 (12.5%) children and breathlessness in 2 (5.0%). [Table 2]

Autonomic storm

Of the 40 children, 31 (77.5%) presented with autonomic storm, whereas 9 (22.5%) did not. All 12 children who developed myocardial dysfunction had autonomic storm. [Table 3]

Cardiac involvement

Among the 40 children, 12 (30.0%) had myocardial dysfunction. Echocardiographic abnormalities were detected in 6 (15.0%) children, while ECG abnormalities were observed in 10 (25.0%). [Table 4]

Troponin I and myocardial dysfunction

The mean Troponin I level among children with myocardial dysfunction was 3.5738 ± 6.7733, compared with 0.0329 ± 0.0840 among children without myocardial dysfunction and was statistically significant. [Table 5]

Table 5: Comparison of Troponin I levels according to myocardial dysfunction

Troponin I	Myocardial dysfunction (n=12)	No myocardial dysfunction (n=28)	p value
Mean ± SD	3.5738 ± 6.7733	0.0329 ± 0.0840	<0.001*

Statistical test: Independent-samples t-test/Welch's t-test, as appropriate.

ROC analysis

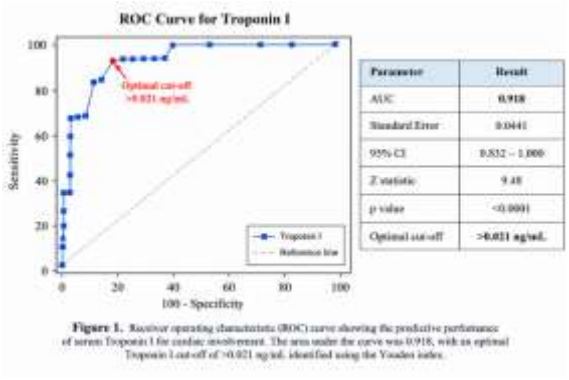

Figure 1. Receiver operating characteristic (ROC) curve showing the predictive performance of serum Troponin I for cardiac involvement. The area under the curve was 0.918, with an optimal Troponin I cut-off of >0.021 ng/mL identified using the Youden index.

The AUC of 0.918 demonstrates excellent discriminatory ability of Troponin I. At a cut-off of >0.021 ng/mL, the sensitivity was 91.67% and specificity was 78.57%. Thus, Troponin I demonstrated good potential for identifying children at risk of myocardial dysfunction. [Figure 1]

DISCUSSION

The present prospective observational study evaluated the predictive value of cardiac troponin I for myocardial dysfunction in children with scorpion sting envenomation. Among the 40 children studied, 12 (30%) developed myocardial dysfunction. This finding indicates that clinically significant cardiac involvement remains an important complication of pediatric scorpion envenomation. The occurrence of myocardial dysfunction in nearly one-third of the study population emphasizes the need for early cardiovascular assessment in children with systemic envenomation.

Abimannane et al. evaluated 72 children with Indian red scorpion envenomation and demonstrated that myocardial dysfunction could persist despite initial treatment. Importantly, children who received early antivenom therapy experienced a significantly shorter duration of myocardial dysfunction compared with those requiring additional treatment. Abnormal echocardiography at admission was also a strong predictor of the need for a second dose of antivenom.[8] These findings emphasize that cardiovascular involvement is not merely an incidental finding but may reflect the severity and progression of envenomation.

The present finding of myocardial dysfunction in 30% of children is also consistent with recent pediatric observational data. Choppari et al. studied children with scorpion envenomation in a tertiary-care setting and documented systemic manifestations including myocarditis and pulmonary oedema. Their findings reinforce the vulnerability of children to significant cardiovascular and respiratory complications following scorpion sting.[9]

The cardiovascular effects of scorpion venom can occasionally mimic acute coronary syndromes. Verma et al. described a child with scorpion sting who developed severe left ventricular dysfunction, ST-segment elevation and clinical features consistent with Kounis syndrome. The rapid normalization of electrocardiographic changes and

recovery of ventricular function demonstrated the potentially reversible nature of severe venom-associated myocardial injury.[10] This observation is relevant to the present study because myocardial dysfunction may occur even when the underlying mechanism is transient myocardial stunning or ischemia rather than permanent myocardial necrosis.

Clinical severity is influenced by age, autonomic manifestations and the development of respiratory or cardiovascular complications. Rebahi et al. evaluated 606 children with severe scorpion envenomation and found that younger age, tachycardia, respiratory distress and other systemic manifestations were associated with poor outcome.[11] These findings support the need for early identification of children who are likely to develop severe systemic toxicity.

Recent Indian literature similarly emphasizes the importance of early recognition and treatment. Kumar highlighted that children are more susceptible to severe manifestations of scorpion envenomation and that cardiovascular complications, pulmonary oedema and myocarditis are important causes of morbidity and mortality. Early administration of prazosin and antivenom, together with appropriate cardiovascular support, can reduce severe complications.[12]

A particularly important finding in the present study was the strong discriminatory performance of cardiac troponin I. ROC analysis demonstrated an AUC of 0.918 (95% CI: 0.832–1.000; $p<0.0001$), with an optimal Troponin I cut-off of >0.021 ng/mL. This indicates excellent ability of cardiac troponin I to discriminate children with myocardial dysfunction from those without myocardial dysfunction in the present cohort.

The importance of cardiac biomarkers in scorpion-associated myocardial injury has also been highlighted in the recent systematic review by Fereidooni et al. Their review included 703 cases of scorpion-associated myocarditis and found that elevated troponin, echocardiographic evidence of ventricular dysfunction and cardiovascular manifestations were frequently present. The authors emphasized serial cardiac markers and echocardiography as useful tools for early recognition and monitoring of myocardial involvement.[13]

The association between biochemical myocardial injury and systemic toxicity has also been demonstrated in broader reviews. Elmourid et al. reported that scorpion venom can produce myocardial and pulmonary injury accompanied by biochemical abnormalities, particularly in severe envenomation. Children were identified as a particularly vulnerable group with a higher risk of severe outcomes.[14]

The present study therefore supports the concept that cardiac troponin I can serve as an early biochemical indicator of myocardial involvement. Its potential advantage is that it can provide objective evidence of myocardial injury when echocardiography is unavailable or cannot be performed immediately. However, troponin elevation should be interpreted in conjunction with the clinical condition, ECG findings and echocardiographic assessment rather than as an isolated diagnostic criterion.

Recent epidemiological evidence also confirms that severe cardiovascular complications remain clinically important. Alhelail et al., in a systematic review of scorpion envenomation in Saudi Arabia, reported that severe cases may develop pulmonary oedema, cardiac arrest and myocarditis, with children generally experiencing more severe manifestations.[15] Although the epidemiology and scorpion species vary between regions, the consistent occurrence of cardiac toxicity across different geographical settings supports the importance of cardiovascular surveillance.

Myocardial ischemia is another potential mechanism underlying cardiac injury. Bahloul et al. reviewed myocardial ischemia following severe scorpion envenomation and found evidence of myocardial hypoperfusion across electrocardiographic, echocardiographic and biochemical investigations. Their findings suggest that catecholamine-mediated vasoconstriction, increased myocardial oxygen demand and altered coronary perfusion may contribute to myocardial injury.[16] This mechanism provides a plausible explanation for the elevation of troponin observed in children with myocardial dysfunction.

Recent advances in cardiac biomarkers may further improve early identification of myocardial dysfunction. Almeida et al. evaluated newer biomarkers in children and young patients with scorpion stings and found that soluble ST2 and FABP-3 were associated with left ventricular dysfunction. Ultrasensitive troponin demonstrated an AUC of 0.89 and a sensitivity of 84.6%, supporting the continued usefulness of troponin as a marker of cardiac injury while suggesting that newer biomarkers may provide additional diagnostic information.[17]

The clinical importance of myocardial injury is further demonstrated by recent pediatric case reports. Akbari et al. described toxic myocarditis in a 3.5-year-old child following Hemiscorpius lepturus sting, with reduced ejection fraction and elevated cardiac biomarkers. Cardiac function subsequently improved with antivenom and supportive treatment.[18] Although a single case cannot establish predictive performance, it illustrates the potential for rapid-onset myocardial dysfunction in young children and the importance of continuous cardiovascular monitoring.

Treatment may influence the course of myocardial dysfunction. Kestenbom et al. evaluated antivenom therapy in children with Middle Eastern scorpion envenomation and reported rapid resolution of systemic manifestations, with complete recovery in the treated cohort and no deaths.[19] Although these findings relate to a different scorpion population,

they reinforce the importance of early recognition and appropriate treatment of systemic envenomation.

More recent pediatric evidence also supports a risk-stratified approach to monitoring. Kestenbom et al. evaluated 287 children and found that fewer than 1% of children with mild envenomation developed delayed systemic symptoms, whereas children with more severe envenomation were younger and more likely to require hospitalization.[20] These findings suggest that clinical severity assessment can help determine monitoring requirements, while children with systemic toxicity or evidence of cardiac involvement require more intensive observation.

Overall, the present study demonstrates that cardiac troponin I has excellent discriminatory ability for myocardial dysfunction in children with scorpion sting envenomation. The AUC of 0.918 and the optimal cut-off of >0.021 ng/mL suggest that cTnI may be useful for early cardiovascular risk stratification. The findings are particularly relevant in settings where echocardiography is not continuously available.

However, cardiac troponin I should complement rather than replace clinical assessment, ECG and echocardiography. Troponin reflects myocardial injury, whereas echocardiography directly evaluates ventricular function. A combined approach using clinical assessment, serial ECG, cardiac troponin I and echocardiography may therefore provide the most effective strategy for identifying children at risk of myocardial dysfunction.

The present findings also highlight the potential clinical value of early biomarker assessment. Children with elevated troponin concentrations may benefit from closer cardiovascular monitoring, early echocardiographic assessment and timely initiation or escalation of supportive therapy. Larger prospective multicentre studies are required to validate the >0.021 ng/mL threshold across different troponin assays and pediatric populations before it can be adopted as a universal clinical cut-off.

CONCLUSION

Myocardial dysfunction is a clinically important complication of scorpion sting envenomation in children and was observed in 30% of the study population. The present study demonstrated that serum cardiac Troponin I has excellent discriminatory ability for identifying myocardial dysfunction, with an AUC of 0.918 (95% CI: 0.832–1.000; $p<0.0001$). A Troponin I concentration of >0.021 ng/mL was identified as the optimal cut-off for predicting myocardial dysfunction.

These findings indicate that cardiac Troponin I may serve as a useful early biochemical marker for cardiovascular involvement in children with scorpion envenomation. Its measurement may help identify children who require closer cardiovascular surveillance and early echocardiographic evaluation, particularly when clinical manifestations alone may underestimate the severity of myocardial injury. However, Troponin I should be considered an adjunct rather than a substitute for echocardiography and ECG, as these modalities provide complementary information regarding electrical abnormalities and ventricular function. An integrated approach combining clinical assessment, ECG, cardiac Troponin I and echocardiography may improve the early recognition of myocardial dysfunction and facilitate timely intervention. The present findings support the incorporation of cardiac Troponin I into the early evaluation of children with suspected significant scorpion envenomation. Larger multicentre prospective studies are required to validate the proposed >0.021 ng/mL threshold and establish its applicability across different troponin assays and pediatric populations.

Ethics Approval

Institutional Ethics Committee approval was obtained before commencement of the study.

Conflict of Interest

The authors declare no conflict of interest.

Funding

No external funding was reported in the source thesis.

Acknowledgements

The authors acknowledge the Department of Paediatrics, Villupuram Medical College Hospital, the supporting departments and the children and their families who participated in the study.

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