COMMENTARY



Case for a one-health approach to venomous snakebite, using the epidemiological triad model, for mitigation

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Abstract

Background Snakebite envenoming (SBE) was listed as a Neglected Tropical Disease (NTD), by the WHO in 2017. SBE kills more victims than all the other NTDs put together. SBE is a condition associated with poverty, inequity, inaccessibility and poor health systems. The major burden of SBE is borne by the countries of South-Asia, led by India, with an estimated 58,000 deaths annually. This as compared with the USA or Australia where deaths due to SBE is in a single digit, despite having equally venomous species. SBE is also a significant cause for loss of livestock in the Tropics. Research in the domain of snakebite has largely been limited to study of venoms and therapeutic aspects, and not as much on snake behaviour and habitats, and the environment.

Body Snakebite is most often accidental, preventable and treatable. For mitigation of snakebite and the complications thereof, snakebite and SBE need be viewed from a one-health framework. The one-health approach to snakebite factors for the role of the environment, habitats, study of snakes, venom, factors and circumstances contributing to the accident. The current one-health framework proposed using the 'epidemiologic triad' model of agent-host-environment, allows for a better understanding and descriptione of the snake-human/livestock conflict. With snakes being the agent, humans/ livestock the host, and the ecosystem harbouring snakes the environment. This approach helps us to delineate the individual attributes influencing the snake-human conflict, and its outcomes. In the proposed one-health model we expand on the agent-host-environment (proximal factors), to an outer setting of more distal factors which too have an influence on snakebite and SBE. The outer setting includes the social determinants of health, eco climatic factors, socio-cultural factors, health systems, infrastructure and development all of which either directly or indirectly have a bearing on snakebite, and the outcomes resulting from the accident. (Fig. 1).

Conclusion The one-health model built on the epidemiologic triad model helps encompass most of the factors that influence or lead to the snake-human/livestock conflict. This model will facilitate preventative measures and help address the steps required to mitigate death and morbidity due to SBE.

Keywords Snakebite, Snakebite envenoming, One-health, Epidemiologic triad, Snake-human conflict, Social determinants, Neglected tropical disease, Climate change

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Background

Snakebite envenoming (SBE) is a major preventable cause of morbidity and mortality in the Tropics. There are an estimated 4.5 to 5.4 million bites annually worldwide, resulting in envenoming in roughly half of them. This in turn leads to 81,000–138,000 deaths, with an additional 400,000 permanent disabilities. SBE is listed as one among twenty-four neglected tropical diseases (NTDs). SBE results in more deaths than all the other NTDs put together. The socioeconomic impact of SBE is also considerable with approximately 70% of victims being male, and in the 20–65 age bracket, the economically productive age groups [1–4].

Snakebite is also the most commonly occurring 'human-wildlife' conflict worldwide, by far outnumbering deaths and attacks from other wildlife species. SBE, additionally is also a major cause for loss of livestock in the tropics [5].

Introduction

As per the One Health Global Network definition, 'One Health recognizes that the health of humans, animals and ecosystems are interconnected. It involves applying a coordinated, collaborative, multidisciplinary and crosssectoral approach to address potential or existing risks that originate at the animal-human-ecosystems interface [6].

Snakebite is a potential hazard in all ecosystems where snakes exist. Snakes inhabit all parts of the globe other than for the Antarctic continent and the island nations of New Zealand, Iceland, Hawaii and Greenland. Snakes are most abundant in the Tropics, which is also home to 40% of humanity. The likelihood of a snakebite, both in humans and livestock, increases in proportion to the chance of a snake-human/livestock encounter.

Snakebite is most commonly accidental and rarely provoked. Snake-human/livestock conflict and its consequences are influenced by a number of factors including population density of humans, livestock and snakes; phenotype of snakes; availability of prey; weather; ecosystems; social contexts; occupation and social determinants.

Snake-human conflicts and encounters have increased over the years primarily related to an increasing human population, habitat loss and degradation, and human encroachment into forests. Other causes include persecution by humans, with all snakes being killed at sight within certain communities. Additional causes include rampant use of pesticides and rodenticides, as also free and unscientific snake-handling by snake rescuers [6–9].

Research in the field of snakebite has focussed more on study of venom and therapeutic aspects and less on snake taxonomy, habits, behaviour, ecosystems, effect of climate change, and circumstances leading to conflict. A one-health approach to snakebite being more comprehensive would consider the above aspects, which would help guide mitigation, and preventive strategies [6, 7].

Snakes are an essential link in the ecosystem and play a key role in controlling rodent populations, with consequential health benefits and also increased agricultural output. Estimates suggest that nearly 200 million people can be fed by food grains that are destroyed by rodents every year [10]. Additionally, snake venom components have immense therapeutic value with Captopril, Eptifibatide, Tirofiban, and Batroxobin, all being sourced from snake venom [11].

Main content

One-health approach and its relevance to snakebite

The milieu and circumstances leading to snake-human/ conflict are better studied using the one-health approach. This is crucial for preventing snakebite and mitigating the consequences of SBE.

Snakebite is associated with certain outdoor activities like walking, playing, swimming or even while indoors. Snakebite is an occupational hazard especially among farmers, herders, fishermen, forest-produce gatherers, snake handlers, forest guards and workers in brick-kilns, saw-mills, and plantations [6, 7].

Snakebites in women commonly occur with activities like gathering firewood, cutting grass, farming activities like planting and harvesting, cleaning the hen-coop or cow-shed, or inside the house especially in the store room/granary. Children get bitten most often while playing outdoors, swimming or even when inside the house [6, 12].

Snakebite and SBE is seasonal and peaks with the onset of the monsoons across the tropics, probably related to an increase in snake movement and also increase in agricultural activity. The monsoon months (July-August) in the tropics are also the preferred time when eggs hatch or live-young are delivered, depending on species [6, 7, 12].

Certain socio-behavioural habits and cultural practises like stacking firewood on the outer wall of the house; locating a chicken coop, cow-shed or haystack close to the house; pets in the house; litter; storing of farm produce inside the house (grains, coconut, cured rubber sheets etc.); walking bare feet or with feet uncovered; not using a torch at night; sleeping on the floor and not using or tucking a mosquito net adequately; branches of trees overhanging into houses; unkept plots of land in residential areas; free snake-handling, are all known to increase the likelihood of human-snake conflict. Open defaecation is a habit which is associated with snakebite in certain countries [6–8, 12].

Snakebite incidence varies on a geographical and temporal scale, resulting from the interaction of anthropic and environmental drivers [6]. A number of additional factors weigh in on the snake-human conflict and is best studied using the framework of the '**epidemiological triad**' which has typically been associated with the study of infectious diseases.

The epidemiological triad model, with snakes as the '**agent**', humans and life-stock as '**host**' and the ecological factors that contribute to the human-reptile conflict as the '**environment**', helps make a case for a composite one-health approach to snakebite and SBE. (Fig. 1)

The 'agent' factors to be considered include.

- Whether medically relevant snake of consequence and biting species
- Dose of venom injected
- Size and age of the snake
- Whether a 'defensive' or 'predatory' bite [13]
- Time of the day of the bite
- Season when bitten
- Multiple or single bite
- Sex of the snake
- Whether the snake had fed prior to the bite
- Intraspecies variation in venom composition and toxicity by geography

The 'host' factors of importance include

- Site on the body where bitten
- Body mass of the victim
- First-aid measures used
- History of previous bite and treatment
- Comorbid conditions which could influence health outcomes
- Whether under the influence of alcohol when bitten
- Whether a provoked bite
- Time lapse to definitive care

The **'environmental'** factors that are relevant which factor for the human-reptile conflict include.

- Environmental factors like rainfall and altitude
- Temperature and weather conducive to snake survival
- Presence of forest, tree or plant cover
- Availability of prey
- Abnormal weather patterns and natural calamities like floods and landslips
- Effects of climate change

The proposed one-health framework allows for the analysis of proximal influencers of the snake-human/livestock conflict through the model of the 'epidemiologic triad' and the other relevant factors determining incidence and resultant outcomes as the outer setting (represented as petals in the Fig. 1). The 'epidemiologic triad' model in the context of snakebite and SBE helps make a case for the one-health approach to snakebite, enunciating on the number of varied factors that influence snake-human/ livestock conflict. The outer settings to conflict which have a bearing on outcomes of SBE include other determinants like ecoclimatic, cultural, social determinants, health systems and infrastructural development [14–16].

The outer settings influencing snake-human conflict are linked to poverty, inequity and social determinants, with snakebite being most prevalent in impoverished populations, usually below the health radar in low-middle-income-countries. Inadequate infrastructural and social development; poor literacy and lack of awareness; poverty; climate change; occupation; cultural and behavioural habits and customs; access to health care of quality all weigh in as distal factors to both snake-human/livestock conflict and health outcome with envenoming [6, 14–17].

Inadequate **infrastructure and social development** including lack of roads, lighting, electricity, running water in the house, toilets, cooking gas, all of which contributes to the snake-human conflicts, either directly or indirectly.

Eco-climatic factors influence a wide array of natural and human systems, including biodiversity, habitat suitability, species migration patterns, and human-wildlife interactions. For instance, paddy farmers during sowing or harvesting, rubber plantation workers during tapping, and tea plantation labourers during harvesting are especially vulnerable. Forestry workers, wildlife researchers, and ecotourism guides face heightened risks in dense vegetation where snakes thrive, while urban expansion into natural habitats increases snake encounters for construction workers and residents. Climatic events like flooding displace snakes into human settlements, endangering relief workers and residents in affected areas. Mining and quarrying disrupt underground habitats, exposing workers to venomous species, while fishers and those working near aquatic ecosystems encounter semiaquatic snakes during activities like fishing or net-setting. These examples underscore the broad impact of eco-climatic conditions, shaped by biodiversity, land use, and climate, on snakebite risks across various ecological and occupational settings.

Health systems play a crucial role in preventing the event of snakebite, and of mortality, disability and morbidity in cases of SBE. Access to equitable quality health-care, with staff trained in the diagnosis and management of both airway and envenoming, alongside availability of anti-snake venom, ventilators, ambulance services for referral, are all major factors which determine health outcomes.

SBE more so than most other diseases is socially determined. Literacy, economic status, living conditions, and social security from among the **social determinants** of health, weigh in on snake-human conflict, treatment seeking behaviour, and health outcomes. A large community survey across 11 states in India revealed that 53% of the bitten were below the poverty line (BPL) and that only 13% of the victims had some sort of Insurance cover (unpublished). Cost of treatment in the private sector and lack of resources, both material and human in the nearest public health centres are reasons that drive victims to seek alternate systems of care who are more easily accessible (faith-healers, traditional healers etc.).

The **sociocultural** drivers for snakebite include certain cultural and behavioural practises like killing snakes on sight, open defaecation, revering snakes, beliefs and practices followed when bitten, sleeping on the ground or in the open, all of which contribute to the conflict. Open defaecation is not uncommon as an activity associated with snakebite, which also is commoner in women who



Fig. 1 One-health framework to snakebite factoring for the proximal causes for snake-human/livestock conflict through the 'epidemiologic triad' and the distal factors responsible for both incidence and health outcomes with SBE

tend to use the fields or cloistered high grass covered areas at an earlier hour for privacy 12, 18, 19, 20.

The interconnectedness between the humans, snakes and the environment that they live in, which defines the one-health approach is better viewed through the lens of an epidemiologic triad and its outer settings in the context of snakebite and SBE.

Discussion

For countries to be able to meet the WHO-SDG (Sustainable Development Goal) of a 50% decrease in bites and death due to SBE by 2030, a one-health approach is critical. The various determinants of the snake-human conflict need be addressed to meet the ends. Current research in the field of snakebite and envenoming has centred on diagnosis, therapeutic aspects and on study of snake venom, and not as much on the study of snake's taxonomy, habits and preventative measures. For prevention of snakebite, knowledge of snake phenotypes, habits, snake population and distribution are crucial in order to avoid snake-human/livestock conflict [20]. It is equally important to understand the correlation between the various ecological factors driving snake behaviour and activity in relation to snakebite and SBE. As to what extent climate change has influenced incidence of snakebite and SBE has also largely been ignored. The effect of climate change on each component of the triad, agent-host-environment need be studied in detail for mitigation of SBE. SBE it would seem is an interface where environment, agriculture, climate change, human behaviour, poverty, neglect, human greed and inequity meet. The health seeking behaviour and health systems are an integral part of this continuum of care, all of which need be analysed and researched.

Conclusion

For a more targeted approach towards mitigating the burden of deaths and disabilities due to SBE in humans and livestock, the continuum of agent-host-environmenthealth systems need be considered. The epidemiological triad in the context of snakebite parallels dogs in rabies where eradication of the agent is not the target, whilst prevention prevails. A one-health framework led multisectoral, coordinated approach involving ophiologists, botanists, meteorologists, ecologists, veterinarians, clinicians, basic scientists, anti-snake venom manufacturers, non-governmental organisations (NGOs) and other stakeholders, is a pre-requisite for mitigation and prevention. The Snakebite Information and Data platform launched by the WHO includes epidemiological data on SBE, venomous snakes and anti-snake venom which in our view needs to be more granular, and to factor for the one-health approach to snake-human-conflict.

The comprehensive one-health framework would allow for a more detailed study of the snake-human/livestock conflict, and would thereby guide preventive measures and mitigation.

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Author contributions

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Competing interests

None of the authors have any competing interests to declare.

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