



## Snakebite incidents, prevention and care during COVID-19: Global key-informant experiences

Janneke van Oirschot<sup>a,\*</sup>, Gaby I. Ooms<sup>a,b</sup>, Benjamin Waldmann<sup>a</sup>, Priyanka Kadam<sup>c</sup>

<sup>a</sup> Health Action International, Amsterdam, the Netherlands

<sup>b</sup> Utrecht Centre for Pharmaceutical Policy and Regulation, Division of Pharmacoepidemiology and Clinical Pharmacology, Utrecht Institute for Pharmaceutical Sciences (UIPS), Utrecht University, Utrecht, the Netherlands

<sup>c</sup> Snakebite Healing & Education Society, Mumbai, India

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### ABSTRACT

Snakebite envenoming is a long-neglected disease causing significant morbidity and mortality in snakebite endemic low- and middle-income countries (LMICs). Global awareness on snakebite was increasing steadily up to 2020, and an increasing number of countries began to acknowledge the issue, when coronavirus disease 2019 (COVID-19) started to have an unprecedented impact on societies and health systems. To better understand how snakebite incidents, prevention and care are being affected during this global emergency, we collected perspectives of snakebite community- and health system stakeholders in a qualitative key-informant study. An open-ended survey and semi-structured interviews were conducted to gather information on changes in snakebite occurrence and circumstances, community responses, access to care and health outcomes in LMICs since the COVID-19 pandemic. Forty-three informants from 21 countries participated in the study. Based on informants' experiences, in spite of COVID-19 lockdowns, exposure to snakes did not change in many rural agrarian communities, where incidences are usually highest. However, we did find several access to care issues relating to avoidance of formal care, transport barriers, overburdened healthcare systems and -providers, and antivenom manufacturing and supply disruptions, which were unique per context. On a brighter note, ventilator availability had increased in several countries, although not automatically benefitting snakebite patients directly. In conclusion, we found apparent effects of the COVID-19 pandemic on snakebite prevention and care, although its severity was highly context- and time-dependent. Interactions between the pandemic effects and snakebite incidents most severely impact remote rural communities, showing the need to invest in community-based prevention and care.

### 1. Introduction

Snakebite envenoming is a preventable and treatable disease that mostly affects poor communities with low access to basic care (Harrison et al., 2009; Longbottom et al., 2018). The condition causes a significant and avoidable disability- and death-toll in endemic low- and middle-income countries (LMICs) (Kasturiratne et al., 2008). In addition to this, affected individuals and families may face economic hardship and (psycho)social consequences (Bhaumik et al., 2020; Hasan et al., 2012; Vaiyapuri et al., 2013). However, due to inadequate reporting systems and scarcity of research, accurate data on the global impact of snakebite is poor, making the true burden unknown.

Snakebite has long suffered from neglect on all levels, however, in

2017 the global health community finally took notice and the World Health Organization (WHO) re-categorised snakebite as a priority neglected tropical disease (NTD). In 2019, the WHO released a comprehensive global roadmap strategy to reduce snakebite deaths and disability by 50% by 2030 (World Health Organization, 2019). While global awareness has increased, health systems in many snakebite endemic countries are still not equipped to respond adequately. Lack of expertise, equipment and access to medical commodities, specifically effective antivenom, are common issues at health facilities, while timely access to care and effective health-seeking behaviour are challenges at the community level (Fry, 2018; Ooms et al., 2021; Williams, 2015). Then, in early 2020, coronavirus disease 2019 (COVID-19) started to have an unprecedented impact on societies and health systems across

\* Corresponding author. Overtom 60 (2), 1054 HK, Amsterdam, the Netherlands.

E-mail address: [Janneke@haiweb.org](mailto:Janneke@haiweb.org) (J. van Oirschot).

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the world. Countries saw medical supply chains disrupted, healthcare personnel, beds and equipment diverted to COVID-19, and government-imposed restrictions on movement, which can all have serious population health effects (Chi et al., 2020).

Several scientific editorials, short communications and perspective pieces have described concerns about the closure of health facilities for non-COVID-19 related care and the repurposing of health facilities, risks of limited bed availability, specifically for patients requiring specialist care in rural settings, lack of personal protective equipment (PPE), issues in the continuity of medicine manufacturing and supply chains, disruption of research efforts, and insufficient health resources, for NTDs in general and snakebite specifically (Abdela et al., 2020; Molyneux et al., 2020; Moos, 2020). Furthermore, papers touched upon the cessation of national monitoring of NTD programmes and community-based NTD prevention activities (Abdela et al., 2020; Molyneux et al., 2020; Moos, 2020). Also, people with (NTD-related) disabilities might experience additional issues with access to health services and care (Molyneux et al., 2020). Finally, comorbidity of snakebite and COVID-19, like many other NTDs, could have potential interactions, for example, because both conditions may cause respiratory distress, a pro-coagulant state or an inflammatory response (Gutman et al., 2020).

Despite the renewed attention and progress in recent years on snakebite control and management, we risk falling backwards if the above concerns are not unpacked and mitigated. The COVID-19 pandemic may well negatively affect every aspect of snakebite, from the number of events, to health-seeking behaviour, treatment, and health outcomes. Also, shifting priorities due to the pandemic in already vulnerable health systems are likely to impact snakebite care on all levels. To better understand how these aspects have been affected during this global emergency, we collected the perspectives and stories of community- and health system stakeholders from snakebite endemic LMICs. Collecting this information is of critical importance as it helps to consolidate our understanding of how snakebites and snakebite care were impacted during COVID-19 to inform the global health community on both how this impact might be mitigated, and how health systems can be better prepared and made more resilient to shock.

## 2. Methods

### 2.1. Study design

A cross-sectional qualitative study design was used, comprising an open-ended survey and semi-structured interviews among key stakeholders whose work contributes to snakebite prevention or care. Key informant interviews are a useful tool to retrieve rich information on short notice and therefore suited to gain exploratory insights into an urgent issue (Marshall, 1996). The interviews were preceded by a short survey asking six of the same open-ended questions to all participants, to ensure the interviewer had basic insights into the situation before the start of the interview and could ask targeted follow-up questions. This methodology facilitated efficient working, allowing the researchers to gather a substantial amount of information within a short timeframe.

### 2.2. Tools

The WHO's Snakebite Envenoming Strategy for Prevention and Control was used to guide the development of interview questions (World Health Organization, 2019). Specifically, the interview guide covered questions regarding three of the strategies' four strategic objectives: 'empowering and engaging communities', 'strengthening health systems' and 'ensuring safe, effective treatment' (World Health Organization, 2019). We developed questions to assess access to snakebite services and care using the dimensions of access as described by Peters et al.: availability, financial & geographical accessibility, acceptability and quality (Peters et al., 2008). Both the survey and

interview guide covered questions on whether, since the COVID-19 pandemic, there had been changes in snakebite occurrence and circumstances, community behaviour and responses to snakebite, access to care, health outcomes after a snakebite and on the impact of potential pandemic-related regulations by the government.

### 2.3. Participants & recruitment

Key informants were individuals who worked in snakebite prevention and care. They could have a range of different professions, as long as their work gave them insights into the snakebite situation in communities, hospitals or the broader health system. Participants were recruited through Health Action International's (HAI) and Snakebite Healing and Education Society India's (SHE-India) networks of individuals affiliated to snakebite. Also, snowball sampling was used to recruit new participants when the respondent came from an under-represented area in our sample. Participants were invited over email.

### 2.4. Data collection

The surveys and interviews were conducted between December 9, 2020 and February 11, 2021. The researchers used a research- and interview guide to ensure harmony in study procedures. In addition, they used the survey responses to identify the participants' experience and issues that were relevant to expand on during the interview. Hence, while the same topics were covered in all interviews, the focus varied depending on the participants' expertise and survey answers. The antivenom manufacturers were an exception, as we asked them specific questions about orders, production, export, and distribution. The interviews took between 12 and 63 minutes and were conducted online using the video calling platform Zoom (one using Skype). The majority of interviews lasted around 30–45 minutes (72.2%) and only two finished within 15 minutes, when the participant had not seen considerable changes due to COVID-19. Conversations were recorded and in Zoom, the live captions setting was used to generate automatic transcripts of the conversation.

### 2.5. Data analysis

The automatic transcripts were checked and corrected by the researchers and analysed using a thematic analysis with directed content coding. Relevant segments of text were extracted from each interview and coded into themes based on a predetermined set of codes related to the interview topics (Hsieh and Shannon, 2005). After completion of coding into the general themes, subthemes were identified and coded using open content coding, and results were synthesised per code while remaining sensitive to links and patterns across the data. The research team met regularly to discuss findings and interpretations. After an initial synthesis of results, all survey responses and interviews were retraced to see if they provided additional insights that were missed. Direct quotes are included in the results section to elaborate on themes—the stakeholder group and country of the respondent is included in parentheses.

### 2.6. Ethical considerations

Under Dutch law, this study did not require the approval of an Ethical Review Board (Ministerie van VWS, 2020). However, the following steps were taken to safeguard ethical conduct: Data was de-identified and reported anonymously. Prior to participation in the study, participants were sent comprehensive information about the study purpose and procedures through a participant information sheet and informed consent form. Verbal informed consent was obtained from all participants prior to the start of the interview and was recorded on audio. All study participants were above 18 years of age.

### 3. Results

#### 3.1. Sample

Ninety-four individuals were invited to partake in the study; 27 did not respond, eight responded that they lacked insights as they for example had not been involved in snakebite services during the pandemic, eight did accept the invite but did not respond to the follow-up emails to schedule an interview date or provide survey data, six had other priorities, one became co-author instead, and one could not participate because of COVID-19 infection, leading to a final sample size of 43 participants.

Seven participants completed only the survey but not the interview, and one completed the interview but not the survey. Thirty-five participants completed both the survey and the interview. Participants came from 21 different countries and included community actors, healthcare providers, health authority stakeholders, researchers, antivenom manufacturers and advocates (Table 1). Among healthcare providers were many emergency physicians and toxicologists. Community actors were snake handlers, community educators and general snakebite points of contact, many of which were member of a snakebite-focused community organisation or non-governmental organisation.

#### 3.2. Point of departure

The study’s scope covered ways in which the COVID-19 pandemic impacted snakebite prevention and care worldwide. However, a direct correlation between snakebite and the COVID-19 pandemic could be hard to measure when faced with an existing absence of awareness, prevention and care services and programmes. Many informants believed the pandemic had a negative effect on snakebite interventions and services. But, when due to its neglected state, antivenom, medical care, surveillance, effective health-seeking behaviour, and dedicated funds were all already lacking, the situation may not have noticeably worsened due to the pandemic.

#### 3.3. Circumstances of snakebite

Many informants mentioned that snakebite surveillance, reporting and information systems had been problematic or lacking, which became worse during the pandemic. Therefore, reliable and up-to-date population statistics on snakebite incidence before and during COVID-19 were unavailable in practically all countries. This lack of data, combined with decreased contact with communities, generally resulted in informants sharing information on snakebite incidence and circumstances based on reasoning, observation, and local information sources.

Nevertheless, informants reflected on how the pandemic had influenced the risk of snakebite and the circumstances under which they occurred. Many, across continents and countries, explained that rural agrarian communities, a high-risk group, had not stopped their activities as movement restrictions were often not enforced, enabling rural workers to continue food production and other labour activities (P4, 9, 10, 16, 18, 19, 21, 22, 26, 30, 36, 38, 39). Some additionally mentioned that an increased part of the population was now resorting to agricultural work to support themselves, likely putting them at closer contact with snake habitats than before (P12, 14, 15, 29, 39, 40). In line with this, in Kenya, Tanzania and Uganda (P29, 39, 42), informants expected the closure of schools, in combination with a drop in family income, to result in children being more exposed to snakes outdoors: “Before, children were not getting bitten as much as now because they would be in school, and yet now they are spending much more time in their gardens” (P42, healthcare provider, Uganda).

Some informants thought rural migration could have increased the risk of snakebites, with people moving back to rural villages from the cities (P4, 22, 29). Conversely, others posed that exposure to snakebites could have decreased due to less population movement in environments

**Table 1**  
Participant characteristics.

Participant number	Stakeholder group	Country	Completion survey	Completion interview
P1	Health authority	Angola	x	x
P2	Research & community	Angola	x	x
P3	Healthcare provider	Bangladesh	x	x
P4	Healthcare provider & Health authority	Bangladesh	x	x
P5	Health authority	Bangladesh	x	
P6	Research & antivenom manufacture	Brazil	x	x
P7	Research & community	Brazil	x	
P8	Healthcare provider	Brazil	x	
P9	Research	Brazil	x	
P10	Research	Cameroon		x
P11	Healthcare provider	Colombia	x	x
P12	Healthcare provider	Colombia	x	x
P13	Research	DR Congo	x	
P14	Community	Ecuador	x	x
P15	Community	eSwatini	x	x
P16	Healthcare provider	Ethiopia	x	x
P17	Health authority	Ghana	x	x
P18	Healthcare provider	India	x	x
P19	Community	India	x	x
P20	Community	India	x	
P21	Community	India	x	x
P22	Community	India	x	x
P23	Healthcare provider	India	x	x
P24	Healthcare provider	India	x	x
P25	Antivenom manufacture	India	x	x
P26	Research	India	x	x
P27	Healthcare provider	Indonesia	x	x
P28	Advocacy	Kenya	x	x
P29	Community	Kenya	x	x
P30	Research	Kenya	x	x
P31	Healthcare provider	Malaysia	x	x
P32	Healthcare provider	Malaysia	x	x
P33	Research	Morocco	x	x
P34	Community & Healthcare provider	Nepal	x	x
P35	Healthcare provider	Philippines	x	x
P36	Community	South Africa	x	x
P37	Antivenom manufacture	South Africa	x	
P38	Health authority	Tanzania	x	x
P39	Research	Tanzania	x	x
P40	Advocacy	Uganda	x	x
P41	Advocacy	Uganda	x	x
P42	Healthcare provider	Uganda	x	x
P43	Advocacy	Zambia	x	x

Footnote: x indicates that the component was completed.

with high risk of human-snake interactions and increased time spent at home (P1, 5, 8, 20, 24, 25, 31). Interestingly, three informants, of which two performed snake rescues, saw increased infiltration of snakes in or close to human habitats (P6, 20, 34): “We have seen some snakebite envenoming occurring in places where we usually do not see [snakes]. Let me give you an example, a case of snakebite envenoming in a person that was swimming in the waterfall. This waterfall is located in a park that had been closed for three or four months and as this park opened for tourists, this case occurred in one of the first groups that was allowed to visit or use the resources of this park. And it was amazing that this snake was very close to these people where they were not usually seen, because as a place to visit by people, animals used to be far away” (P6, research & antivenom manufacture, Brazil). In Indonesia, a healthcare provider had seen an increase in snakebites that were the result of snake shows and attributed this to more people seeking entertainment due to loss of jobs and closure of schools (P27). Similarly in South Africa, a community actor saw an increase in bites from snakes kept in captivity, as people had more time to interact with them (P36).

### 3.4. Snakebite hospital admissions

Various informants had seen the number of snakebite hospital admissions decrease during the first wave of COVID-19 in their country (P1, 3, 4, 8, 10, 16, 23, 24, 26, 29, 31, 33, 35). “The patients are [now] coming back to us, but there was a crisis in the middle of those months, due to the snakebites. Snakes kept coming but patients stopped coming” (P16, healthcare provider, Ethiopia). For example, a tertiary hospital in Bangladesh with a dedicated snakebite ward saw a 25% reduction in the total number of snakebite hospital admissions in 2020 (from 1013 in 2019, to 755 in 2020). Interestingly, outside of the months with strict lock-down restrictions (April to August), they had admitted more patients than in 2019 (P3). Also, in countries where it is customary to have attendants accompanying a patient to the hospital (Bangladesh, India; P3, 19, 23), these could be hesitant to bring patients (P3) or were not allowed to accompany them (P19).

Informants gave two major reasons for the decrease in snakebite hospital admissions during the first months of COVID-19, relating to avoidance of formal healthcare due to fear, uncertainty, rumours and/or stigma surrounding COVID-19 and its care, and due to transport difficulties as transportation systems were affected by regulations and hesitancy among service providers. Regarding healthcare avoidance, healthcare providers had for example seen: snakebite patients avoiding admission and going home or seeking care elsewhere after realising the hospital also admitted COVID-19 patients (P24, 36); several snakebite patients asking for early discharge (P24, 31); and two teenage snakebite victims who were afraid to come to the hospital, and died at home due to complications resulting in sepsis (P16). Transport-wise, informants had for example seen challenges with non-operational, COVID-19 oriented, or overburdened ambulance services (P15, 21, 34, 36, 43), a snakebite victim brought to the hospital in a wheelbarrow (P15, 41), people carrying a victim by foot (P19, 41), or using carriages or motorcycles (P19). Two community actors reported that because of transport challenges, a partnership with a private ambulance services had developed (P15) and police had helped out with their cars (P19) respectively. Other informants had seen an increase in snakebite cases (P4, 9, 34, 42), but did not directly relate this to COVID-19, but for example, to increased rainfall or floods. Informants across countries and continents indicated that as result of the above barriers, the use of traditional- and faith healing had increased. Data to support this was not available, but suspicions were based on anecdotal experiences.

When patients had managed to reach a health facility, specific admission policies or procedures could further delay the receipt of treatment (P19, 27, 34, 36), for example, when patients had to wait for a COVID-19 polymerase chain reaction (PCR) test upon admission even if they required emergency treatment. Community actor P19 showed records of a 60-year-old snakebite victim who died while waiting for this

test. A healthcare provider in Nepal explained: “It was a hard time to get the patient inside the ICU (intensive care unit) because they would ask for a PCR test, which we don't do regularly in snakebite cases at all. [...] They were asking like ‘what if the patient is an asymptomatic carrier of COVID? We have to sterilise the whole ICU; we have to stop everything.’ So yeah, it was a hard time referring the person in such a situation” (P34).

### 3.5. Situation in hospitals

Logically, the situation in hospitals varied per context and over time. Many observed that priority was given to treating COVID-19 patients, and that healthcare systems and providers suffered from the increased care burden.

Informants in eSwatini, Indonesia and South Africa reported a serious shortage of hospital beds at the time of the interview, due to the high number of COVID-19 patients, causing other patients, including snakebite patients, to face neglect and in some cases, be discharged too early (P15, 27, 36). Other informants reported that the temporary closure of health facilities due to COVID-19 outbreaks, or the redesignation of health facilities only to manage COVID-19 patients had decreased access to care for snakebite patients (P3, 18, 21, 22, 25, 26, 28, 33–35, 40). In a few situations snakebite victims were, as result of this, referred to far away hospitals causing delays in treatment (P18, 22, 27, 36). Other informants had seen no change in availability of beds (P2, 19, 31, 38), while some had unexpectedly seen increased beds available for snakebite patients because other disease burdens decreased, or patients avoided seeking healthcare (P3, 4, 24).

Almost every context and region reported challenges with providing consistent health services, as healthcare providers were overburdened, reduced in number, redeployed to COVID-19 care, quarantined, contracted or died from COVID-19, or, especially in the first months, were afraid of COVID-19. In some cases, inexperienced healthcare providers appeared to be deployed to handle snakebite care (P6, 36). Some used specific strategies to promote staffing for snakebite care, relating to remote and online management or consultation (P4, 24, 19, 23) and paying extra allowances (P23, 32). Interestingly, a few informants explained that, because they ran a well-established or specialised snakebite clinic or ward, this had minimised the impact of the pandemic on their service provision and had limited healthcare avoidance by patients (P3, 8, 23, 39).

Due to issues with accessing care, some informants observed that snakebite patients reported to health facilities with advanced symptoms and consequently having worse outcomes (P11, 13, 15, 16, 18, 27, 29, 36, 42). In eSwatini, for example: “People are not receiving antivenoms. The cytotoxic bites are leading to massive necrosis, amputations, to the extent I've never seen in all the years I've been doing snakebite [work]. [...] I had a five-year-old child who was bitten on the ear by a puff adder, and it caused swelling of the face and the throat. We were trying desperately to get this child to a facility, and the little boy died. And a little 18-month-old baby died, and a four-month-old baby died, very similar circumstances” (P15, community actor). A Bangladesh example of two medical colleges showed how variable outcomes could be; both facilities admitted similar numbers of venomous snakebite cases, but one had only one fatality and the other recorded 49 deaths. They were still establishing the cause, but the latter had faced a tremendous COVID-19 burden (P4). Informants had little information about patients with both snakebite and COVID-19, stating they did not know about such cases or their outcomes. Only one informant had managed two patients with COVID-19 and snakebite, both Russell's Viper bites with fatal outcomes (P23).

### 3.6. Availability of snake antivenom

Lack of antivenom availability before COVID-19 was reported by several informants, mostly those from sub-Saharan Africa and Latin America (P1, 2, 10, 11, 13, 14, 16, 30, 39, 40, 42), which could worsen during the pandemic. In Tanzania, for example, a snakebite clinic with

the only constant source of antivenom in the region, was running low on stock because the funds used to buy antivenom came from tourists who were previously visiting the clinic but had now stopped coming (P39).

In Brazil, the government encouraged the antivenom manufacturer to continue production and distribution (P6), in India, the antivenom manufacturer, despite import and distribution issues, was still able to fulfil their orders, but had observed a one-third reduction in Indian antivenom demand over the course of 2020, received a cancellation for an order from Nepal, and experienced issues with delivering antivenom products to several African countries due to flight restrictions (P25). In South Africa, production had been severely affected by restrictions on staff numbers allowed to work on a given day and had been insufficient to meet demand (P36). And in the Philippines, antivenom production, which already failed to meet the country's demand, decreased even further due to a shift of funds to COVID-19 (P35).

Informants from Bangladesh, Malaysia, eSwatini, South Africa and Indonesia reported they had not received new supplies of at least one type of antivenom during the pandemic. In some cases, informants had been able to meet needs with existing stock (P3, 32), in other cases it had led to shortages and clinicians rationing antivenom or administering below the recommended dose (P15, 27, 36). Some, interestingly, reported the use of available antivenoms had stagnated due to lower patient numbers at hospitals or inadequate antivenom distribution in-country (P1, 10, 29). Informants from Bangladesh, Brazil, Ghana, India, Malaysia, Morocco, and Nepal had seen no issues with antivenom stock-outs during 2020.

### 3.7. Availability of ventilators

In several contexts, the pandemic had led to an increased availability of ventilators, which in some cases led to positive outcomes for snakebite patients (P15, 27): “Where before with critically ill Black Mamba patients that required ventilation, the death rate was almost 100%. Now for the first time in eSwatini's history, we've had nine people on ventilators and all nine have survived” (P15, community actor). In other countries, ventilators were reserved only for COVID-19 patients, but can benefit snakebite patients later (P3, 4, 18, 21, 36, 40). Still others thought the increase, which was mostly reserved to higher-level facilities, did not benefit snakebite patients who usually access rural health centres (P10, 26, 34). A few countries had started local manufacturing of ventilators or innovated their oxygen administration methods (P5, 27, 36). Cameroon, for example, now uses affordable oxygen concentrators which do not require trained personnel (P10).

### 3.8. Health authority priorities

Many informants explained snakebite had never been a health authority priority and that existing meagre efforts were further deprioritised during the pandemic, with funds, activities, research, and human resources ceased or redirected towards COVID-19 (P1, 2, 10–12, 14–16, 19, 21, 26–29, 33, 34, 38, 40–43). In Angola, for example, a researcher and community actor explained that many experts, including the informant, were reassigned to COVID-19 related-work, causing the informant to stop all snakebite-related activities (P2). The exceptions were Bangladesh and Brazil, where informants reported the government had continued prioritising snakebite during the pandemic (P3, 6).

### 3.9. Continuation of snakebite community programmes

In almost all contexts, existing community education and outreach programmes ceased due to COVID-19. The foreseen impact of discontinuation differed per context. In Bangladesh, the outreach programme had been in existence for 25 years, causing the informant to infer that temporary suspension would not impact awareness built up over the years (P3). A community actor in Ecuador, in contrast, explained: “Some communities are not going to recognise me. Again, I need to start building up

the trust in me, in order to open the community, which I lost. [...] I lost 10 months of work. Well, in these 10 months, I lost my job for many years” (P14). Several informants had turned to online formats or television for their programmes, which they generally evaluated positively. Some also reported downsides, such as challenges to simulate hands-on training (P31) and lack of digital channels in rural communities (P24). In several countries, physical awareness activities had started to pick up again (P16, 22, 34), with restricted group size and hygiene precautions.

Some informants also reported snake control efforts had been affected (P6, 15) and lack of recognition of snake catchers as essential service: “So, if we go out at 10 o'clock at night to go and remove a snake from somebody's house where it's a threat to them, we're not allowed to do that. We can do it, but we risk getting caught and locked up for that.” (P36, community actor, South Africa).

### 3.10. Recommendations

Informants came up with several recommendations to improve snakebite services and care during a pandemic:

*Strategy for continuity of care* – during a pandemic, snakebite care should be prioritised as a health emergency. A proper referral system and rapid response strategy to access health services should ensure redesignation of hospitals to COVID-19 does not increase travel time to snakebite-treating hospitals.

*Strong community-based connections and surveillance systems* – Strengthen community snakebite information and sensitisation, surveillance, and reporting systems to improve insight in the snakebite situation in communities during emergencies.

*Decentralised health services* – more so during a pandemic, easing access to health services is pivotal. For example, by strengthening pre-hospital care, decentralising antivenom supply, transforming ambulance services into mobile emergency clinics, training community health workers on snakebite, and investing in regional specialised snakebite units, drone delivery, telemedicine envenomation specialists for remote consultations and a home management strategy.

*Safeguarded supply of commodities* – The pandemic response should not compromise the existing supply chain, and distribution systems of COVID-19 supplies and vaccines could be used for snakebite commodities.

*Online collaboration and education* – Using online collaboration to continue global and national awareness programmes on preventive measures, first aid, snakebite management, policy development and advocacy efforts to achieve the WHO global target of lowering the death and disability toll by 50% by 2030.

*COVID-19 lessons learnt* – Learn from the mass public campaigns as used for COVID-19 awareness creation. Also integrate snakebite interventions with COVID-19 activities, learn from the team approach of managing COVID-19, and use COVID-19 related facilities and skills, such as oxygen and critical care delivery systems, for managing snakebite.

## 4. Discussion

This is the first study to collect experiences on the impact of COVID-19 on snakebite incidents, prevention, and care from key informants across LMICs. As was already apparent and reported elsewhere, in many places, health systems were seriously affected by the pandemic. Patients' ability to reach care and acceptability of care were affected, decreasing access. Healthcare facilities and -providers faced an increased burden from COVID-19, which had the most acute consequence for all patients requiring hospitalisation, including people bitten by a snake (Bandyopadhyay et al., 2020; Carter et al., 2020; Davies et al., 2020; Dubey et al., 2020; Jensen and Molina, 2020; Moos, 2020). These are effects also reported during the Ebola Virus Disease epidemic in 2014–2015 (Delamou et al., 2017; Morse et al., 2016). Furthermore, prioritisation of COVID-19 by health authorities further restricted essential healthcare resources necessary for the treatment and care of

snakebite patients. COVID-19 has globally laid bare the consequences of weak health systems, ill-prepared for cross-board health threats. As shown by this study, disease burdens other than those directly linked to the pandemic can emerge as a consequence. Although this research could not establish the magnitude of effect, this is likely having a serious impact on the snakebite health and socioeconomic burden, as the long term health effects after snakebite envenoming include amputations, deformities, chronic ulceration, chronic renal failure, neurological impairment, blindness, muscular weakness, depressive symptoms and post-traumatic stress disorder (Waidyanatha et al., 2019). While, if timely and properly managed, patients often experience a full recovery.

How the pandemic and lockdown measures impacted exposure to snakebites depends on complex dynamics, including the composition of measures taken, human and societal behaviours, and snakes' response to it, which are unique for each context. A general belief held by many informants was that rural farming or herding communities were only marginally affected by restrictive measures, which were unlikely to have caused a change in exposure, hence, as before, remained at high risk. Mobility, including urban to rural migration as a result of loss of employment or economic activity and school closures may have increased exposure. However, an overarching issue was the lack of reliable, up-to-date, and comprehensive statistics on snakebite events to confirm these observations. In addition to the changes identified in this study, local news sources from India and Nepal reported several fatal snakebite incidents among people who had to quarantine at poorly equipped government facilities (Azad, 2020; Deuba, 2020; Shahi and Gahatraj, 2020; Times Now, 2020).

Snakebite research, surveillance and community outreach efforts are generally underfunded. We found that during COVID-19, existing snakebite initiatives were commonly de-prioritised or discontinued, further contributing to the existing gap in services and support. Discontinuation of surveillance and community outreach efforts was in line with early NTD guidelines issued by the WHO in April and May 2020 (WHO, 2020a; 2020b). Due to this, less information is available on the scale of many disease burdens in resource-poor settings. Combined with weak health service delivery, this causes a magnitude of hidden consequences of the pandemic, which go well beyond the COVID-19-related burden and should be monitored (Mobula et al., 2020). While no studies have been conducted to measure the impact of programme discontinuation on snakebite incidents and outcomes, studies on other NTDs found that while consequences are likely to be negative, they will vary in intensity depending on the NTD: for snakebite it will depend upon, inter alia, prevalence prior to interventions and continuation of snake control efforts (Hollingsworth et al., 2021). It is argued that NTD interventions need to reach the same or an even higher coverage and efficacy than previously to mitigate the impact of the pandemic (Chaumont et al., 2020; Hollingsworth et al., 2021). To realise this, authors explain novel catch-up strategies are needed, informed by up-to-date data, guided by leadership from the WHO and flexible donor support, and requiring sustained advocacy for NTDs prioritisation on the global health agenda (Chaumont et al., 2020; Toor et al., 2020). Although snakebite is notifiable in some countries, as a first step it is essential that snakebite become a notifiable disease in all endemic countries, to ensure the impact of snakebite and its determinants can be adequately measured.

On a hopeful note, informants brought up inspiring examples of how they had managed to work around restrictive measures, going the extra mile to maintain their snakebite services, for example, by using online communication platforms. This is a low-cost method with high potential reach in many LMICs (Kadam et al., 2021). Completely replacing community outreach efforts with online programmes, however, risks overlooking the most remote and poorest communities where digital inequalities may exist. Therefore, we recommend going back to physical outreach and resuming surveillance efforts as quickly as possible, while also exploring the potential of using local radio when engaging with communities which are off-the-grid.

Community engagement for snakebite prevention and snake control are the simplest ways to reduce the snakebite burden (Kadam et al., 2021). Crucially, when health systems are overburdened, snakebites should be prevented at all costs. Unfortunately, in some contexts we found that snake control efforts were impeded or had ceased, as they were not recognised as an essential service. The WHO guidelines on community-based healthcare in the COVID-19 pandemic recommended the continuation of essential community-based interventions for vector control, which were specified as the reduction of vector breeding sites, specifically mentioning mosquito control for areas affected by dengue (WHO, 2020b). While these guidelines have not specified snake control, and recognising snakes are not vectors, we argue snake control efforts should continue unabated. Classifying snakebite prevention and snake control efforts as essential services in the WHO guidelines would exempt snakebite programme staff from measures restricting their movement and allow them to resume their lifesaving work.

The substantial decrease in snakebite hospital admissions seen in many contexts during the initial months of the pandemic is a worrisome finding. While a lower snakebite risk due to movement restrictions is a potential explanation, in many contexts it is more likely that it is caused by changed health-seeking behaviour and lower access to care following a snakebite. Several studies among predominantly high-income countries found healthcare utilisation had decreased substantially, with the largest effect on 'minor ailments' and 'elective treatment' (Czeisler et al., 2020; Moynihan et al., 2020; Rijksinstituut voor Volksgezondheid en Milieu, 2020). Our study suggests that in many LMICs, it is not just minor ailments, but for a life-threatening emergency like snakebite lower numbers of patients were admitted in health facilities. While in some contexts informants noticed people with snakebites were still accessing health services, in many other contexts, they felt that both fear of COVID-19 and transport difficulties had resulted in an inclination to avoid seeking care and to resort to traditional healing or alternative treatment. Interestingly, a few specialised snakebite clinics or hospitals with established snakebite management services seemed to suffer less from healthcare avoidance and impact on service provision, potentially due to established community trust and the low likelihood for such clinics to manage COVID-19 patients. The issue of decreased hospital admissions highlights the need to invest in community-based care, including pre-hospital care and ambulance services, something reiterated by our informants and the WHO community guidance: "Ensuring that the community health workforce is trained and equipped to address acute conditions is critical, as restrictions on movement, recommendations to limit in-person encounters in facilities and fears about the safety of facility-based care will increasingly shift acute care to the community setting" (WHO, 2020b). Poor rural communities at high risk of snakebite envenoming are likely to also suffer the worst consequences from the pandemic: they are faced with low access to sanitation, health services, transportation services, information, education, communication technologies, social protection, food security and public infrastructure (Food and Agriculture Organization of the United Nations, 2020; Moos, 2020). Therefore, investments and infrastructure facilities must prioritise these highly vulnerable groups and snakebite care should be integrated with other community health emergency care.

Part of the reason for avoiding care seemed to originate from rumours or misinformation. Rumours travel fast, so it is essential that trustworthy information travels even faster to ensure snakebite patients do not become victims of misinformation. Therefore, it is critical to not only invest in strong contingency plans, but to also engage with and properly inform communities about this, including health facility measures taken, transport possibilities, and access to care pathways, while being aware of potential stigma (Bruns et al., 2020). Furthermore, traditional healers, who often play an important role in community health across the global south, including for snakebite patients and especially so during the pandemic, should be provided with further education in prevention, first aid, and treatment to support access to evidence-based care pathways.

At the time of data collection, in several contexts, a COVID-19 PCR test was required on admission to a health facility which could add delays to critically urgent care. In their operational guidance for maintaining essential health services in the COVID-19 context, the WHO recommended prioritising the most critical NTD cases, which require individual case management (WHO, 2020c). In line with these guidelines, snakebite should, even during COVID-19, be treated as an emergency. Countries should move away from admission policies and procedures that delay the time to treatment, which is a core predictor of health outcomes in snakebite cases. The increasing availability of rapid antigen tests for COVID-19 in LMICs can be a pivotal solution to this issue (WHO, 2020d).

In terms of medical equipment and supplies, COVID-19 has exposed vulnerabilities in medical supply chains globally (Miller et al., 2020). The snake antivenom supply chain was already fragile and inadequate before COVID-19, especially in Sub Saharan Africa, depending mainly on exports from a few manufacturers, who, in case of production issues, cannot be easily substituted by others (Habib et al., 2020). Unfortunately, during the pandemic, additional production and distribution issues further weakened the antivenom market, and, accompanied by lower prioritisation by some governments (for both procurement and production), caused the fragile antivenom supply to diminish further. Another study had similar findings: through a survey among 12 antivenom manufacturing laboratories it established an overall reduction in antivenom manufacturing (for snakes, scorpions, spiders, and caterpillars) in the first half of 2020 in Latin America, albeit not necessarily due to COVID-19 related factors. Further, it found that: “ten laboratories reported a drop in the personnel dedicated to antivenoms, seven laboratories had a reduction in the acquisition of consumables for antivenom production, and four laboratories reported a reduction in the overall budget assigned to antivenom manufacture” (Gutiérrez et al., 2021). Interestingly, in our study, in a few contexts, also domestic antivenom supply seemed to have had difficulty reaching the patients’ bedside due to disruptions in the supply chain, causing risks of stock expirations (WHO, 2020a).

To strengthen the antivenom supply chain, it is crucial to improve the technical capacity of national regulatory authorities to ensure products are suitable for local needs, and to consider setting up regional agreements between snakebite affected countries to ensure all have a basic level of supply security and are resilient to pandemics and other future emergencies. Further, innovative distribution mechanisms used to deliver treatments for COVID-19, when effective, should also accommodate other essential commodities including those for snakebite treatment. Noteworthy is that in the case of ventilators we saw promising innovations and responses which, although mostly for the purpose of combatting COVID-19, will likely benefit snakebite patients requiring ventilation in the future.

Finally, while there may be a risk of misdiagnosis of neurotoxic snakebite patients as COVID-19 case and interactions between snakebite envenoming and COVID-19 in cases of comorbidity, our informants had little information about such incidents. Future research should further explore such interactions.

#### 4.1. Strengths and limitations

To our knowledge, this study is the first of its kind on a timely issue, for which we have gathered real-life experiences and perspectives from informants directly involved in snakebite prevention and care. A key-informant study is a helpful design to gather extensive insights within a limited timeframe, however, it also has drawbacks. While we managed to include a wide variety of perspectives within the timeframe of the study, global representation was skewed towards India, some relevant countries were missing (e.g., low representation of Latin America and Northern Africa), and we had just single perspectives for a number of countries. Further, only a minority of respondents came from countries with a low COVID-19 burden. The interviews yielded a good grasp of the

issues that informants working in snakebite prevention and care had experienced, which showed overlap in many contexts. Nevertheless, inclusion of more countries and informants would have led to a more complete understanding. Further, as key informants all have their own realities and experiences, it can be difficult to draw conclusions based on information which may be different or contradicting. Therefore, we have been cautious in interpreting and generalising findings. In addition, although we felt we gathered genuine responses, socially desirable response cannot be ruled out, for example, in case of delicate issues such as asking healthcare providers if they have been able to manage patients, antivenom manufacturers if they could fill their orders, or health authorities if they had procured antivenom. Further, it is important to acknowledge that data were collected from December 2020 to February 2021, which was before the second or third wave of COVID-19 in several countries, some of which were profoundly affected by it (e.g., Brazil and India). Likely, this also had profound impacts for snakebite victims, as anecdotal evidence shows (SHE India, 2021). Hence, this study only provides a snapshot of the situation in LMICs. Finally, language barriers could be an issue as we did not have French or Portuguese speaking co-authors. We tried to accommodate participants as much as possible (e.g., by translating the survey) and held two interviews in Spanish at the request of the interviewee, and one using a mixture of English and Hindi. As the team lacked a Portuguese or French speaking researcher, the level of detail that could be acquired during some interviews was lower. We limited the impact of this on the study’s reliability by enabling participants to answer the survey questions in their native language and using the survey as point of departure for the interview. One single participant could eventually not be interviewed due to being uncomfortable with speaking in English.

## 5. Conclusion

This key-informant study found apparent effects of the COVID-19 pandemic on snakebite prevention and care, although its severity was highly context dependent. The interaction between the pandemic effects and snakebite incidents is likely to have the most severe consequences for remote rural communities, who have to overcome additional transport barriers and misinformation, while being struck by economic losses with low economic reserves. Investments in community-based prevention and care could partially mitigate this impact, while structural issues with quality assured antivenom supply should be addressed concurrently. This demands urgent and focused investment by the WHO and governments, who have been pushed in problematic financial positions by COVID-19. Hence, persistent and coordinated advocacy is required globally to continue pulling snakebite away from neglect in times of a pandemic.

## Recommendations box

During the COVID-19 pandemic.

- Governments should provide clear and transparent directives on movement and essential services. Non-governmental organisations and community-based organisations responding to snakebite should be classified as essential service and be exempt from movement restrictions or other obstacles to perform their lifesaving work.
- Snakebites should be treated as a medical emergency and receive priority in healthcare admission. Delaying admission policies should be removed to avert needless mortality and morbidity.
- Governments should invest in robust reporting and surveillance systems that capture a range of indicators associated with snakebite, suitable for use during a pandemic or other emergencies.
- Governments should inform communities about healthcare contingency plans and available care-seeking pathways for emergencies, such as snakebites, during the pandemic to reduce fear, distrust, and misinformation.

- Investments in community-based care are critical to safeguard emergency care provision, including for snakebite, during any pandemic or emergency. For example, by community engagement in snakebite prevention, first-aid, and health seeking behaviour.
- In some regions, the positive impact on snakebite treatment outcomes resulting from increased availability of ventilators during the pandemic should be further analysed and considered by policy-makers, but not in isolation from wider investments in snakebite treatment, management, and care.

Beyond the COVID-19 pandemic, substantial investments in antivenom production, distribution and storage systems, healthcare provider training, and community sensitisation are urgently needed to reduce the burden of snakebite in many endemic countries.

### Ethical statement

The work described has been carried out in accordance with the Code of Ethics for Research in the Social and Behavioural Sciences Involving Human Participants (2016). <https://www.eur.nl/eshcc/media/67289>.

### Credit author statement

**Janneke van Oirschot:** conceptualization, methodology, investigation, formal analysis, writing - original draft. **Gaby Ooms:** conceptualization, methodology, investigation, formal analysis, writing - original draft. **Benjamin Waldmann:** conceptualization, methodology, resources, investigation, writing - review & editing. **Priyanka Kadam:** resources, investigation, writing - review & editing.

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### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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